Modifying Lean Production for Implementation in Production of Digital, Customized Products

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ABSTRACT

Title  
Modifying Lean Production for Implementation in Production of Digital, Customized Products

Authors  
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Purpose  
To evaluate how lean production should be modified to be suitable for implementation in the production of digital, customized products and how the first phase of this implementation can be conducted.

Research Questions

RQ1: What constitutes waste when producing digital, customized products, and to what extent can the waste be eliminated?

RQ2: Which lean concepts and tools are suitable to apply in the production of digital, customized products?

RQ3: What steps are necessary for initial implementation of lean production for production of digital, customized products, and how should they be prioritized?

Methodology  
The empirical findings are the result of a single case study focused around in-depth analysis and understanding of concepts and relationships. The data is collected through interviews, workshops and observations during a period of three months.

Conclusions

RQ1: The types of waste are; Waiting, Transportation, Overprocessing or incorrect processing, Excess inventory, Unnecessary efforts, Defects and Unused employee creativity. Waste are further classified as removable, non-removable and in some instances necessary.

RQ2: Unsuitable concepts: *Value stream mapping (varying level of unsuitability), Kaikaku*, Just in time, Stopping the line (without modifications) and Physical visual controls. Redundant concept: Pull. Especially suitable concepts: 5 Why, Decentralized responsibility, Digital visual controls and Isolating variation. Suitable concepts: Elimination of waste, Root cause analysis, Genchi genbutsu, Kaizen events, Flow, Stopping the line (with modifications) and Standardization.

RQ3: Step I: Aligning the production strategy and process with the organization’s strategy and goals. Step II: Standardization.
SAMMANFATTNING

Titel
Modifieringar av Lean Production för implementering i produktion av digitala, kundanpassade produkter

Författare
Emmeline Kemperyd och Susanne Mideklint

Handledare
Martina Berglund, avdelningen för kvalitetsutveckling

Liu

Syfte
Att utvärdera hur lean production bör modifieras för att vara lämpligt för implementering i produktion av digitala, kundanpassade produkter och hur den första fasen av implementationen bör genomföras.

Forskningsfrågor
F1: Vad utgör slöseri när man producerar digitala, kundanpassade produkter, och i vilken utsträckning kan slöseriet elimineras?

F2: Vilka lean-koncept och lean-verktyg är lämpliga att använda i produktion av digitala, kundanpassade produkter?

F3: Vilka steg är nödvändiga för initial implementation av lean production i produktion av digitala, kundanpassade produkter, och hur ska de prioriteras?

Metod
En fallstudie med fokus kring djupgående analyser och förståelse för koncept och samband utgör de empiriska resultaten. Datan är inhämtad genom intervjuer, workshops och observationer under tre månader.

Slutsatser
F1: Typerna av slöseri är: väntetid, transport, onödiga eller felaktiga processsteg, överproduktion, onödig ansträngning, defekter och outnyttjad kreativitet. Typerna av slöseri är vidare klassificerade som eliminerbara, icke eliminerbara eller i vissa fall nödvändiga.


F3: Steg I: Strömlinjeforma produktionsstrategin med organisationens strategi och mål. Steg II: Standardisering.
Acknowledgments

As we conclude our five years at LiTH with this master thesis, we close the door on five wonderful years filled with both joy and frustration. Frustration from four and a half years of demanding studies, which have however created a solid foundation for this master thesis. Joy from all the wonderful people we have had the opportunity to meet, the places we have had the opportunity to travel to and the many new experiences we have been lucky enough to get. Our final semester has been spent mostly in Bangkok, Thailand, thereby sealing our degree in a way we find utterly suiting. These five years have been filled with not only hamburgers at Flamman, but also Singapore Slings in rooftop bars, providing us with unsurpassable international experience; an experience which has now been expanded to include even more rooftop bars.

In Bangkok we had the opportunity to work with a wonderful bunch of people, without whom this master thesis would not have been possible - and our stay there much less fun. First of all, a big thanks to our supervisor and CHRO at the company, whom with his huge experience offered us invaluable advise concerning not only our thesis but also our future careers. The company’s CSO, who offered us to write our master thesis for the company studied. CEO and great visionary at the case company who helped us in being a big fan of our ideas. Production and Studio Manager respectively whom took the time to answer our questions and attend our workshops despite their overly busy schedules. To not risk failing to mention anyone we would also like to thank everyone else at the case company we have been in contact with, whom helped us by answering our questions, attending our workshops and showing us the best lunch spots.

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S.M. & E.K.

Stockholm, 11 of June 2014
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1 | Introduction

How come no one has ever considered lean production for digital, customized products? Is it impossible? Is it too challenging? Is it suitable? Is it perhaps even more suitable than to the areas subjected to studies so far? Recalling the famous words of Dalai Lama XIV (Lama): “Where ignorance is our master, there is no possibility of real peace.” there is no turning back now that the questions have been raised. And the only way forward is to search for answers to these formerly unanswered questions...

The first chapter of this master thesis aims to provide the reader with background and problem description, which subsequently leads to the purpose of the study. Directions for the Reader finishes the chapter, and will serve as a guide to the disposition of the report.
1.1 Lean Production

Lean production has developed from the Toyota Production System and is well-renowned for providing high quality at a low cost. It further builds on the 4P’s of the Toyota Production System; philosophy, process\(^1\), people and problem solving. The benefits historically gained by implementing lean production are vast (Liker and Meier, 2006). Womack and Jones (1996) state that without any financial investments lean production initially doubles productivity without need for increasing the work force or work space, and at the same time decreases the number of defects, minimizes inventories and dramatically reduces lead times.

Lean production has in the past decades grown from a production system to a concept involving not only production, but the whole enterprise - what is commonly referred to as the lean enterprise (Womack and Jones, 1994; Åhlström, 2004; Liker and Meier, 2006). An important part of the lean enterprise is the concept of lean thinking, which Liker and Meier (2006) argue can be used in almost any context, and which is based on the core principle of lean production: reducing lead times by removing non value adding waste.

1.2 Digital, Customized Products

Digital products and customized products are both on their own challenging to produce, and different challenges arise depending on the level of digitization and customization respectively. Even though producers of the products face different challenges one can assume that what they at least have in common is the need for continuously decreasing lead times and increasing productivity. These are both desirable results which lean production has as described above proven to be able to provide.

Merging the two factors digital and customized in their extremes serve as an clarification for the quite new area of digital, customized products. Firstly the level of customization is divided into mass production and mass customization, as suggested by Pine (1993). Secondly the level of digitization is divided into non-digital and digital products. The result of finally combining the four extremes into a two-by-two matrix are four product segments emerging. The matrix, which can be viewed in figure 1.1, includes examples of products within these segments. The segment chosen for further research is that of digital, customized products (upper right corner), denoted DCP in the report.

\(^1\)The definition of process used in the report is the one of Bergman and Klefsjö (2010): "a network of interrelated activities that are repeated in time, whose objective is to create value to external or internal customers".
Figure 1.1: Visualization of the product segments created by combining the degree of customization with the level of digitization

1.3 Problem Background

An abundance of research is available concerning lean production (e.g. Womack and Jones (1994, 1996); Rother and Shook (2004); Hines et al. (2004); Liker and Meier (2006)), and lately this has begun to apply to some areas of modifications of lean (e.g. lean service as discussed by among others Bowen and Youngdahl (1998); Allway and Corbett (2002); Åhlström (2004); Keyte and Locher (2008); Piercy and Rich (2009) and lean for the public sector as discussed by Radnor and Walley (2008)) as well. In other areas of modification, such as agile, peer reviewed research is still lacking, while there is an abundance of literature addressing management functions (e.g. Poppendieck and Poppendieck (2003, 2007); Cockburn (2007)).

The mentioned authors are for the most part united in their opinion that lean production is possible to modify and apply to not only volume products but to products where flexibility is of high importance as well. Some authors even go so far as suggesting lean production to better suit a flexible service company than a traditional manufacturing company (e.g. Bowen and Youngdahl (1998)).

However, even though it has been concluded that modifications of lean are both necessary, possible and give good results, research concerning how these modifications should be carried out is unsatisfactory. Even when there is a suggested implementation model (e.g. Keyte and Locher (2008)) for implementation in a service context, little is said about implementation in other highly flexible areas. The extremely flexible area of digital, customized products is one such area which has previously gained little attention from lean researchers concerning how implementation should be done. When literature on implementation for highly flexible areas, such as for example software development, is available it is seldom peer reviewed and therefore must be seen as not providing enough of a contribution to the research area.
1.4 Purpose

The purpose of this study is to evaluate how lean production should be modified to be suitable for implementation in the production of digital, customized products and how the first phase of this implementation can be conducted. To fulfill the purpose a case study is conducted.

1.4.1 Research Questions

Three research questions have been created to assist in fulfilling the purpose of the study. The questions are stated below and the analysis aims to provide answers to them.

*RQ1: What constitutes waste when producing digital, customized products, and to what extent can the waste be eliminated?*

*RQ2: Which lean concepts and tools are suitable to apply in the production of digital, customized products?*

*RQ3: What steps are necessary for initial implementation of lean production for production of digital, customized products, and how should they be prioritized?*

1.5 Delimitations

Liker and Meier (2006) suggest implementation of lean production to start with the process. This suggestion was adopted in this thesis, and the target of the first phase of implementation was therefore considered to be improvements to the process. Due to time constraints implementation of lean production to the other three cornerstones of lean production - philosophy, problem solving and people - could not be considered.

Rother and Shook (2004) suggest the implementation of a lean process and value stream, what they refer to as value stream design, to start within the walls of the company; that is, without considering improvements made possible by improving operations at suppliers and/or customers. Due to this recommendation and the inherent time constraints of a master thesis, the focus has been on the value stream within the walls of the company and processes performed by parties outside the organization were considered to be fixed in both cost and duration.

In further accordance with the suggestions made by Rother and Shook (2004) concerning where to start improving processes, the case study was not only limited to include the organization but also limited to focus on the manufacturing processes solely, hence among others sales and distribution processes were determined to be
outside of the scope. This corresponds to what Keyte and Locher (2008) refer to as the cross-functional level, which is their suggested level of focus when transforming a specific process within the company.

To visualize the delimitations described above the lean enterprise, as suggested by Womack and Jones (1994) and Åhlström (2004), is used. The lean enterprise according to Åhlström (2004) can be viewed in figure 1.2, where the focus of this thesis has been marked with a blue border.

Finally, studying the ongoing processes in a company and subsequently analyzing root causes and relationships is a time consuming but necessary process when attempting to implement lean production (Liker and Meier, 2006). The case study therefore had to be limited to one single company.

![Figure 1.2: The different function areas of the lean enterprise (Åhlström, 2004)](image)

### 1.6 The Case Study

The company targeted for the case study was founded in Sweden, but has been headquartered in Asia since 2010. There are at the moment about 350 employees, consisting mainly of students and recent graduates. The company has experienced a very high growth rate and the forecasts suggest the growth will not decline during the upcoming years. Instead, the company is anticipated to continue to grow and expand the current market share. The company serves customers all over the world, but so far the main focus has been on customers in Northern Europe, USA and Australia.

As a result of the high growth rate a need for efficiency improvements has emerged. The company is made up of two departments; one which produces high volume products and is highly efficient, and one which has been using ad hoc solutions to deliver digital, customized products. Both departments have functioned well in the past, and the volume department is still in good shape with good scaleability. The aim is to scale up production of the more customized products as well, but the current way of working has proven to be inefficient for larger volumes. When attempted it has resulted in low utilization of resources, long lead times, challenging production planning and a decrease in the quality delivered.

The business area in which the company operates is digital visualization of properties; existing as well as new construction. The production of digital visualizations of existing properties is done in the volume department whereas the digital visualizations of new construction objects are produced in the other department. The company’s
offering for new construction customers consists of a package within which different 
products and quality levels can be chosen. A master thesis by Ridderström and Sigot 
(2013) concluded that the new construction products were digital, and customized to 
a very high extent, hence the concerned department is a suitable instance for fulfilling 
the purpose of the research.


1.7 Directions for the Reader

The disposition of the master thesis and the contents of each chapter is as follows:

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<td>4</td>
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<td><strong>Analysis</strong></td>
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<td>6</td>
<td><strong>Conclusions</strong></td>
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The theoretical frame of reference aims to provide the reader with the necessary theoretical background. It is made up of the views of well-cited authors; of both textbooks and peer reviewed articles. This gathering reflects the research previously conducted in the area, on which the research in this master thesis builds and which therefore forms a basis for the analysis.
2.1 Lean Production and Modifications

As mentioned in the introduction the foundation of lean production is removing waste to diminish costs and reduce lead times (Liker and Meier, 2006). A common misconception about lean production is that to reduce waste, completely new ways of working must be put into place (Rother and Shook, 2004). This is according to Rother and Shook (2004) not the case. Even companies that have come far on their lean journey use the same manners of production as other companies; they just plan them differently. While the production processes are often the same, the information flow and what triggers production often differs greatly between lean companies and others (Rother and Shook, 2004).

Further lean production has in the past decades found use in many areas outside of its traditional factory setting (Keyte and Locher, 2008). In the early years, a lot of criticism was raised against lean production, mainly regarding its limited applicability in other contexts than high-volume manufacturing. In the past decades measures have been taken to breach the gaps previously found in lean production, mainly through modifications for suitability in other contexts (Hines et al., 2004). When applying lean production in another environment, some adjustments are however necessary (Keyte and Locher, 2008).

Even when lean tools can not be applied directly, thinking lean can benefit the company (Liker and Meier, 2006). Liker and Meier (2006) suggest taking a step back and looking at the core principle of lean production; reducing lead time by removing waste, and further suggest this to be the way to apply lean production even outside of the manufacturing world.

2.1.1 Lean Service

One modification to lean production which has gained a great deal of researchers’ attention is that to the service industry. When implementing lean production in service industries, there are both similarities and differences with the manufacturing industry to be taken into account. Some of the authors on the subject of lean in the service industry claim the transfer of lean production to a service context to be impossible, whereas some researchers argue that statement to be an outdated point of view and suggest that using only a few modifications very good results will surface (Bowen and Youngdahl, 1998). Supporting the latter opinion it has lately been proven that the implementation of lean service results in both cost reductions and quality improvements (Allway and Corbett, 2002; Åhlström, 2004).
Product vs Service

In table 2.1 examples of similarities and differences between a product and a service is presented.

