Increase production volumes at a small, fast-growing company

A case study at Plejd AB

Master's thesis in Production Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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MASTER'S THESIS 2020

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Abstract

The smart home industry is growing, and it is becoming more popular and easy to control home appliances and lighting using a mobile phone app. Plejd is a company that develops and manufactures products for smart home automation. It is a growing company that, within a few months, will move to a new production facility to be able to increase its production volumes. This master's thesis aims to map Plejd's current production flow to identify and analyse areas of improvement that would enable the company to scale up its production volume. Two research questions have been formulated to support the purpose of the project: how is the current production flow structured and how can changes in the current production achieve a higher production volume.

A triangulation between literature study, qualitative methods with interviews and observations, and quantitative methods for collecting numerical data have been used. The literature study was conducted to get a theoretical background to the project. Interviews, observations, and collecting numerical data were used to map Plejd's current state through value stream mapping. Furthermore, production capacity was calculated to estimate how far away Plejd was from the ambition to produce 100,000 products per month.

Problems in the production were identified based on the mapping of the current state. Subsequently, several improvements are presented focusing on reaching higher production volumes, which are summarised in a map of the future state. The suggestions for improvements presented in the project are; merge small operations into stations, optimising the bottleneck in production, using overlapping of operations to a greater extent, investing in more SMT assembly racks, and introducing standard operating procedures for the operators. With these improvements, in combination with investments to increase production capacity should Plejd accomplish its goal of producing 100.000 products per month.

Keywords: Value stream mapping, Lean production, Production volume, Production capacity, Capacity calculations, Electronics production, Printed circuit board

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Jonna Bengtsson & Matilda Milding
Gothenburg, June 2020

Abbreviations

C/O - Change over time

CT - Cycle time

ERP - Enterprise resource planning

PT - Process time

PCB - Printed circuit board

PPT - Planned production time

PTH - Plated-through hole

SME - Small and medium-sized enterprises

SMED - Single Minute Exchange of Dies

SMT - Surface mount technology

VSM - Value stream mapping

WIP - Work in process

Contents

List of Figures

List of Tables

1
Introduction

In this chapter, the introduction of the project is presented. First, the background for the project is presented, and then the aim, research questions, and limitations are defined. Lastly, the thesis outline for the project is described.

1.1 Background

The smart home industry is growing, and it is getting more popular and easy to control home appliances and lighting with the help of a mobile phone app (Blumtritt, 2019). Plejd is a company that aims to be innovative in this field by creating a product that differentiates itself from other products on the market. They do so by developing and manufacturing smart lighting and home automation that is integrated into the customer's home and does not require any changes to the existing lighting or appliances, Figure 1.1 illustrates the integration. Plejd works with certified electricians, which supply Plejd's products to the customers and perform the product installation. Today more than 150,000 households are equipped with Plejd's products, and over 10,000 electricians are currently working with Plejd's products (Plejd, 2020).

Figure 1.1: Illustrative image of installed Plejd products (Plejd, nd).

When Plejd started, a contract manufacturer produced all of their products while they invested in a small production facility to build their prototypes. The interest in production grew, and it was decided that in addition to their prototype production, manufacture products from their ordinary product line. Plejd has produced a slim collection of products in its facilities in the last years. The manufacturing process of these electronic products, in short, comprises of soldering components on a printed circuit board, which is then encased in some type of plastic shell depending on the product. Then, the product is packaged for delivery. Figure 1.2 shows a selection of Plejd's products.

Figure 1.2: A selection of Plejd's products (Plejd, nd).

Even though Plejd recently started their production, they will move to larger facilities in a few months. The company has expanded from 4 employees to around 85 employees in the last three years, and the move will promote further development and expansion. The move to another location is a step for Plejd to increase the production volume of its main products while still producing prototypes. They have the ambition to increase their production volumes from around 15.000 products per month to in the future manufacture 100.000 products per month. It is a challenge for many companies to increase their production volumes drastically (Tillväxtverket, 2011). However, it is an additional challenge for Plejd, who does not yet have routine and stability in their production system.

1.2 Aim and Purpose

The project aims to map Plejd's current production flow to identify and analyse areas of improvement that would make it possible for the company to scale up its production volume.

The purpose of this project is to explore Plejd's possibilities to increase their production volumes. By analysing the current production system, it will be possible to understand what improvements can be made to achieve a more effective production and, thus, higher production volumes. It is also of interest to see if today's production system can meet Plejd's goal of manufacturing 100.000 products per month, and if not, what could be done to reach that goal.

1.3 Research questions

The following questions will be answered to achieve the aim of the project:

- How is the current production flow structured?
- How can changes in the current production accomplish a higher production volume?

1.4 Limitations

The following limitations have been defined for the project:

- The project is performed at Plejd's production in Mölndal.
- The project will not take into consideration the effects of combining the primary production and the production of prototypes.
- The project will only map and analyse the production flow of one product family.
- Implementation of the result will not be a part of this project.
- The project will not take into account any costs related to the proposals for improvements.
- The project time is limited to 20 weeks.

1.5 Thesis outline

The report is structured as follows:

Chapter 2: Theory
The theory chapter is the result of the literature study. The theory starts with an introduction about production systems where certain production parameters and printed circuit board assembly are explained. The theory continues with a brief introduction to lean production with a description of value-added activities and wastes. Then the four parts of value stream mapping are described, followed by the theory of capacity, and finally, sustainable production is described.

Chapter 3: Methods
The first part of the method chapter explains the project's process. A description of the literature study follows this before moving on to the qualitative methods that involve interviews and observations, and quantitative studies. The process of value stream mapping is then presented and then continues with an explanation of the capacity calculations. The last sections describe the validity and reliability of the results when using these methods and research ethics