The level of customer and front-line employee interaction as described in table 2.1 was in a study conducted by Skaggs and Huffman (2003) found to have an additional aspect to it. The interrelation between the two parameters; customer co-production and complexity of the offering, was found to affect the company performance and customer satisfaction, as seen in diagram in the figure 2.1.

Skaggs and Huffman (2003) argue the reason the two combinations high complexity - low customer co-production and low complexity - high customer co-production result in the best service performance is that the skill level of the customer is not high enough for a high level of customer co-production for complex products. In other words, when customer co-production increases the customer skill level usually does not follow, resulting in a decrease in the quality of the end product. Educating customers and thereby increasing their skill level is one way of decreasing the risk of quality defects for the end product (Skaggs and Huffman, 2003).

Table 2.1: Examples of differences and similarities between services and physical products.

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
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<tr>
<td><strong>Customer focus</strong></td>
<td><strong>Order and delivery point</strong></td>
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<tr>
<td>Customer value is</td>
<td>Production, consumption and evaluation occur</td>
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<tr>
<td>the most essential</td>
<td>almost simultaneously in the service industry</td>
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<td>factor to consider</td>
<td>whereas in the manufacturing industry they are</td>
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<tr>
<td>and needs to</td>
<td>usually separated (Bowen</td>
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<tr>
<td>pervade the whole</td>
<td>and Youngdahl, 1998).</td>
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<td>company and all</td>
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<td>processes (Bergman</td>
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<td>and Klefsjö, 2010),</td>
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<td>regardless if the</td>
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<td>output is a physical</td>
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<td>product or a service.</td>
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<td><strong>Cost reduction focus</strong></td>
<td>The competitive climate is very high in both</td>
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<td>industries putting high pressure on delivering</td>
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<td>higher quality at lower prices, which means</td>
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<td>companies need to lower their resource</td>
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<td>consumption. Eliminating waste such as</td>
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<td>inventories and setup times is therefore</td>
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<td>important in the manufacturing industry</td>
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<td>(Womack and Jones, 1996) as well as in the</td>
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<td>service industry (Åhlström, 2004) to</td>
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<td>realize cost reductions and be able to gain a</td>
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<td></td>
<td>competitive advantage.</td>
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<tr>
<td><strong>Customer and front-line employee interaction</strong></td>
<td>The level of customer interaction with front-line employees is higher in the service industry than in the manufacturing industry and employee performance and behavior is therefore a crucial factor for the quality a customer perceives when consuming a service (Åhlström, 2004).</td>
</tr>
</tbody>
</table>
2.1.2 Agile

Another specialized application of lean production is to sectors with high demand variability; be it variability in volumes or mix. For this application so called agile solutions have been suggested (Hines et al., 2004).

Naylor et al. (1999) describe agile as making use of market knowledge in a volatile market place, and thereby exploiting profitable opportunities in that same market place. They contrast this with lean which in their opinion primarily means to ensure a level schedule.

Both lean and agile are according to Naylor et al. (1999) closely related to the positioning of the decoupling point; that is, the point which separates customer driven production from production based on planning. The decoupling point can be moved further down the value stream by differentiating products later in the production process, which decreases risks associated with running out of stock as well as those associated with products becoming obsolete. The positioning of the decoupling point is determined by a combination between the longest lead time a customer finds acceptable and the point of the value stream where variability in product demand is the most volatile. Several possible placements of the decoupling point, and their effect on the supply chain, are shown in figure 2.2. (Naylor et al., 1999)
Agile vs Lean Production

Some of the main differences between agile and lean production, according to Hines et al. (2004), are summarized in table 2.2.

Table 2.2: Main differences between lean production and agile (Hines et al., 2004)

<table>
<thead>
<tr>
<th>Lean</th>
<th>Agile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfy the customer by adding value and eliminating waste</td>
<td>Satisfy the customer by configuring to order</td>
</tr>
<tr>
<td>Measure output-criteria such as quality, cost and delivery</td>
<td>Measure customer satisfaction</td>
</tr>
<tr>
<td>Smooth work flow</td>
<td>Allow for unpredictability</td>
</tr>
<tr>
<td>Plan ahead</td>
<td>Face unpredictability</td>
</tr>
</tbody>
</table>

Naylor et al. (1999) suggest the categorization of the importance of characteristics inherent in both lean production and agile shown in table 2.3. Notable is that use of market knowledge, integrating the supply chain and lead time compression are of equal importance for both lean and agile (Naylor et al., 1999).

Notable from table 2.3 is also that in agile manufacturing rapid reconfiguration of processes is of high importance, since the processes must be able to respond quickly to changes in market demand. While this is important in lean production as well, it is not as important. Since agile does not demand smooth or leveled demand, the processes
must also be robust and able to handle both disturbances and variations. (Naylor et al., 1999)

Table 2.3: The importance of characteristics inherent in both lean production and agile (Naylor et al., 1999); xxx = essential, xx = desirable, x = arbitrary.

<table>
<thead>
<tr>
<th>Key concept</th>
<th>Lean</th>
<th>Agile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of market knowledge</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>Virtual corporation/value stream/integrated supply chain</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>Lead time compression</td>
<td>xxx</td>
<td>xxx</td>
</tr>
<tr>
<td>Rapid reconfiguration</td>
<td>xx</td>
<td>xxx</td>
</tr>
<tr>
<td>Robustness</td>
<td>x</td>
<td>xxx</td>
</tr>
<tr>
<td>Smooth demand/level scheduling</td>
<td>xxx</td>
<td>x</td>
</tr>
</tbody>
</table>

### 2.2 Waste

An important part of lean production is the concept of *waste*. In lean production waste is viewed as everything which does not add value for the customer (Liker and Meier, 2006). The key point here is that the customer and her requirements decide what constitutes waste, hence what is waste in one company or context may not be waste in another (Hines et al., 2004). Market standards are also of importance, since they dictate what the customer can expect from other suppliers (Keyte and Locher, 2008). When evaluating service processes there are two different types of activities that do not constitute waste to consider; value-adding activities and supporting activities that do not create value perceptive to the customer but are necessary to support the current business model. The latter are activities that can not be removed without changing the business model beforehand (Keyte and Locher, 2008). This can be contrasted with the traditional view of lean production where everything is either value adding or waste (Liker, 2004). The main types of waste are commonly referred to as seven or eight (Liker and Meier, 2006) where among others Liker and Meier (2006) and Keyte and Locher (2008) choose to follow the convention of eight. The eight types of waste and examples of them, as suggested by Liker and Meier (2006) and Keyte and Locher (2008), are shown in table 2.4.
<table>
<thead>
<tr>
<th>Waste</th>
<th>Example from manufacturing (Liker and Meier, 2006)</th>
<th>Example from service (Keyte and Locher, 2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overproduction</td>
<td>Producing earlier than needed or producing too much</td>
<td>Printing papers earlier than needed, purchasing earlier than needed, handling cases before the next person is ready to take over</td>
</tr>
<tr>
<td>Waiting</td>
<td>Employees who spend their time watching automated machines, employees waiting for the next process step, no work available because of lack of stock, processing delays, equipment downtime, bottlenecks</td>
<td>Downtime and response times of computer systems, waiting for acceptance from other parties, waiting on information from customers</td>
</tr>
<tr>
<td>Transportation</td>
<td>Moving of work in progress (WIP) during a process and moving material or finished goods to and from storage between processes</td>
<td>Large e-mail attachments</td>
</tr>
<tr>
<td>Over processing or incorrect processing</td>
<td>Taking unnecessary steps to process parts, processing inefficiently due to poor design of tools and/or products, providing higher quality than necessary, doing unnecessary/extra work when there is nothing to do</td>
<td>Repeated entry of the same data, making extra copies, unnecessary reports or transactions, internal messages, time reports, budget processes</td>
</tr>
<tr>
<td>Excess inventory</td>
<td>Excess raw materials, WIP and finished goods</td>
<td>Piles of cases; either electronically or on paper, brochures</td>
</tr>
<tr>
<td>Unnecessary movement</td>
<td>Any movement performed by employees which does not add value; for example walking or reaching for tools</td>
<td>Moving to and from copying machine, printer, archives, fax machines and other offices</td>
</tr>
<tr>
<td>Defects</td>
<td>Producing defective parts or correcting them</td>
<td>Incorrect registrations, design faults, changes in construction orders, staff turnover</td>
</tr>
<tr>
<td>Unused employee creativity</td>
<td>Loss of time, ideas, skills, possible improvements and learning opportunities due to not listening to employees</td>
<td>Limited responsibility and authority, managing and control, unsuitable equipment</td>
</tr>
</tbody>
</table>
Eliminating waste is of similar importance within agile as within lean production, however all types of waste may not be possible to eliminate in an agile value stream (Naylor et al., 1999). For this reason the concept of value-adding activities within agile has been expanded to include also those activities that are non-value adding but necessary (Naylor et al., 1999), similar to what is suggested within lean service (Keyte and Locher, 2008). While lean focuses on removing waste and aims to be as flexible as possible, agile focuses on being flexible and aims to remove as much waste as possible in the process (Naylor et al., 1999).

The main goal of lean production is to root out waste, with the aim of freeing up resources that may then instead be used to create value for the customer. However, not all waste are considered as bad as others - and which are worse may vary with the context (Liker and Meier, 2006). With this in mind Liker and Meier (2006) argue that sometimes it might be desirable to substitute one type of waste for another. Just removing waste or substituting it for a "better" type of waste, however, is not enough. To become truly lean one must also remove the underlying reasons for waste (Rother and Shook, 2004); the root causes (Liker and Meier, 2006).

### 2.3 Lean Concepts and Tools

Today, lean production is not just the utilization of a set of tools developed by Toyota; it also incorporates tools from different areas. It is not uncommon to make use of tools from approaches such as six sigma, TQM and MRP in addition to the classical tools of lean production. Any concept which provides added customer value can be used together with a lean strategy, even when traditional shop-floor tools such as kanban can not be utilized (Hines et al., 2004; Liker and Meier, 2006). When implementing lean production in other than the traditional area of manufacturing the different techniques and modifications fitting for the specific area must be given careful consideration (Åhlström, 2004). However, supporting Bowen and Youngdahl (1998) and Åhlström (2004) found all lean principles to be applicable to services, including but not limited to:

- Elimination of waste
- Pull instead of push
- Decentralized responsibility
- Continuous improvements

Bowen and Youngdahl (1998) also found, among others, the following concepts in both industries:

- JIT pull
- Flow production
- Employee empowerment

Allway and Corbett (2002) confirm the above by stating the concepts and tools applicable in production of physical goods and services as well as the importance of grasping the need for efficiency improvements to be the same. Table 2.5 consists of the lean tools which have been found to be compatible with the implementation of lean production in previous case studies within the service industry. In the following sections the lean tools and methods most commonly encountered when studying among others Rother and Shook (2004), Liker (2004), Liker and Meier (2006) and Keyte and Locher (2008) are described in more detail.

Table 2.5: Lean tools found to be compatible when implementing lean production in service companies.

<table>
<thead>
<tr>
<th>Lean tools</th>
<th>Compatibility found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaizen Events</td>
<td>Radnor and Walley (2008)</td>
</tr>
<tr>
<td>Visual Controls</td>
<td>Radnor and Walley (2008)</td>
</tr>
<tr>
<td>5S</td>
<td>Radnor and Walley (2008)</td>
</tr>
<tr>
<td>JIT</td>
<td>Bowen and Youngdahl (1998)</td>
</tr>
<tr>
<td>Value-stream mapping</td>
<td>Radnor and Walley (2008); Bowen and Youngdahl (1998)</td>
</tr>
<tr>
<td>Process mapping</td>
<td>Radnor and Walley (2008); Bowen and Youngdahl (1998)</td>
</tr>
<tr>
<td>Kanban</td>
<td>Radnor and Walley (2008)</td>
</tr>
<tr>
<td>Employee Empowerment</td>
<td>Bowen and Youngdahl (1998); Åhlström (2004)</td>
</tr>
<tr>
<td>Multitasking</td>
<td>Åhlström (2004)</td>
</tr>
</tbody>
</table>

2.3.1 Root Cause Analysis

Root cause analysis is central to lean production, since it is not just waste which should be removed but also the underlying causes (Rother and Shook, 2004; Liker and Meier, 2006). Root cause analysis is the basis for problem solving the lean way, and can be done by means of different tools. Two of the concepts and tools for root cause analysis are genchi genbutsu and the 5 Why method (Liker and Meier, 2006), as detailed below.
Genchi genbutsu

*Genchi genbutsu* is an important concept in lean production, which basically means that you should see the problem for yourself. The concept consists not only of seeing the problem for yourself, but also of making sure you thoroughly understand the problem as well as its implications. A decision to devote time and resources to solving the problem should not be made before this is done (Liker and Meier, 2006). Liker and Meier (2006) argue that this thorough understanding of the problem and its implications will lead to a quicker solution requiring less resources for implementation.

5 Why

A good way to identify the root cause of waste is to use the *5 Why methodology*. This methodology consists of asking "Why?" five times each time waste is found (Keyte and Locher, 2008). The aim of this technique is to identify what constitutes symptoms of an underlying problem, what are the actual problems, and what are the root causes of those problems (Liker and Meier, 2006). By not settling for a first answer to the question of what is the reason for doing things a certain way Liker and Meier (2006) argue that the real root causes can be more easily discovered, and that addressing these is what will provide the greatest benefits.

2.3.2 Kaizen vs Kaikaku

An important concept in lean production is that of *kaizen*, which stands for incremental improvement. Another important concept is that of *kaikaku*, which means "radical change" (Womack and Jones, 1996). This concept is not unique to lean production, but is also practiced in business process re-engineering, albeit under a different name (Willoch, 1994).

Implementing lean production in an organization is according to several authors a kaikaku effort, which often yields very good results (Womack and Jones, 1996; Liker and Meier, 2006). But when practicing continuous improvement – kaizen – in addition, these results can be even further improved; usually productivity is doubled again within two to three years; while inventories, lead times and errors are cut in half (Womack and Jones, 1996).

Kaizen Events

*Kaizen events* are aimed at improving specific parts of the process or organization (Liker and Meier, 2006), and are often performed in areas where a need for a kaizen burst has been identified (Rother and Shook, 2004). Kaizen events often yield very good results, and can act as a way to gain momentum within the organization and build a willingness to change further (Liker and Meier, 2006).
2.3.3 Pull, Flow and Just in Time

*Pull* production is production in the opposite way of that of traditional manufacturing; what is commonly called push production. In push production products are produced in volumes and variations as suggested by a forecast, and stored until the customer wants them. This is not only true for the entire production process at the company but even inbetween processes. Push leads to inventory building up all over: raw material, WIP as well as finished products (Liker, 2004). When utilizing pull production, production is instead initiated by the customer. What is produced is determined by what the customer actually needs. The distinction is commonly made that push production is made to stock, while pull production is made to order (Liker and Meier, 2006).

Good *flow* in a production process is distinguished by the idle time for any WIP being kept to a minimum. When flow has been achieved products flow through the production process without waiting in inventories, which places a high demand on the right resources being in the right place at the exact right time. (Liker and Meier, 2006)

Just in time is a concept which demands a great amount of flow. *Just in time* means that everything should be done just in time: products should be finished exactly when the customer requires them, raw materials should be delivered exactly when the company needs it and WIP should arrive at a process step exactly when the producer can start working on it. (Liker, 2004)

2.3.4 Stopping the Line

One of the core principles of lean production is that of stopping to fix problems, to make sure that quality gets right the first time. If a problem occurs but is not solved, all units produced after the first defect unit will run the risk of falling victim to the same problem. The methodology of *stopping the line* consists of actually stopping production when a defect is found, and not starting it again until the problem has been solved – at least temporary (Liker and Meier, 2006). According to Liker and Meier (2006) stopping the line may decrease productivity in the short run, but will increase it in the long run.

2.3.5 Visual Controls

*Visual controls* are ways of making immediate what the workers should be aware of (Liker, 2004). This could be work standards, markings on the floor detailing where different things go, orders to complete or lights that flash when an error has occurred (Liker and Meier, 2006). The aim is to not let any problems stay hidden, but to make it obvious when abnormalities occur. Visual controls should preferably be designed to be clear and simple, thereby being easy for everyone to understand (Liker, 2004).
2.3.6 Standardization and Isolating Variation

Standardization is the starting point of continuous improvement, and therefore an important foundation of lean production. The reason for its high importance is that unless a process is standardized there is no way to determine what areas are in need of improvements, or even what constitutes improvements (Liker, 2004). If processes are not standardized an improved process in reality just adds one more way the job can be done - a way that might still not be used, or at least not by all (Liker and Meier, 2006).

Standardized processes act as something to judge performance against (Liker, 2004). With standardized processes it is easy to determine what is normal or abnormal and also if a suggested action would actually improve performance (Liker and Meier, 2006).

According to Liker and Meier (2006) there are a few prerequisites for creating standardized work:

- The work task must be repeatable
- The equipment must be reliable and have very little downtime
- Quality issues must be minimal

The three conditions above also indicate that the process is stabilized, why having a stabilized process can be viewed as a prerequisite for standardization. There is sometimes built-in variation which can not be overcome, and standardization might then seem impossible. However, there is a way around this. First, the variation must be separated from the remainder - and the remainder can then be standardized (Liker and Meier, 2006).

2.3.7 Value Stream Mapping

Value stream mapping is a method for visualizing the value stream for a product or product family, and is commonly used to visualize the current state of a process as well as the proposed future state (Rother and Shook, 2004). It is important not to map out the value stream the way it should look, but according to how it actually looks. It should show the real flow, and not that which is intended (Liker and Meier, 2006).

In accordance with the pull philosophy of lean production mapping starts in what is usually considered "reverse"; with the customer. This means that the internal value stream is followed from the shipping dock and back to the point where deliveries are made to the raw materials inventory. Apart from showing what processes make up the value stream, detailed in the map should always be whether there exists a push
or pull relationship between processes, inventory levels for all inventories and suitable
time measurements (Liker and Meier, 2006). For each process, inventory and flow of
material or information an informative figure is drawn, detailing different information
depending on what it represents (Rother and Shook, 2004).

Rother and Shook (2004) recommend that the person mapping the current state
collect all data herself, whilst walking along the same path as material and information
flow. She should employ the use of a stop-watch, instead of relying on standard times
or data that has been collected previously. That data might have been collected at
a time when the value stream was working perfectly; but the interest here lies in
finding out how it works today. Some data might be difficult to collect yourself, here
historical data can be used.

Mapping the current state should not take a lot of time; time has precedence over
detail, a view voiced by both Rother and Shook (2004) and Keyte and Locher (2008).
Rother and Shook (2004) also suggest using rough estimates of numerical data instead
of spending time on finding exact numbers. This suggestion is based both on the
precedence of time over detail as detailed above and the fact that the processes might
not be stable. If the processes are unstable, there is no use in gathering numerical
data since variability of processes will be high (Rother and Shook, 2004).

The benefits of value stream mapping are suggested by several lean authors, including
reason for value stream mapping being suggested as the best tool for mapping value
streams is that it does not allow waste to be hidden, but instead the waste become
easy to identify (Rother and Shook, 2004; Liker and Meier, 2006; Keyte and Locher,
2008).

2.4 Successful Implementation of Lean Production

Womack and Jones (1996) identified the first step to successfully implementing lean
production. The first step concerns determining the needs of the customer: what
capabilities is he looking for in a product, and when and where does he want this
product? This starting point makes it possible to distinguish actual customer value
from waste. When customer value is not determined before lean techniques are applied
the company runs the risk of only becoming better and more efficient in producing
waste. Not until after the customer value has been determined do they recommend
that the removal of waste should start.

Liker and Meier (2006) state that implementation of lean production can start with
any of the four cornerstones of people, process, philosophy and problem solving. As
mentioned they do however suggest process as the starting point of choice, and to
start by removing waste in the processes. With standardization as a prerequisite for
removing waste it is therefore necessary to start by standardizing processes.
3 | Methodology and Execution

In this chapter the applied methodology is presented. The chapter begins with a presentation of the research design. In this section of the chapter the different parts and phases of the study are discussed together with the methodological choices available, before the chosen alternative is stated. Based on the discussion, the second part of the chapter further discusses the credibility of the study.
3.1 Research Design

In this section the different parts and phases of the research is discussed, with the aim to provide the reader with insight into the reasoning behind the methodological choices made.

3.1.1 The Foundation: A Case Study

According to Yin (2009) case studies are a preferable choice when an in-depth study is required, as is the case when attempting to implement lean production (Liker and Meier, 2006). Due to this and the inherent time constraints of a master thesis a single case study was considered the best feasible choice. The single case study allowed for an adequate depth of the study enabling observation of the effects of the processes of a company in a real setting during a period of three months. Denscombe (2003) highlights characteristics of a case study, which are summarized in table 3.1.

Table 3.1: Characteristics of case studies, according to Denscombe (2003).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Depth of study</th>
<th>Relationships/processes</th>
<th>Holistic view</th>
<th>Natural settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>rather than breadth of study</td>
<td>rather than end products/outcomes</td>
<td>rather than isolated factors</td>
<td>rather than artificial settings</td>
<td></td>
</tr>
</tbody>
</table>

Case studies have been questioned in the past, having been said to rely on "some notion of statistical generalization" (Dubois and Gadde, 2002). The approach of systematic combining (by some authors named abduction (Alvesson and Sköldberg, 2007)), which was chosen for this study and is described further below, assures sampling to become a systematical and continuous process and thereby not as random as in other approaches where samples are taken from a single point in time. This approach therefore addresses the issue of statistical generalization (Dubois and Gadde, 2002).

Another fact to consider carefully is that a case study runs the risk of becoming overly complex, due to it having its foundation in the real world. Therefore some results might have been important for the authors, but are not very important for the reader (Dubois and Gadde, 2002). Leaving out parts is therefore difficult but is, according to Yin (2009) as well as the authors, essential in ensuring that the results do not become a blur for the reader.

Logical coherence is an important foundation for generalizing the results and evaluating the quality of the case study (Dubois and Gadde, 2002; Yin, 2009). For the
reader to be able to evaluate the adequacy of the research processes and conclusions, she should be provided with an overview of them as well as accurate information throughout the report. The overview of the design of the research process can be seen in figure 3.1. The phases are: purpose, literature study, case study, analysis and conclusions, and are made up of activities which are also illustrated in the figure.

![Figure 3.1: Overview of the design of the research process](image)

At the bottom of figure 3.1 there is an arrow which represents the ongoing, iterative process; an approach which is especially suited for a study aimed towards refining existing theory (Dubois and Gadde, 2002; Alvesson and Sköldberg, 2007). As mentioned, this type of research process where the frame of reference, gathering of empirical data and to some extent the analysis is worked on in parallel exists under different names; systematic combining (Dubois and Gadde, 2002) and abduction (Alvesson and Sköldberg, 2007). Moving back and forth between the different research phases has proven to provide the researcher with a deeper understanding of both theory and empirical findings. This is because theoretical facts are hard to grasp until they have been experienced. After the empirical equivalent has been experienced new areas of interest might surface or a need for a more in-depth theory chapter on the same subject might appear (Dubois and Gadde, 2002). This is a way of working the authors of the thesis are familiar to and comfortable with, hence an additional reason for the choice of research model.

**Matching the Company with the Case Study**

The company was regarded as suitable in two of the dimensions suggested by Denscombe (2003); typical instance and extreme instance. According to Denscombe (2003) a well grounded matching can be made based on one of the dimensions. The
authors therefore found the suitability of the case company especially high since their point of view is that it is well-founded in both respects. Yin (2009) also suggests the choice of a single case study when the instance is the typical organization for the aim of the study. The evaluation can be seen in table 3.2.

Table 3.2: Discussion of the parameters of a suitable case company.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>The case company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical instance</td>
<td>A well established company with all processes in-house. Both large and small sized customers from all over the world.</td>
</tr>
<tr>
<td>Extreme instance</td>
<td>Larger sized company compared to the average of the industry, hence demanding a higher level of efficiency.</td>
</tr>
</tbody>
</table>

3.1.2 Purpose

The first step after deciding on conducting a case study was establishing the purpose. As a foundation of the purpose a background study of the existing theory on lean production and its modifications was conducted, which resulted in the problem background. The problem background then led to settling the purpose. This was done in accordance with suggestions by Denscombe (2003), who argues that an introductory research phase is necessary to make sure the research builds on existing knowledge.

When the purpose was in place it was further broken down into research questions, aimed to act as guidelines throughout the rest of the research process. The research questions also acted as a foundation for the analysis, and the conclusions were structured so as to answer them.

3.1.3 Literature Study

This phase began with, as the headline suggests, a comprehensive literature study, performed in several steps:

- Literature search
- Choice of literature
- Writing the theoretical frame of reference

In accordance with the approach suggested by Dubois and Gadde (2002) and the research model presented earlier, additional literature was added when it was deemed necessary. The steps detailed above were therefore performed at each such iteration. Below, these steps are described and discussed in further detail.
Literature Search

The literature studied covered published books as well as articles. The material was found through searches of scientific databases. Examples of key words used were: digital products, mass customization, lean service, lean production unique products, lean production digital products, lean production customized products, lean production, lean production modification, lean agile, agile.

Another way of identifying interesting literature was by sorting through books and articles covered in the authors’ previous studies at the university, as Saunders et al. (2009) suggest. Working through previously studied material provides a good evaluation of the current state of research on the topic as well as good references to study in more depth (Saunders et al., 2009). Well-cited books were found to provide a good foundation and structure for the theoretical frame of reference, and articles often served as complementary theory adding new dimensions to well established research.

Choice of Literature

Saunders et al. (2009) emphasize the importance of conducting a well planned literature search, including a clear definition of against which parameters to evaluate literature. The evaluation parameters used for this thesis were divided into two categories and successive phases. The two phases were selection and dimension. The selection phase was conducted before studying the literature in depth. The parameters against which literature was evaluated during this phase were for it to be well cited, the work of prominent researchers and on topics relevant for the purpose. Greater emphasis was given to these parameters when the topic was one which was widely covered.

The dimension phase was conducted after the literature chosen during the selection phase had been studied. The aim was to divide the literature into the different topics relevant for the frame of reference as well as the different views and approaches expressed by the different authors.

When choosing literature for in-depth study no outspoken parameter of time limitation was used. Instead, during the selection and dimension parts of the study, the date of publishing was taken into consideration and if no contradictory research had surfaced since the research was kept.

Theoretical Frame of Reference

After the selection and dimension phase, the theoretical frame of reference was written. As with the other phases this was done as part of an iterative process, which was conducted every time a need for additional theory emerged.
3.1.4 Case Study

Empirical data was gathered through interviews, observations and the study of documents. How the different parts were carried out will be covered further in this section.

A decision was made not to give reference to specific persons in the empirical findings. This was done to make sure that no one felt uncomfortable giving the whole picture, thereby providing the authors with a more accurate view.

Interviews

Interviews were conducted as part of the case study and two methods were mainly used for them; semi-structured and unstructured interviews. These types of interview tactics are what Saunders et al. (2009) call non-standardized. The non-standardized interviews allowed for in-depth studies where new aspects surfaced and enhanced the authors’ understanding. Analyzing adjectives used or emotions shown by the interviewee was responsible for creating this other dimension, as was the personal contact. The latter also provided the authors with the possibility to adapt their way of interviewing after the interviewee to create better conversations (Saunders et al., 2009).

The number of interviews conducted, roles of the interviewees and the type of interviews held are summarized in table 3.3. The basic idea of choosing interviewees was to match the goal of the interview with the work tasks and responsibilities of the interviewee to enable in-depth understanding and analysis, in accordance with Denscombe (2003). If the goal of the interview was to explore strategies, goals and visions of the company, interviews and workshops were conducted with mainly managers. Further if the goal was to map the production processes and to find out more about the daily work the production leaders were targeted for interviews and workshops. Finally to get the complete picture cross-functional interviews and workshops were conducted.

Initially, semi-structured interviews were conducted with key persons to get an overview of the company and its processes. The questionnaire found in appendix A acted as a guideline for these interviews, and was adapted after the role of the interviewee, as is suggested for semi-structured interviews (Saunders et al., 2009).
Table 3.3: Summary of interviews made during the case study.

<table>
<thead>
<tr>
<th>Position</th>
<th>Type of interview</th>
<th>Number of interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEO</td>
<td>Workshop</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>In-depth interview</td>
<td>2</td>
</tr>
<tr>
<td>CEO Custom Products Nordic</td>
<td>Workshop</td>
<td>1</td>
</tr>
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<td>General interview</td>
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<td>In-depth interview</td>
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<td>CHRO</td>
<td>Workshop</td>
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<td></td>
<td>General interview</td>
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<td>In-depth interview</td>
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<tr>
<td>Client Support Coordinator Custom Products</td>
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<td>General interview</td>
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<td>CSO</td>
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<td>General interview</td>
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<td>In-depth interview</td>
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<tr>
<td>Production Leaders Custom Products</td>
<td>Workshop</td>
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<tr>
<td></td>
<td>General interview</td>
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<td></td>
<td>In-depth interview</td>
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<tr>
<td>Project Leaders Custom Products</td>
<td>Workshop</td>
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<tr>
<td></td>
<td>General interview</td>
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<td></td>
<td>In-depth interview</td>
<td>3</td>
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<tr>
<td>Production Manager Custom Products</td>
<td>Workshop</td>
<td>7</td>
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<tr>
<td></td>
<td>General interview</td>
<td>1</td>
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<td></td>
<td>In-depth interview</td>
<td>8</td>
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<tr>
<td>Production Manager Volume Products</td>
<td>Workshop</td>
<td>1</td>
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<tr>
<td></td>
<td>General interview</td>
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</tbody>
</table>
The interviews were recorded and only minor environmental mind notes or follow-up questions were written down during the interview. Soon after the interview one of the authors was responsible for listening to the recordings and summarizing the content for future use. This was done in accordance with one way of controlling bias suggested by Saunders et al. (2009). The reason for not taking notes during the interview was to not lose focus and to be able to ask the right type of follow-up questions. The environmental mind notes that were taken were to encapsulate information which the recording device could not capture; a technique suggested by Denscombe (2003). The interviewer and interviewee bias, a debated quality issue regarding interviews (Saunders et al., 2009), was further handled by listening to the interview afterwards and transcribing the interview in as much detail as possible. The summary then became more objective than what would otherwise have been the case. To look upon the interview a second time with a critical view of the self in the interview is important for eliminating bias further (Denscombe, 2003).

Some of the interviews were conducted through Skype, since the company is geographically dispersed. Saunders et al. (2009) argue that the implication of these types of interviews is some loss of the richness of interaction and spontaneity, something which the authors agree with. Therefore the semi-structured interview technique with a bit more focus on structure than otherwise was adopted for these interviews.

**Observations**

Observations were chosen as a means of gathering data since it is in line with the concept of genchi genbutsu, the lean method of seeing the problem for yourself to gain a deeper understanding of it (Liker and Meier, 2006).
The observations provided the authors with the possibility to bear first hand witness to events without taking part in them as described by Denscombe (2003). The risk of interpreting the observations in a biased way, as discussed by Dubois and Gadde (2002), was considered small since the authors had no previous knowledge about the employees or this kind of production.

The main focus of the observations were on the production processes, but also behaviors and attitudes were observed to complete the empirical part of the study. Rother and Shook (2004); Liker and Meier (2006); Keyte and Locher (2008) emphasize the importance of finding out and mapping what the processes looks like, not what they should look like. Therefore observations were conducted on a day to day basis during the case study to insure the observations to be in a natural setting. Observations made in a natural settings will reveal how things normally happen (Denscombe, 2003), hence fulfilling the aim of the observations of the study. As the authors gradually gained knowledge about the production processes the observations got into more and more detail compared to the general observations made from the beginning.

Study of Documents

For the authors to gain in depth knowledge about the case company and their processes, internal documents were studied. Examples of documents studied were budgets, business plans, organizational charts and steering documents. This type of data is secondary data and serves a good purpose when there is no time to gather data from scratch (Saunders et al., 2009). Saunders et al. (2009) further argue that secondary data is sometimes the most accurate to use in analyses.

Only documents used by management were studied, since these documents were considered to be kept up to date and controlled to be very accurate. This decision was made to not risk the quality and precision of data, parameters which are often questioned when secondary data is used (Saunders et al., 2009).

3.1.5 Analysis and Discussion

The research conducted in this master’s thesis is qualitative research which means that it is associated with words rather than numbers (Denscombe, 2003). The fusion between theory and empirical findings was therefore translated into words and descriptions. As suggested by Denscombe (2003) the analysis was made to be very descriptive for the reader to judge the situations herself or himself. This is the reason for the merger of the analysis and the discussion.

The process of analyzing qualitative data has been compared to solving a puzzle (Saunders et al., 2009). One have to look at the big picture, find missing pieces and match pieces together in a logical way. The chosen approach of systematic combining
as described above allows the authors going back finding the missing pieces as soon as they were determined missing during the analysis.

The analysis was divided into the research questions to focus the analysis and to be able to easily form the answers to the research questions in the subsequent phase. Some findings were then subjected to further analysis whereas some were taken at face value.

### 3.1.6 Conclusions

Upon the analysis the conclusions were drawn. The conclusions were in the same way as the analysis divided into the research questions, and these questions were answered to the extent allowed by the study. In parallel areas for further research emerged and were documented.

### 3.2 Credibility of the Study

To measure and confirm the credibility and quality of the case study four tests were performed, as suggested by Yin (2009). The tests were construct validity, internal validity, external validity and reliability (Yin, 2009), all elaborated upon in the following sections.

#### 3.2.1 Construct Validity

In a case study subjective judgments might have affected the data (Yin, 2009). Therefore validity is concerned with findings being what they appear to be (Saunders et al., 2009).

Constructing validity was done by combining two tactics suggested by Yin (2009): multiple sources of evidence and having key informants review drafts of the case study. The use of multiple sources originated from the multiple products the company produces, enabling the study of multiple processes. The conclusions were therefore drawn from the findings of several processes. The drafts of the analysis and the compilation of data was continuously reviewed by key informants at the case company, to ensure the correctness of data acquired.

#### 3.2.2 Internal Validity

Internal validity is to what extent the conclusions of the study are causal (Yin, 2009).
The extensive use of lean production for the analysis is regarded to ensure the internal validity of the study, since lean production puts great emphasis on the processes and makes sure all casual relationships of the processes clearly surface (Liker and Meier, 2006). The study covers an industry where the use of lean production has not been explored, which implies that some parameters might differ. To tackle this challenge, research of the applications to industries other than the manufacturing industry and how modifications have been made there were used to make the reader and the authors aware of additional variables that might have effect in different contexts.

3.2.3 External Validity

External validity is concerned with the generalizability of the research. Generalizability is to what extent the findings can be applied in other contexts. (Yin, 2009; Saunders et al., 2009)

Matching the case company with the study was made on the grounds of the company being the typical instance for production of DCPs meaning the research settings being general already, as discussed previously. Therefore not as great emphasis needs to be put on ensuring generalizability as it would have otherwise. Yin (2009) suggests that matching the empirical findings with relevant theory will ensure the external validity, something which has been carefully done throughout the study; especially when making the choice of utilizing a systematic combining strategy throughout the research.

3.2.4 Reliability

According to Yin (2009); Saunders et al. (2009) reliability is to what extent the research would yield the same result if repeated using the same research techniques.

To ensure the same results would be achieved if the case study was to be performed once again, the research design of the study has been well documented, as suggested by Yin (2009). The documentation covers elaboration of the processes studied as well as the questionnaires for the interviews conducted. Some of the data gathered is harder to reproduce, for example the environmental and emotional observations. However, as previously discussed, measures were taken to counteract the effects of this.
This chapter presents the empirical findings. It is based in the case study, and starts off with a presentation of the situation at the company in all for the topic relevant aspects. Both internal and external aspects are explored, with the aim of providing the reader with a good basis for the analysis. After the initial presentation, the challenges found are gathered and presented. The final part of the chapter then presents how suggestions for the company were developed and presented.
4.1 The Production Process

Initially, value stream mapping was attempted for mapping the production process. It quickly proved difficult mapping the process according to what it actually looked like. A need for adding loops emerged, as did a need for averaging different versions of the process. When approaching members of the production unit concerning the accuracy of the value stream map their response was that it might be correct, but it could also look completely different. This led to value stream mapping becoming both difficult and time consuming.

A decision was made to abandon value stream mapping, due mainly to the process lacking stability and being very large and complex. These reasons are explored in more detail below.

4.1.1 No Initial Stability

The production process is neither stabilized nor standardized and can therefore be carried out in different ways by different people, for different customers and at different points in time. This became clear during observations and interviews. What also became clear is that there are several different, distinct processes in place for different customers - even when they order the same products as other customers. There are also several loops in the process, and these loops can be repeated as few or as many times as needed, varying with each project. Even when the loop has a maximum number of repeats, for example when customer feedback is desired, one or more extra loops can be added as needed.

When interviewing different persons about the process, they all had a different take on what it looks like; even when belonging to the same function or holding the same role. What everyone expressed is however that new processes, or actually modifications to the existing process, are developed often. The aim of these is to solve issues which have arisen with the process in place, often for a specific customer.

The lack of stability and a standardized process was the main reason value stream mapping failed. Detailing of process times and cycle times proved to be impossible when every project goes through the same production process a varying number of times, and even follows a different path between production processes.

4.1.2 Large, Complex Process

All process steps are carried out for all orders, no matter which products and quality levels have been ordered. Workshops revealed that some customers do not need all of the steps performed, but they are included anyway. In other cases, commonly when a customer needs more process steps than others, a new process will be developed for a specific customer.
Management has previously made an attempt to separate the process into modules, where an individual product and quality level has its own process which can be combined with the rest. The aim of this is to be able to combine the modules needed for different customers, products and quality levels. This has not been fully implemented, which became clear when the process was mapped out. Having developed these processes however left management with the perspective that they have in fact standardized their processes already.

**Large Amount of Handovers**

Observations revealed that the process contains a great amount of handovers between different persons and departments. Almost all handovers are done digitally; by assigning orders, sending e-mails, communicating or sending files over Skype or transferring WIP between servers. In all other cases the handovers are done verbally, where one person tells another that their part of the process can be initiated.

During the workshops there was a clear lack of understanding of the consequences of a handover. Many employees, as well as management, look upon handovers as actions which are not critical, since files can be transferred quickly. They do not take into account how much server capacity it uses or what the effects of each interruption are.

Due to the view that handovers are not a problem no actions have been taken to decrease their number.

**4.1.3 Production According to Customer Specification**

Production is always done according to customer specification and input material, why it is necessary that these are correct. Members of the production unit revealed that when material is missing or incorrect production is usually stalled; however, sometimes it will begin anyway after pressure from other parts of the organization. In the latter case production is based on incorrect or incomplete material, which leads to the producers sometimes having to guess what and how to produce. It was revealed by interviewees that incorrect material is often due to customers’ inexperience with the product at hand, as well as their inability to determine what constitutes correct and complete material.

The high degree of customer interaction was stated by artists and designers as a reason why their work is not always as good as they believe it can be. They expressed a feeling of being inhibited by it, and thereby incapable of producing what according to them will yield the best end result. Due to fear of not providing the customers with what they have expressively asked for, artists and designers often ignore their artistic feeling and instead produce completely according to customer specifications. According to them the customers lack the whole picture as well as the experience needed, and producing according to feedback therefore most of the time will not yield
results which are as good as what would have been possible without the feedback - when only the artist and designer’s knowledge would have been used.

Customer Previews

During the workshops it became clear that one reason for the process being so large and complex is the use of customer previews. There is initially a set number of times, which however often changes and can vary between processes for different customers, during the production process when the customer can preview the outcome. The planned previews occur at set points in time, as decided in the initial planning phase, and one or more days is set aside at each instance for the customer to preview the product. Following this, corrections are made based on customer feedback.

Several sources state that different customers give different kinds of feedback, and the amount of feedback also differs greatly. Some customers do not give feedback at all whereas some customers provide plenty of feedback, are very demanding and require a lot of involvement during the production process. A general opinion is that while some customers like to be able to see the result along the way, even if they do not always provide feedback, others feel it demands too much of them. Workshops revealed the reason behind using previews for all customers to be that customers are not satisfied with the first result; however, further probing revealed that some customers are actually satisfied with the very first result.

A workshop was held with the aim of determining ways of decreasing the need for previews. One of the ways suggested was to show the customer a number of reference products during the sales phase. Another was to demand that the customer make all choices for product details before start of production, or else agree to let the experts at the company decide.

4.1.4 The Individual Production Processes

Interviews and observations revealed individual products to have distinct production processes which combine with the rest to create the overall process. The processes are often intertwined, where production steps in one process may depend on production steps in others. The production of an individual product is commonly completed by one producer, while quality control and other supporting functions are completed by other persons.

No physical movements are made that are not necessary to produce the product, as determined through observations. Papers are not printed and everything needed for the production is attainable from the producers’ computers.

When the individual processes were observed it was clear that some of the individual production processes are standardized, while others are not. They are however all repeatable, since production is always made according to specifications and customer
input. The production systems used are according to the general opinion reliable, with very little downtime. There is however no one keeping track of when, why or how often downtime occurs.

Every producer has the mandate to decide how to produce, but should always follow customer specifications and input material. When questions arise the production leaders approached stated that the producers in their team decide for themselves or ask the production leader. The decisions they need to make differ greatly, due to them often concerning input material which in turn differs greatly. The general opinion is that it is necessary for the producers to be able to make decisions on their own, and that production leaders would have too much on their hands if this was not the case. An opinion was also raised that this in the end amounts to shorter lead times.

4.1.5 Quality Control and Errors

Several quality controls in sequence were revealed by observation of the process; it is not uncommon for a product to go through three steps of quality control before reaching the end customer. Even so, interviews reveal that a lot of errors are reported by customers. Due to the nature of the product what is an error and what is an opinion of taste is not always clear, why the discovery of what the customer assumes to be an error often leads to discussions. The general opinion is that some customers will discuss the error until they get their way; even if it implies involving additional parts of the organization.

During interviews and workshops the question of "What are the most common errors?" was commonly answered with "There are no common errors, they differ with every product.". When errors do occur the general opinion is that they are due to inexperience, unclear input material or specifications or differing opinions of style - never faulty tools or software.

Interviews with the production unit revealed that 17% of all errors reaching customers are due to production errors, a number they considered as good enough. Interviews with top management however revealed that they reckoned this number to be quite a lot higher, while even 17% is in their opinion far too high.

4.1.6 Variations in the Process

Through observations, interviews and workshops several areas of the process with high degrees of variability surfaced. Together with participants in the workshops they were categorized into three categories:

- Variation possible to remove or separate from the process.
- Variation possible to remove or separate from the process in the future.
• Variation which is probably not ever possible to remove or separate from the process.

The first category consists of variation which can with some effort be removed, without need for extra resources. Variations in the concerned category are: input variation, output variation, process variation and communication variation. Input variation was due to the input material not being consistent or complete and also due to the difficulties of determining the demands of the customer before initiating production.

Output variation was determined closely related to the designers and artists having extra time to put into the products in low season and minimal time for producing in high season. It is also connected to the lack of control over quality, even though quality controls take place more than once for every single product. Because of there not being a fixed process, process variation is as previously discussed large, and the many number of ways communication can be done makes up the communication variation.

Production times can be seen as quite fix if not a lot of R&D resources are put into the development of tools, programs and automatic scripts. The production time variation is therefore categorized as possible to remove or separate in the future. Demand is naturally variable, and this variation is not thought to ever be possible to remove.

Due to the lack of stability in the process lead times vary greatly.

4.2 Information Flow

Observations and interviews revealed that communication within the organization, within the process and with external parties such as customers is done ad hoc and in several different ways. There are no clear paths set for any kind of communication; whether it be preview feedback, questions from customers or questions from the production unit regarding input material. Communication is done in person, over telephone, by e-mail, via web forums and over Skype. The mode differs with person, urgency and response time; when one communication channel does not provide a quick enough response another may be used. The same goes for persons; when one person can not provide what is desired quickly enough another person may be approached. It is not always clear who should be contacted for different purposes; instead a decision is made by the person initiating contact. Response times are not set either; the respondent chooses within which time to answer and the instigator chooses what amount of time he finds acceptable to wait for an answer.

Interviews further revealed that customers can communicate with several persons within the organization: their seller, project manager, client support coordinator, production leaders for different production teams and, for some customers, management functions - both for the company as a whole and for the production unit. Within
the organization employees are also free to communicate as desired; it was revealed that it is not uncommon for the seller to in regard to a single order communicate directly with the production manager, project manager and client support coordinator as well as through the CEO or other member of top management.

Both persons within and outside of the production department express a fear of information getting lost, or not reaching all recipients in need of it. This is exceedingly the case when the customer communicates with several persons within the organization.

Due to their digital nature all deliveries are done through digital mediums. Deliveries are made up of a varying number of files, of varying sizes – some too large to be delivered as e-mail attachments.

All input material is also received in digital format. Files are received from customers through the ordering system, by e-mail, over Skype or over an ftp server\(^1\). Deliveries to customers are done by e-mail, over Skype, over an ftp server or over a public file delivery service.

**Communication Channels**

Not all communication modes are available to all customers. For example, some have access to a web forum for questions as well as an ftp-server for delivering and receiving files. As is the case with the processes, new modes of communication and file transfer are developed as a solution to problems or as demanded by customers or the process.

The advantages and disadvantages discovered for the different modes of communication and file transfers are explored in table 4.1. All manners of communication are made increasingly difficult due to the company and its customers operating in different time zones.

### 4.3 Production Planning

All products produced were revealed through observations and interviews to be customized to the point that no production can be initiated before a complete order has been made by the customer. The customer must however choose from a prespecified product offering, and new products are seldom developed as per customer request. Due to this the products are made to order.

Due to the digital nature of the products there is no need to plan for purchasing of raw material, and no purchasing is therefore made according to forecast. Interviews with production management revealed that orders are often made ahead of time,

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\(^1\) An ftp server is a server type which is used to transfer files and can commonly handle large files of all types. By connecting to the server any user with access to the username and password can upload and download files.
Table 4.1: Advantages and disadvantages with different modes of communication, as discovered at the case company.

<table>
<thead>
<tr>
<th>Mode of communication</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>In person</td>
<td>Easy, quick, provides opportunity for direct follow up questions, friendliest way of communicating</td>
<td>Interruption, only possible when working in same space</td>
</tr>
<tr>
<td>Telephone</td>
<td>Easy, quick, provides opportunity for direct follow up questions</td>
<td>May cause interruption</td>
</tr>
<tr>
<td>E-mail</td>
<td>Easy, possible for the recipient to answer in her own time</td>
<td>Long response times, follow up questions may incur further increased response times, restriction on file sizes</td>
</tr>
<tr>
<td>Web forums</td>
<td>Easy, everyone involved can see questions and answers, possible for the recipient to answer in her own time</td>
<td>Long response times, follow up questions may incur further increased response times</td>
</tr>
<tr>
<td>Skype</td>
<td>Easy, quick, possible to interact over web cam, provides opportunity for direct follow up questions</td>
<td>May cause interruption, restriction on file sizes</td>
</tr>
<tr>
<td>Ordering system</td>
<td>No restriction on file sizes</td>
<td>Only possible at ordering point</td>
</tr>
<tr>
<td>Ftp</td>
<td>No restriction on file sizes</td>
<td>Knowledge about ftp servers necessary</td>
</tr>
<tr>
<td>Public file delivery service</td>
<td>No restriction on file sizes</td>
<td>Not safe way of delivering files</td>
</tr>
</tbody>
</table>

leaving more than enough time for production. Resource planning is therefore made according to preliminary orders, which proves difficult since not all orders are made ahead of time. Even if there is often more than enough time for production, it is not uncommon that an order is placed too late in relation to the desired delivery date. When this happens the desired delivery date has usually still been promised to the customer by the sales unit, why the production unit must produce in a shorter time than usual. This affects both other orders and resource planning as a whole. However, even when a need for extra resources is determined no extra resources are put in place quickly enough, according to the same management functions.
Observations showed that the customer order is sent to one point in the value stream: the production manager. The production manager then sets a time plan for production of the order and relays this to the production units using a document detailing all deliveries. They produce according to time plan and the general opinion is that they manage to keep this most of the time, even when orders must be pushed through on a tighter schedule. Production is planned so as to be finished just in time for the customer’s deadline, why a late delivery is according to opinions voiced in interviews not a possibility. Due to the early decoupling point, all production is done in accordance with a pull system.

The production manager states that he plans production with large safety margins, to cover all sorts of variations and challenges. Hence in every process step the product spends a lot of time waiting for processing. The result is a very high level of accumulated waiting time, indicating a small proportion of value adding time. This was also clear from observation of the lead times compared to the actual production times. Apart from safety margins, the need to plan for previews and produce according to feedback from previews also add to lead times.

4.4 Customer Requirements and Value

The authors encountered challenges establishing what customer needs the products are satisfying. Firstly, interviews with top management revealed that the company has not decided on what customer segment to target, hence the customer needs of the targeted segment have not been mapped out. Secondly, workshops revealed that customers have trouble communicating the requirements they wish the product to satisfy beforehand. The uniqueness of each product makes it almost impossible to picture the end result and communicate what different details should look like before the start of production. Another reason for the difficulties is that the customer does not know what is possible to demand or expect, due to the lack of references and experience stemming from the product class still being in its infancy.

When posed with the question of whether the products actually satisfy customer needs neither management nor other persons approached were certain of this. Whether the actual needs satisfied by the products correspond to needs expressed by customers is something else which they are not sure of.

4.4.1 Outspoken Requirements

The outspoken requirements that could be established through interviews and workshops are as follows:

- Fully customized. The products need to be customized and uniquely produced for every single customer.
Conformity with originals. Some products are used as legal documents and therefore naturally need to have the highest level possible of conformity with originals.

Flexibility. Because of the fully customized products and need for conformity with originals, the production unit is expected to change already produced products if the in data changes, which it does continuously.

High quality. Quality is often described as final details such as lighting and artistic touches.

Accuracy of delivery. Dates for print and sales start is set before delivery making the delivery date crucial.

At the most the same lead time as competitors. The customers lack experience with the product offering and the only point of reference is the competitors, placing the demanded lead time on the same level as what the competitors can offer.

4.5 Alignment with Goals and Strategy

Interviews with top management revealed that the company has no clear market strategy, and no definitive decision has been made as to what customers to focus on. They further revealed that the company’s goals are stretch goals, concerning growth and future market share.

Even though no definitive market strategy exists, top management has a view of which customers they wish to pursue: customers with lower demands for quality for whom products can be more mass-produced. This is according to the production management not reflected in the current customer stock where a large proportion of revenue comes from customers with very high demands, for whom new processes, communication methods and products need to be developed continuously. All in all the customer stock is a wide mix of customers, with varying demands. This has resulted in the production unit seeking to satisfy ever changing needs, and not necessarily achieving a perfect match between customer and need. They expressed that a clear customer strategy is needed for a more standardized approach to be possible. A clear customer strategy is also needed to be able to determine what customer needs to satisfy.

It was revealed during interviews and workshops that what strategy and goals are already in place have not been communicated clearly to the rest of the organization. It was further revealed that the production unit does not believe that the voiced customer strategy is the one which will actually be pursued - since this has previously not been the case.
4.6 Challenges

As maybe noticed, a great deal of challenges were discovered in the production processes of the case company. The challenges has been described above and are here summarized in table 4.2.

Table 4.2: Identified challenges in the production process of the case company.

<table>
<thead>
<tr>
<th>No standardized process; varies with customer, person and situation</th>
<th>Several quality controls in sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production errors</td>
<td>Production errors reaching customers</td>
</tr>
<tr>
<td>Resource planning made difficult due to varying lead times</td>
<td>New developed processes not always put in place</td>
</tr>
<tr>
<td>Unnecessary process steps</td>
<td>Quick, temporary fixes for problems instead of solutions for underlying causes</td>
</tr>
<tr>
<td>Resource planning made difficult by changing demands for lead time</td>
<td>Many handovers</td>
</tr>
<tr>
<td>Deciding what mode of communication to use</td>
<td>Deciding who to communicate with</td>
</tr>
<tr>
<td>Varying available modes of communication for different customers</td>
<td>No set response times for cases</td>
</tr>
<tr>
<td>Several points of interaction</td>
<td>Information might get lost</td>
</tr>
<tr>
<td>Unsafe transfer of information</td>
<td>Different time zones</td>
</tr>
<tr>
<td>Communication which interrupts work</td>
<td>Restriction on size of transferred files</td>
</tr>
<tr>
<td>No existing mapping of customer needs</td>
<td>Difficulties transferring customer needs to production</td>
</tr>
<tr>
<td>Not satisfying needs that do exist</td>
<td>Satisfying needs that do not exist</td>
</tr>
<tr>
<td>Input not consistent</td>
<td>Input not complete</td>
</tr>
<tr>
<td>Output not good enough</td>
<td>Output too good</td>
</tr>
<tr>
<td>Varying production time</td>
<td>Varying demand</td>
</tr>
<tr>
<td>Tracking KPIs</td>
<td></td>
</tr>
</tbody>
</table>

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4.7 Actions Taken

Following the identified challenges, lean tools were utilized to find their root causes. The lean tools used for this was genchi genbutsu and 5 Why. After root causes had been identified an implementation plan was developed for the company. The different steps taken and tools utilized are described in more detail below.

4.7.1 Root Cause Analysis

Root cause analysis workshops where the 5 Why method was utilized, in combination with observation through genchi genbutsu, led to the discovery of two root causes which, at least in part, contributed to most types of waste. These root causes were lack of standardization and lack of alignment with goals and strategy.

The following types of waste were considered to at least in part be due to lack of standardization:

- Waiting for response concerning unexpected questions and issues
- Longer lead times than necessary
- Many handovers
- Several quality controls in sequence
- Unnecessary process steps
- Output varies with available time for production
- WIP due to excess time planned
- Deciding that external or internal communication is necessary
- Deciding what mode of communication to use
- Deciding who to communicate with
- Modifying communication based on customer
- Communication which interrupts work
- Production errors
- Production errors reaching customers
- Correcting errors
- Discussing errors with customers
• Input not complete
• Input not consistent
• Incorrect interpretation of customer needs reaching production
• Information might get lost
• Artists are not allowed their artistic freedom

Lack of standardization was also found to be the source of challenges such as difficulty of tracking KPIs, difficulty resource planning due to varying lead and production times, developing processes which are not used and implementing quick fixes instead of solving root causes.

The following types of waste were considered to be at least in part due to lack of alignment with strategy and goals:

• No existing mapping of customer needs
• Satisfying needs that do not exist
• Not satisfying needs that do exist
• Developing processes which are not used
• Modifying communication based on customer

Lack of alignment with strategy and goals was also found to be the source of challenges such as lack of alignment between strategy and customer stock, lack of communication on strategy and goals as well as the production unit not trusting top management.

All in all, the only types of waste and challenges that were found to not at all be possible to attribute to the two mentioned root causes were waiting for customer feedback, large attachments and varying demand. The latter of which is considered impossible to remove, while the middle one is considered as inherent in digital production. Waiting for customer feedback was considered to be possible to remove if a process was put in place which did not incorporate this element.

### 4.7.2 Implementation plan

The implementation plan was made up of kaizen events, and the suggestion for the company was to continue utilizing kaizen events in the future as well. Kaikaku as a more radical change was part of the first plans for an implementation plan: to change the processes radically, almost overnight, and to be able to start over with a new, suitable process providing high levels of customer value. This was met with
suspicion and an attitude of not believing it would be possible. The reasoning was
that it would disturb the daily operations and lead to loss of customers, something
the authors agreed was a possibility. For this reason kaizen events were instead chosen
for the implementation plan. The recommendation of using kaizen events was met
with positive responses and a will to implement these changes.

The implementation plan was developed with a twelve month horizon, but suggested
to be revised every three months. For the revision of the implementation plan the
authors suggested the following agenda:

1. Evaluate how far implementation has come, as well as how far the implementa-
tion of the individual steps has come
2. Remove parts which have already been successfully implemented
3. Re-schedule implementation of parts which have not come as far in implementa-
tion as they should have, or which are determined not be possible to implement
as planned
4. Add new things to the last, "new", three month period

Following this agenda the implementation plan will never be finished, but new areas
will be added every three months.

4.7.3 Specific Improvement Suggestions

It was suggested to create an ordering system, as a means of visual control. The
ordering system should be one in which customers can place orders, producers receive
the orders they are to produce and both production management, team leaders and
producers see how many orders are waiting, if any orders have been delayed and other
important information.

The possibility of creating a physical visual control system was discussed, but the
digital nature of the product meant that there was no guarantee that all members of
production were contained in the same area. And due to one of the benefits of digital
production - for production to be possible anywhere - this was not a restriction the
authors wished to impose.

Another suggestion was for production to be done as soon as possible, instead of just
in time as is the case today. Instead of including customer previews the customer
would then have time after delivery to order the changes desired, which was quite
often the case even before, and still meet their deadline. In this way the lead time
for orders which did previously not even need previews can also be shortened.

A modification to the approach of stopping the line was also suggested for the case
company. The modification consists of the following:
• Full responsibility for quality of products lies within the team producing the product group

• A dedicated quality control function within each production team

• Products which are not considered good enough by the quality control function are sent back to the producer who produced it in the first place, for rework
5 | Analysis and Discussion

The analysis and discussion chapter aims to merge the theoretical frame of reference with the empirical findings. The empirical results are analyzed and discussed in relation to what has been stated in the theoretical frame of reference, and from this the conclusions emerge. The chapter is divided into sections based on the previously determined research questions, where each section can be studied individually. Finalizing the chapter is a discussion of the methodology.
5.1 RQ1: What constitutes waste when producing digital, customized products, and to what extent can the waste be eliminated?

Before starting the analysis of the first research question recall the different opinions on waste presented in the theoretical frame of reference. Liker and Meier (2006) suggested waste to consist of everything which does not create value for the customer, hence what is waste depends on the customer’s needs which in turn depends on products and situation (Keyte and Locher, 2008). Liker and Meier (2006) continued to suggest that waste should be rooted out completely, with only minor exceptions. Waste in a service context however was elaborated upon by Keyte and Locher (2008), who suggested some types of waste to be non removable and the result of support processes which must be in place to support the current business model (Keyte and Locher, 2008). Lastly, Naylor et al. (1999) suggested agile to meet volatile demand, in which waste was regarded as being necessary in some cases in order to maintain a flexible process. With this as well as the examples of types of waste in service and manufacturing industries in mind, the challenges found in the production processes of the case company have been categorized in the eight by Liker and Meier (2006) suggested categories of waste. The challenges were also analyzed according to the above discussion of to what extent the waste is possible to eliminate. The categorized challenges are found in table 5.1.

Table 5.1: Categorized waste challenges in the production processes of the case company.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Established types of waste in DCP companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overproduction</td>
<td>-</td>
</tr>
<tr>
<td><strong>Waiting</strong></td>
<td>Longer lead time than necessary</td>
</tr>
<tr>
<td></td>
<td>Waiting for response concerning unexpected questions and issues</td>
</tr>
<tr>
<td></td>
<td>Waiting for customer feedback</td>
</tr>
<tr>
<td><strong>Transportation</strong></td>
<td>Many handovers</td>
</tr>
<tr>
<td></td>
<td>Large attachments</td>
</tr>
<tr>
<td><strong>Over processing or incorrect processing</strong></td>
<td>No existing mapping of customer needs</td>
</tr>
<tr>
<td></td>
<td>Satisfying needs that do not exist</td>
</tr>
<tr>
<td></td>
<td>Unnecessary process steps</td>
</tr>
</tbody>
</table>
Table 5.1: Categorized waste challenges in the production processes of the case company, continued.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Established types of waste in DCP companies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output varies with available time for production</td>
</tr>
<tr>
<td></td>
<td>Several quality controls in sequence</td>
</tr>
<tr>
<td>Excess inventory</td>
<td>WIP due to excess time planned</td>
</tr>
<tr>
<td>Unnecessary movements</td>
<td>Deciding that internal or external communication is necessary</td>
</tr>
<tr>
<td></td>
<td>Deciding who to communicate with</td>
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<td></td>
<td>Deciding what mode of communication to use</td>
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<tr>
<td></td>
<td>Modifying communication based on customer</td>
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<tr>
<td></td>
<td>Developing processes which are not used</td>
</tr>
<tr>
<td></td>
<td>Implementing quick fixes instead of solving root causes</td>
</tr>
<tr>
<td></td>
<td>Communication which interrupts work</td>
</tr>
<tr>
<td>Defects</td>
<td>Production errors</td>
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<td></td>
<td>Production errors reaching customers</td>
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<td></td>
<td>Correcting errors</td>
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<tr>
<td></td>
<td>Discussing errors with customers</td>
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<td></td>
<td>Input not complete</td>
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<td></td>
<td>Input not consistent</td>
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<tr>
<td></td>
<td>Incorrect interpretation of customer needs reaching production</td>
</tr>
<tr>
<td></td>
<td>Information might get lost</td>
</tr>
<tr>
<td>Unused employee</td>
<td>Artists &amp; designers are not allowed their artistic freedom</td>
</tr>
<tr>
<td>creativity</td>
<td></td>
</tr>
</tbody>
</table>
5.1.1 Overproduction

Waste due to overproduction; producing earlier than needed or too much, was not observed during the case study. The company’s products are made to order and therefore the risk of producing too much or earlier than needed is non existent. All fully customized products will be made to order and therefore this class of waste can be further stretched to regard as redundant for all fully customized products. The digital aspect of the product does not affect waste in this category either way since customization already rules out the risk of overproduction.

In summary; overproduction is a non existing waste when producing DCP.

5.1.2 Waiting

The indications of customers and employees waiting, and thereby the presence of the waste of waiting, were clear in the case company during the empirical study. Customers waiting for their delivery because of longer lead times than necessary, and employees and customers both waiting for answers to unforeseen questions or issues were all categorized as waiting waste following the waste convention of Liker and Meier (2006). However, waiting for customer feedback appeared to be in need of closer attention.

Following the proposal of Liker and Meier (2006), everything not adding value for a customer is waste, and therefore all types of waiting becomes waste from the customer point of view. The concept of customer feedback on the other hand appears to be value adding even though it causes waiting. Depending on what type of customer to satisfy, different levels of customer interaction were requested.

As described earlier the fact that the product is digital and therefore fast evolving, and in addition customized, makes it difficult for some customers to picture the end result, which is the root of the need for continuous interaction and feedback as production progresses. Additionally, in the nature of customized products is the demand of delivering exactly what the customer demands and control points can therefore be needed during the manufacturing. However, during the empirical study different ways of helping the customer to not feel the need for interaction during the production process were found. These actions will be required for elimination of the waste of waiting to be possible to a greater extent. Further, this waste category will depend on what type of customer the company is trying to satisfy. If the target customer is the category indicated who wanted extensive involvement during the production process the waste becomes necessary and bigger than if the target customer is chosen to be the type of customer requiring less involvement.

Overall; employee and customer waiting constitutes waste producing DCP, but waiting due to customer feedback is to some extent necessary and can not be removed without changing the product offering. The waste should instead be minimized and matched
with the needs of the targeted customers, for example by putting in place the actions discussed.

5.1.3 Transportation

Many unnecessary handovers were discovered during the case study. Digital products implies digital handovers and therefore they are not as visible as they would have been if of a physical nature, something which was found at the case company to lead to management and employees not taking action against the large number of handovers or even noticing them at all. This indicates a need for special attention. Since handovers constitute waste taking up server capacity as well as employees’ time, resources which could be used for adding customer value instead, the number of handovers should be minimized to correspond to the needs of the current produced product. Large attachments are also categorized as transportation waste, but since the product is digital it must be delivered in this manner and the waste can therefore not be eliminated. It should however be kept to a minimum.

In summary; transportation in the sense suggested by Liker and Meier (2006) constitutes waste for DCP, and extra attention should be given to handovers. The resulting large attachments is a non removable waste and should be kept as small as possible.

5.1.4 Over processing or incorrect processing

Liker and Meier (2006) and Keyte and Locher (2008) stated over processing or incorrect processing to occur when a product is processed in a way which creates a gap between the end product and the true needs of the customer. Consequently the foundation of knowing what constitutes waste in the category is knowing what the customer needs are and what constitutes customer value. The case company had no existing mapping of customer needs why the authors through some simple probability calculations arrived at the notion that there were an endless number of types of waste to find in the category. Among others probable types of waste are satisfying needs that do not exist and at the same time not satisfying all needs that do exist. Without the mapping in place, a more detailed analysis was not possible and would not be possible whichever industry the company was operating in or whatever modification of lean used.

The case company used the same process no matter what products were produced and what customer they were aiming to satisfy, resulting in unnecessary process steps for the products not incorporating all of the requirements which were covered by the process. Consequently, to produce a customized product there is a certain need for a flexible process allowing process steps to sometimes be present while being disregarded in other cases, according to the requirements of the customer. This is in line with the suggestions of Naylor et al. (1999). Configuration of the process must
be quick and correspond to the product. The result is a process containing necessary "unnecessary" process steps, which will not be regarded as waste when not used, once again according to the proposition of Naylor et al. (1999).

Further, incorrect processing and over processing were also found in the manufacturing processes of the case company through the challenges of "Output varies with available time for production" and "Several quality controls in sequence". These two challenges are viewed as waste in the classical lean sense and in line with the views of Liker and Meier (2006). This type of waste is not connected specifically to DCP, but to all delivery organizations - including DCP manufacturers.

Summing up; for all delivery organizations, including those producing DCP, over processing or incorrect processing starts with knowing what adds customer value. The process needs to be flexible and configurable, consisting of process steps which can be used or disregard as needed, and the process steps not used for a specific process are regarded as necessary waste.

5.1.5 Excess inventory

Excess inventory was found in the shape of WIP due to excess time planned for each process step, a categorization which is in line with the suggestions of Liker and Meier (2006). However, for digital products there are neither raw material inventories, since raw material is not needed for producing DCP, nor inventories holding finished goods, since the receiving party is waiting for the product and the delivery is digital and instant.

Planning each production step is challenging when producing customized flexible products. The products have never been produced before in the same shape and therefore safety margins need to be set higher. This constitutes necessary waste as described by Naylor et al. (1999), but should of course be kept to a minimum.

Overall; Producing DCP, excess inventory is found in the shape of WIP and needs to be minimized. However there will be some excess inventory not in focus of elimination due to the safety margins needed when producing customized products.

5.1.6 Unnecessary movements

Physical, unnecessary movements that do not add value, as suggested by Liker and Meier (2006), appear to be non existent at a first glance for a digitally producing company. However, the authors were surprised in finding a large number of examples of waste during the case study belonging to this category if unnecessary movements were to include mental movements as well as physical movements, or in general: unnecessary efforts. Each employee spent a large portion of his time each day deciding on communication aspects; if to communicate, who to communicate with, what mode of
communication to use and which mode of communication to use with what customer. All the above decisions, as well as the interruption it causes for the one communicated with, take time and focus away from value adding work and is therefore waste according to the definition of Liker and Meier (2006). The high level of communication is to some extent interrelated with the high level of customization; a lot more questions arise when modifying unique products compared to when repeating the same tasks, making it especially important to find ways to minimize ad hoc decisions concerning communication. Customization also comes with the implication of necessary waste due to the high level of flexibility required, in line with the proposal of Naylor et al. (1999).

In summary; the waste category in DCP organizations should better be named as "unnecessary efforts" and especially consists of some necessary waste regarding communication. As concluded many times before, necessary waste should still be minimized.

5.1.7 Defects

The waste of defects is by Liker and Meier (2006) defined as producing errors or correcting errors. Following this definition a lot of defects surfaced during the case study. The authors were not surprised in finding defect related waste, such as: internal production errors, production errors reaching customers, correcting errors and discussing errors with customers. The above mentioned types of waste could be expected to be found in every delivery organization, no matter what products are produced. The products belonging to the DCP category is no reason why the waste can not be eliminated.

An interesting finding was that the input very often was not complete, not consistent or was an incorrect interpretation of the customer needs. This led to errors occurring during the production, with inconsistent end results or products being produced in a way the customer did not expect or desire. Due to the product being customized, translation of customer needs into clear instructions and guide lines as well as correct and complete material is needed for production, which demands that the customer has sufficient knowledge to manage this. Skaggs and Huffman (2003) argue that to maintain high performance of the company and its deliveries, very complex offerings demand a low level of customer interaction or otherwise a high level of education of customers due to their high impact on the end result. DCP can be regarded as a highly complex offering and the findings during the empirical study supports the proposal of Skaggs and Huffman (2003). Education and support to customers to assure input will, according to the definition of waste by Liker and Meier (2006), constitute waste. But since customers have an essential effect on the end result and their own satisfaction, this will be necessary support processes in the way suggested by Keyte and Locher (2008).

Not surprisingly customer specific information was found to be very important when producing customized products. When this type of information got lost the impact on
customer satisfaction was high. Finally, employees looking for information, suggested as a defect waste by Liker and Meier (2006), was also present at the case company.

Overall; producing DCP defects is waste in the classical meaning. The level of customer co-production when producing DCP needs to be set to reflect the strategy, and education or help must be offered to the customer to assure the input is correct and complete. Keeping good control over customer specific information is also vital for the customer value in producing DCP.

5.1.8 Unused employee creativity

A high level of customer co-production gives rise to another aspect as well; the previously mentioned feeling of artist and designers that they did not have enough artistic freedom. As described in the empirical findings this sometimes led to customers receiving results which were not as good as possible; but, however, exactly to customer specifications.

In summary; producing DCP demands experience and knowledge to get a good result and therefore the best end results will be created when employees use their creativity and full potential. Waste is therefore the unused employee potential when the level of customer interaction gets to high.

5.2 RQ2: Which lean concepts and tools are suitable to apply in the production of digital, customized products?

The tools and concepts mentioned below are central to lean production in traditional manufacturing companies. Under the individual sections the suitability of each tool and concept for application in DCP production is analyzed and discussed.

5.2.1 Elimination of Waste

Eliminating waste is a foundation of lean production, and the concept appears in all literature on the subject matter, no matter the industry. The core principle of lean production is even said to be reducing lead times by removing waste, a principle which is further suggested as a way to apply lean production outside traditional manufacturing.

According to lean practitioners (e.g. Liker and Meier (2006)) creating and or handling waste demands resources, which could instead be used to create value for the customer. Since the aim of all production should be to provide customers with what
they desire with as high a quality as possible and for as low a cost as possible, it follows that waste must be removed or kept to a minimum – no matter the industry. What may differ is the manner in which waste is removed.

It was clear from the case study that there were massive amounts of waste, inhibiting the company’s ability to deliver customer value. This serves as a confirmation that waste is present in all types of companies and industries, and that this waste must be removed. The fact that removing waste has previously proven to be appropriate in modifications of lean production to areas outside of mass manufacturing further strengthens the authors in this notion.

Overall, eliminating waste is central to lean production and should be practiced for all companies aiming to implement lean production – no matter the industry.

5.2.2 Root Cause Analysis

Following on the elimination of waste is the lean concept of root cause analysis. In lean production it is important to not remove only the obvious waste and causes of waste, but to remove the root causes of waste. For this reason a root cause analysis was performed at the case company, and this proved to be a valuable tool for determining the root cause. To perform the root cause analysis the concepts of genchi genbutsu and 5 Why were utilized, as discussed in further detail below.

The successful use of root cause analysis at the case company in combination with analysis of root causes being an important foundation of lean production led the authors to the opinion that root cause analysis is both a useful and appropriate tool when attempting to implement lean production in the production of DCP.

Genchi Genbutsu

An essential part of root cause analysis in lean production is to see the problem for yourself, before attempting to solve it. The importance of this concept in the production of DCP became clear to the authors as they initially attempted to understand the challenges facing the production unit without having seen it for themselves. After walking through production and seeing hands on what challenges there were and where they stemmed from the issues became much clearer. With no concrete experience of the type of production at hand the authors could not picture the challenges facing production, and definitely not understand them or the implications they had for the unit.

The experience at the case company led the authors to regard genchi genbutsu as even more important in the dynamic environment that is DCP production. When new technology is utilized, production processes change fast and products vary from one order to another, the importance of genchi genbutsu becomes even more obvious than when producing standardized, physical goods. Liker and Meier (2006) state
that genchi genbutsu aids quicker solutions requiring less resources. The authors’ experience is that for the production of DCP, solutions are not even possible to develop without first utilizing the concept of genchi genbutsu. They therefore agree with Liker and Meier (2006) in the importance of gaining a deep understanding of the challenge before investing time and resources in solving the problem.

5 Why

Famed genius Einstein (Einstein) once said "The important thing is not to stop questioning. Curiosity has its own reason for existing.", and who are we to argue with a man of such intellect. If Einstein inspired Taiichi Ohno the authors do not know, but it is certain that he did in fact inspire Liker and Meier (2006). Root cause analysis as a whole rests on the principle stated by Einstein, but the authors are of the opinion that 5 Why is the greatest manifestation of this in lean production - or maybe even the world.

The 5 Why method was utilized at the case company with good results, and no specific difficulties in utilizing this method were discovered that could be related to DCP production. However, in this type of production issues are often more abstract than in regular production, which can make it more difficult to pinpoint why they arise. The perseverance demanded by this method therefore seemed even more beneficial in this kind of production, precisely because root causes are sometimes more abstract and more difficult to pinpoint.

In summary, root cause analysis is a useful tool in DCP productions by means of genchi genbutsu and the 5 Why methodology. Genchi genbutsu may be even more useful in DCP companies since processes and technology changes faster, and the abstract nature of digital production makes the 5 Why methodology highly useful.

5.2.3 Kaizen Events

Kaizen events are known to lead to good results when used to improve specific areas, and were the foundation of the implementation plan recommended for the case company. The authors are of the opinion that the positive attitude towards kaizen events found at the case company shows that kaizen events are indeed a good way to begin the implementation of lean production and, as suggested by Liker and Meier (2006), build momentum for further change. This goes to show that kaizen events are suitable no matter the industry or company; what changes is what lies within the kaizen event.

Without a doubt, kaizen events are useful when implementing lean production and helps build momentum for further change.
5.2.4 Kaikaku

The authors’ experience at the case company, where kaikaku was met with suspicion and fear of negative side effects, is in line with what the authors consider to be the case for most, if not all, companies and industries and is therefore not considered as something unique to the production of DCP. The authors argue that due to the disturbance of daily operations and risk of loosing customers, kaikaku is great when immediate change is necessary, for example when a company is on the brink of bankruptcy. For these scenarios the authors are of the opinion that companies can benefit greatly from kaikaku, while more stable companies with functioning daily operations can benefit more from kaizen events. In the latter case the authors even argue that, as suggested by the case company, kaikaku could do more harm than good in the short term - even if the kaikaku effort would lead to great results in the end. For this reason the authors also view persuading management of at least somewhat stable companies to make use of kaikaku as difficult; another reason not to use it since involvement and dedication of management is important for any change to be possible.

Some researchers (e.g. Liker and Meier (2006)) suggest that implementing lean production is inherently a kaikaku effort. This view is not shared by the authors of this thesis. While kaikaku is the fastest, and according to the authors - if the initial hurdles to the kaikaku effort are overcome - the easiest, way to implement lean production, it is not considered necessary or even necessarily the best way. Utilizing the incremental improvements of kaizen instead creates momentum while demanding less resources, and also creates a spirit of small, continuous improvements in the organization from the first day of implementation. An added bonus which the authors have discovered is the possibility to review the implementation plan every few months, adding new kaizen events while removing what has already been implemented. This way the implementation and kaizen effort is never finished, but continues in the true spirit of continuous improvement.

An important distinction to be made is however that the study focused on the whole process, which consisted of several interconnected individual production processes. While kaikaku was deemed unsuitable for changing the whole process, the authors argue that it may still be suitable for implementing changes to the individual production processes. The individual production processes will benefit vastly from newly developed technology, which should therefore be implemented quickly in the spirit of kaikaku.

All in all, kaikaku is considered unsuitable for implementing lean production in companies which are at least somewhat stable. It might, however, be suitable for implementation of lean production in companies in desperate need of a quick change, and for improving individual production processes.
5.2.5 Pull

Customized products cannot be produced before demand has been realized, why all production must be initiated by the customer. This implies that the production of customized products will always be a pull system, even if a kanban system or the like is not in place. Inherent in the production of DCP is the lack of inventory: inventory can only be kept in the way of WIP, which has however already been ordered by a customer, and not in the way of raw materials or WIP which is not related to a specific order.

The authors are of the opinion that an important distinction, as made clear by the case company, is that of the decoupling point. For DCP the decoupling point will always be far upstream; no production will be possible beforehand and no material can be ordered since no material is needed for the production. Even when an external party does part of the production this can not be initiated before the order has reached the company. To the authors this signifies an inherent need for a pull system: production is only initiated for real customer orders.

*Summing up, it is clear to the authors that introducing pull in the production of DCP is redundant. It is a simple case of deduction: DCPs are always produced following the pull of the customer. So if it is production of a DCP, it must be pull.*

5.2.6 Flow

The concept of flow is, compared to the concept of pull, one which the authors argue may be present to different degrees for different companies, no matter the industry. The authors are however of the opinion, an opinion which is strengthened by experiences at the case company, that flow is easier to achieve for production of DCP than in the production of non-customized, physical goods. The reason for this is the underlying pull nature of DCP production. Matching of supply and demand is made easier by pull; but matching resources to demand is still difficult, even if supply and demand are completely in tune. The case study exemplified this in that lead times were much longer than actual production time. Since flow was not perfect extra time needed to be allowed for the product to move through the production process, so as to still meet the deadline set by the customer.

*In summary, increasing flow can provide great benefits in all types of production, but since DCP production has already achieved pull the flow efforts can in the authors’ view be initiated earlier.*

5.2.7 Just in Time

Digital products implies that delivery can be made instantaneously, why delivery times are not an issue. Delivering just in time therefore for DCP implies finishing
production just in time. Since no raw material or such is needed for digital production receiving goods just in time is not an issue either, but rather that production starts just in time.

As with pull production, the concept of just in time is in the authors’ view at least in part inherent in the production of digital, customized products. Since all production is done according to customer order production will not start "too early"; that is, not until an actual order has been placed. In the case company production was then planned so as to be able to deliver the products just in time - where just in time meant meeting the customer’s deadline.

In the case of customized production the authors would like to argue that the just in time concept may, while often inherent, not be suitable. Customized production implies some degree of customer co-creation, and as the case study showed this can lead to difficulties when planning to deliver just in time. The authors therefore argue that when producing customized products, which can only be produced when ordered by a customer, and especially DCP, which will not become obsolete as easily as other products and do not demand any raw material to be delivered beforehand, an approach of "as soon as possible" might serve the purpose better. This approach was as previously mentioned the one suggested for the case company and will be implemented for their production.

Overall, just in time is considered as unsuitable for DCP production due to the customized nature of products. Instead, an approach of as soon as possible would be suitable.

5.2.8 Stopping the Line

The aim of stopping the line when an error occurs is to contain the error, to make sure both that it does not reach the customer and that the same error does not occur again. While it became clear to the authors from studying the case company that it is important both to contain errors so they do not reach customers and to analyze them so as not to risk making the same mistakes again, it also became clear that stopping the line immediately to make sure the same error does not occur again is unnecessary. After an error has occurred it is of course important to make the producer aware of the error, to minimize the risk of it occurring again, but the probability of the same error occurring, or even having the possibility of occurring, in the next product produced is very slim. This makes the urgency of containing the error smaller than in more standardized production, where errors may also to a higher degree be due to faulty equipment. This might not be the case for all DCP production but was clearly the case at the company studied - and the authors argue that to a degree, depending on company, stopping the line is always less suitable for DCP production than for traditional, more standardized production.

The modification to stopping the line which was suggested for the case company is something the authors argue could be applied in other DCP productions as well.
Especially if, as was the case at the studied company, there is one person who is responsible for most of the production of the product, which makes accountability easier. Even if the ordinary version of stopping the line could also be applied, the authors are of the opinion that the suggested modification does not decrease short term productivity as much as is common when implementing stopping the line without the modification.

Summing up, stopping the line in its original execution is considered as unsuitable for DCP production. Stopping the line with modification is instead suggested.

5.2.9 Decentralized Responsibility

Lean production suggests decentralizing responsibility in the organization. During the case study it became clear to the authors that this is at least as important in DCP production as in other types of production. In the less standardized DCP production more decisions must be made in the daily course of production than what is the case with more standardized production, why decentralizing responsibility becomes highly important. As noted at the case company, if the producers would not have the authority to make daily decisions both production times and overhead costs would increase dramatically. The authors further consider this to be the case in all similar production departments; DCP usually incorporate some level of creativity and artistic touch, both which demand decisions to be made by the producer.

In summary, decentralized responsibility is highly important in DCP production due to the the customized nature of products demanding producers to make choices on their own.

5.2.10 Visual Controls

Visual controls were already implemented to some extent in the case company, through the document detailing which deliveries were coming up for each and every production team. As production is digital the authors considered the digital version of visual controls suitable, and as previously described suggested the development of an ordering system as a further development of this. As was also previously mentioned creating a physical visual control system was discussed, but discarded due to imposing too much of a restriction on the production.

The experiences at the case company led the authors to the opinion that all companies in all industries can benefit from visual controls, but that the manner of visual control may need to be adjusted to fit the company at hand. Even though the immediacy of physical visual controls has its perks, the authors suggest that for DCP production digital visual controls is still the best choice.

Overall, visual controls are considered as a good tool for DCP if modified to consist of digital visual controls.
5.2.11 Standardization

As earlier described, there was no clear, standardized process. According to lean literature standardization is a prerequisite for continuous improvement, a notion the authors agree with. Standardization was therefore decided to be one of the first courses of action at the case company. The authors’ aim was to create a new process for the company, and did not want to risk creating just one more way to produce, as was suggested by Liker and Meier (2006) is a risk when standardization is lacking. This further led the authors to determine that standardization is very important for all kinds of companies, including those producing DCP.

For standardization to be possible the processes must be stabilized in that they must be repeatable, reliable and with minimal quality issues. The first two criteria were met at the case company while the third was not. This is not something the authors view as specific to DCP, but specific for the company in question. The three prerequisites is however something the authors suggest to be valid for DCP production as well, and something which should be explored before attempting standardization. Another important factor, which may be even more important in more dynamic areas such as that of DCP production, is that of isolating variation so as to be able to standardize the rest. This tool is explored in further detail below.

Isolating Variation

Inherent in the production of highly customized products is according to the authors variation. As suggested by lean practitioners this variation should be isolated and removed before standardization is attempted. Variation and the result of it was clear at the case company. While this may not be the case for all DCP companies, the authors are of the opinion that an investigation into what non removable variation exists and further isolation of this is necessary. Especially since a lot of DCP companies are young and production processes may not have been stabilized as of yet.

Another source of variation is demand variation; both concerning volume and attributes. Increased by products being young and demand not stabilized, this is still somewhat present for all companies. When products are customized they can as previously discussed not be produced according to forecasts, why variations in demand can not be targeted by means of leveling production. This may make production of DCP more suited for agile than purely lean solutions, since the latter suggests keeping a level schedule.

In summary, standardization is as important for DCP production as for traditional manufacturing. Since DCP production is inherently variable isolating variation however becomes even more important than in traditional manufacturing.
5.2.12 Value Stream Mapping

As stated in the empirical results, value stream mapping was attempted but quickly discarded as unsuitable for the process at hand. The reason for this was the great difficulty the authors had in mapping out the process the way it actually looked, which Liker and Meier (2006) among others state as very important, while keeping to the strict rules of value stream mapping. While it might have been possible to after quite some effort arrive at a value stream map which showed most of the picture, the effort this would have demanded was considered to go against the recommendations put forth by both Keyte and Locher (2008) and Rother and Shook (2004). Value stream mapping should according to these authors not be time consuming, but for this process it was very much so. This might not be due to the product at hand being a DCP, but rather the process, which was very big, complex and unstable. For this reason the authors of this thesis suggest that value stream mapping might be highly unsuitable for unstable processes, especially those which are also very large and complex.

Rother and Shook (2004) discuss value stream mapping for unstable processes, and arrive at the conclusion that for these processes rough estimates of measurements should be used since the times will probably vary a lot. The authors of this thesis would as suggested above go even further and claim that for a highly unstable process value stream mapping is not even suitable to begin with.

The greatest benefit of using value stream mapping is suggested to be the easy identification of waste; but for this process the authors found the risk was that waste would actually be hidden by trying to fit the process into a quite strict value stream map. With the loops of the process, which can be gone through as many times as necessary, and highly variable process times, there was no way to map out the process in a manner suitimg for a value stream map.

While value stream mapping was considered to be highly unsuitable for this process, the authors can not certainly say that it is unsuitable for all DCP processes. The authors would however not suggest the use of a value stream map for any large, complex and highly unstable process - be it a traditional manufacturing process or a DCP process. The authors further suggest that the inherent complexity of DCP processes translates to value stream mapping being less suitable for these products than for others.

Overall, value stream mapping was considered unsuitable for mapping out large, complex and unstable processes. These characteristics are further argued to more often be present in processes producing DCP.

5.2.13 General Suitability

When choosing which lean tools and concepts to apply the authors share the view of Åhlström (2004); that it is important to evaluate and decide what tools and concepts
are suitable for implementing lean production in different contexts. This notion was verified after studying the case company, where it quickly became clear that some tools and methods are well suited for application in the production of DCP; some even more than for production of other, more traditional, products. It also became clear that some tools were not well suited for this context at all; due to either the digital nature of the products, customization, or both.

Even if all tools may not be suitable in all contexts, the authors’ investigation found that the core principles of lean production are still well suited. This is a notion the authors consider as transferable to any context. However, customized production is inherently more variable than traditional mass manufacturing, why in some parts agile solutions may be more suited.

All in all, lean production and its core principles are considered as suitable for implementation in DCP production, even if all tools are not suitable and some are only suitable with modifications.

5.3 RQ3: What steps are necessary for initial implementation of lean production for production of digital, customized products, and how should they be prioritized?

As previously described, root cause analysis led to the discovery of two major root causes: lack of standardization and lack of alignment with strategy and goals. Following on this, the authors arrived at the notion that for implementation of lean production to be possible these two root causes first had to be addressed. The reasoning behind this was that if the frequency of almost all waste could be decreased at least to some degree by addressing these root causes then that should be done, in order to hopefully be able to unveil more waste with other root causes.

Aligned with the views of the authors are the views of lean practitioners who have previously addressed the subject of implementing lean production; albeit outside of the world of DCP. Womack and Jones (1996) suggest to start by determining customer needs, to ensure that what is produced satisfies the needs of the customer and is not actually waste. The authors consider determining what strategy to follow and which customers to pursue to be a natural first step to determining what those customers demand. Standardization has by other authors (e.g. Liker and Meier (2006)) been suggested as a prerequisite for determining what constitutes waste, since if it is not clear what is supposed to be then it is not possible to distinguish what is that should not be.

While the targeted segment and strategy for a stable company in a stable industry may be set in stone since a long way back the authors of this thesis are of the opinion
that this is not the case for younger companies, especially in younger industries. Since the industry of DCP is still in its infancy it follows that most companies within this industry will not have a clear definition of what customers to target and what to offer them; why the authors argue that the two first steps suggested here for implementation of lean production are of paramount importance there. However, they will be important for any company without a clear market strategy, with which the production strategy is aligned.

In summary, two steps are the most important for initial implementation of lean production to DCP production and should be gone through before further implementation is attempted. These steps are aligning the production strategy and process with the organization’s strategy and goals and standardizing the production processes.

5.4 Discussion of Methodology

In the following sections the applied methodology is discussed in light of the outcome. Overall the use of an iterative approach, as suggested by Dubois and Gadde (2002); Alvesson and Sköldberg (2007), where the theoretical frame of reference, empirical results and analysis is worked on in parallel, proved successful. It provided the authors with a deeper understanding and therefore better analysis than what would have been possible with a more sequential approach.

5.4.1 Purpose

The introductory research phase suggested by Denscombe (2003) proved to be vital for establishing a suitable purpose. Further, the research questions which were established to aid in fulfilling the purpose were considered to be very useful.

5.4.2 Literature

The literature search was conducted in such a manner that all literature which had not been contradicted was considered current enough. This proved useful since most basic and well-cited literature on the topic of lean production was composed some years back. In the past few years not much new literature on the topic could be found, which among other things the authors ascribe to the fact that other approaches, often somewhat similar to lean production, have taken the stage instead. These modifications often concern more modern types of manufacturing, such as software development. In some of these areas, for example agile, there is still almost no peer reviewed literature available, especially not concerning the basic principles of the approach. For this reason the authors would in hindsight have contemplated including some non-peer reviewed sources as well, in order to gain a deeper understanding of the basics of agile.
5.4.3 Case study

Using a case study for this master’s thesis was vital. In accordance with the suggestions of Denscombe (2003) it provided depth, overview of relationships and processes, a holistic view and the possibility to observe the phenomena in their natural setting. Apart from this the authors were showered with information, which made for both positive and negative effects. The effects were positive in that the massive amount of information provided by the case study, as Denscombe (2003) suggests, provided the authors with a deep understanding. The effects were negative in that the massive amount of information also, as suggested by Dubois and Gadde (2002), made the study highly complex. A thorough and time consuming sorting was necessary in order to decide what information was useful and what was not. The depth provided was however deemed necessary to fulfill the purpose, why the complexity must be viewed as a necessary evil.

An aspect to consider is that of the number of case studies to conduct. In this case the authors are of the opinion that it would not have been possible to conduct more than one case study, due to the time needed to gain the deep understanding necessary. Conducting more case studies would however have provided an extra dimension in that a higher degree of generalizability could have been achieved. The study is still considered to have a high degree of external validity, due mainly to the case company fulfilling two of the instances suggested by Yin (2009); however the external validity could have been increased further by the use of several case studies.

Interviews

Interviews were an important part of the case study, and without them the case study would not have provided as much depth as it did. All types of interviews utilized – semistructured interviews, unstructured interviews, general interviews, in-depth interviews and workshops – proved useful. The tactic of recording all interviews instead of taking notes, and instead taking notes while listening to them afterwards, also proved successful. The aim was to instead be able to notice environmental cues and body language, which the authors made use of. This did however not come without a price; taking notes while listening to the interviews afterwards more than doubled the time needed for interviews.

While the semi-structured interview, which was the most commonly used, provided enough structure most of the time some of the interviews – specifically the more in-depth ones – would have benefitted from more structure. For other interviews, however, less structure was needed and the unstructured interview was then used. These interviews were those were sensitive subjects were discussed, where the authors needed to thread carefully and observe cues given by the interviewees in order to be able to gain as much information as possible without discouraging the interviewees.

Using both general interviews to gain an overview and more in-depth interviews and
workshops when more focus was needed proved to be a good approach. Workshops proved to be a good way to elicit ideas from employees, as well as planting ideas with them with the aim of growing the ideas further. They also proved useful in awakening interest in the subject as well as willingness to try to improve the processes.

The authors tried to conduct all interviews concerning specific subjects with the person closest to them; the person responsible or the person working with it, or preferably both. This resulted in information which is by the authors considered to be as correct as it gets, and when contrasted with information drawn from other parts of the organization the differences were apparent.

**Observations**

Observations were also an important part of the case study. The concept of genchi genbutsu proved highly important, which the authors especially realized when they without thinking about it tried to understand the process from afar. This proved difficult, but as soon as the authors could see the process and the problems for themselves everything fell into place.

Observing in the natural setting of the process, as suggested by genchi genbutsu, did have its negative aspects as well. It was made especially difficult by the production unit operating in another part of the world, which demanded that the authors travel there to perform observations. Generally the authors are of the opinion that observations are time consuming, no matter which company is observed, but that they are still a vital part of a case study, which can not be excluded in order to save time.

**Study of Documents**

Documents were studied at the company, in the manner previously decided. This did however not prove as important as the authors had thought it would be. Reading about the process proved time consuming and often gave an incorrect picture; instead, observing the process and talking to the people involved in it was what proved important.
In this chapter the conclusions formed are presented. The conclusions have emerged from the analysis, which in turn builds on the earlier parts of the thesis. The conclusions chapter is divided into the research questions and the concluding answers to them.
6.1 Answers to Research Questions

The answers to research questions presented here are based on the analysis in the previous chapter. The conclusions reached have already been presented there, but are summarized here for the reader’s convenience.

All in all lean production is concluded to be suitable for application to the production of digital, customized products. Modifications of waste, tools, concepts and implementation is however required according to the conclusions of this report.

6.1.1 RQ1: What constitutes waste when producing digital, customized products, and to what extent can the waste be eliminated?

The answer to RQ1 is summarized in table 6.1. Seven categories of waste remain after the analysis, and consists of the detected examples summarized and their found potential degree of elimination.

Table 6.1: Waste when producing DCP summarized.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Example</th>
<th>Potential degree of elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting</td>
<td>Employee and customer waiting</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>Employee waiting for customer feedback</td>
<td>Partial, necessary waste but should be minimized to fit the business model</td>
</tr>
<tr>
<td>Transportation</td>
<td>Handovers</td>
<td>Complete, special attention required</td>
</tr>
<tr>
<td></td>
<td>Large attachments</td>
<td>Partial, necessary waste but should be minimized to fit the business model</td>
</tr>
<tr>
<td>Over processing or incorrect processing</td>
<td>No existing mapping of customer needs</td>
<td>Complete, special attention required, foundation of the category</td>
</tr>
<tr>
<td></td>
<td>Not satisfying needs that do exist</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>Satisfying needs that do not exist</td>
<td>Complete</td>
</tr>
</tbody>
</table>
Table 6.1: Waste when producing DCP summarized, continued.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Example</th>
<th>Potential degree of elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configurable process</td>
<td>Partial, necessary waste but should be minimized to fit the business model</td>
<td></td>
</tr>
<tr>
<td>Excess inventory</td>
<td>Excess inventory of WIP</td>
<td>Partial, necessary waste but should be minimized to fit the business model</td>
</tr>
<tr>
<td>Unnecessary efforts</td>
<td>Unnecessary efforts regarding communication</td>
<td>Complete</td>
</tr>
<tr>
<td>Defects</td>
<td>All production errors</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>Correcting errors</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>Discussing errors with customers</td>
<td>Complete</td>
</tr>
<tr>
<td></td>
<td>Input not complete</td>
<td>Partial, in need of support processes consisting of necessary waste</td>
</tr>
<tr>
<td></td>
<td>Input not consistent</td>
<td>Partial, in need of support processes consisting of necessary waste</td>
</tr>
<tr>
<td></td>
<td>Incorrect interpretation of customer needs reaching production</td>
<td>Partial, in need of support processes consisting of necessary waste</td>
</tr>
<tr>
<td></td>
<td>Information might get lost</td>
<td>Complete, special attention required</td>
</tr>
<tr>
<td>Unused employee creativity</td>
<td>Artists &amp; designers are not allowed their artistic freedom</td>
<td>Complete, special attention required</td>
</tr>
</tbody>
</table>
6.1.2 RQ2: Which lean concepts and tools are suitable to apply in the production of digital, customized products?

Following the discussion in the analysis chapter, some concepts and tools were found suitable for implementation in DCP production, while others were found unsuitable. Some of the more suitable concepts and tools were even found to be more suitable for implementation in DCP production than in traditional manufacturing. Even if not all lean concepts and tools were found applicable to DCP production, the core principle of lean production - decreasing lead times by eliminating waste - was found to be applicable without modification.

The concepts and tools that were found to be unsuitable for implementation in DCP production were:

- Kaikaku
- Just in time
- Stopping the line (without modification)
- Physical visual controls

Value stream mapping was found to be unsuitable for large, complex and highly unstable processes. For this reason the authors are of the opinion it is less suitable for implementation in DCP production, but might, depending on the process at hand, not be entirely unsuitable.

The concepts and tools that were found to be suitable for implementation in DCP production were:

- Elimination of waste
- Root cause analysis
- Genchi genbutsu
- 5 Why
- Kaizen events
- Flow
- Stopping the line (with modification)
- Decentralized responsibility
- Digital visual controls
• Standardization
• Isolating variation

The following concepts were considered to be more suitable for DCP production than traditional manufacturing:

• 5 Why
• Decentralized responsibility
• Digital visual controls
• Isolating variation

The concept of pull was considered to be redundant for implementation in DCP production.

6.1.3 RQ3: What steps are necessary for initial implementation of lean production for production of digital, customized products, and how should they be prioritized?

The authors argue the following to be two necessary initial steps to implementing lean production in DCP production:

1. Aligning the production strategy and process with the organization’s strategy and goals
2. Standardization

The authors further argue that aligning the production strategy and process with the strategy and goals of the organization as a whole, and standardizing the process, is fundamental to any lean effort. But perhaps even more so in DCP companies, which may not have as solid a customer base as companies in older and more stable industries.

The authors reckon that since DCP production is inherently dynamic, it might not be possible to implement lean production in the traditional way. The authors therefore are of the opinion that the suggested initial steps for implementation may be necessary to repeat, and may for DCP production become the source of continuous improvement.
6.2 Suggestions for Further Research

When processes are standardized and stabilized and when goals and strategy have been set, new areas of waste will surface according to Liker & Meier (2006). Therefore further research and empirical studies on companies further along the process of implementing lean production needs to be done to complete table 6.1. As previously mentioned the authors argue that the suggested initial steps may be necessary to repeat over and over again, something which must also be researched in DCP companies further along on their lean journey.

The authors of this thesis were not able to give a definite response to whether value stream mapping is suitable for use with DCP processes, due to the highly unstable process in the case study. The authors therefore are of the opinion that further research in this area should be attempted, to determine whether value stream mapping is suitable for more stable DCP processes.

The authors came to the conclusion that kaikaku was unsuitable for changing large processes for at least somewhat stable companies, but might still be suitable for changing the individual production processes of the same companies. A related concept which would be of interest to study in relation to this is that of business process reengineering, which the authors of this thesis could unfortunately not cover due to time restraints. An interesting approach would be to evaluate the use of business process reengineering in DCP production, both for large processes and individual production processes.

The researched area should also further be expanded to include additional function areas of the lean enterprise, as illustrated in the introduction of the report in figure 1.2. The authors are of the opinion that further research in for example lean product development for DCP would reveal supplementary interesting findings in an area not previously explored.
Bibliography


Mike Rother and John Shook. Lära sig se. The Lean Enterprise Institute Sweden, Göteborg, 2004.


A | Questionnaire

During the case study several interviews were performed. The following topics and questions formed the basis for the general interviews.

Overview

- Job title
- For how long have you been working at the company?
- What are your work tasks? What type of work are you performing?
- History; have your role changed upon time? How?

Processes

- What is the input to your work?
- When does your job start?
- Who initiates the start of your work?
- What type of information are you given at the input stage and who is giving it to you?
- How do you receive your input from?
- What is output of your work?
- When does your job finish?
- Who formally finishes your job?
- What type of information do you give at the output stage and who is the receiver?
- How do you deliver your output?
- How long does the process take?
- What are the steps in between input and output? What type of information and how do you save the information for later use? Who are you interacting with?
- What problems do you encounter during the process? How can you solve these problems?

**Customer Value**

- What is the value you are creating for your customers?
- What is the value your department, your role are creating for the customer?
- What differs in the product offering in the value received of the customer?
- What is important for the customer? What is less important?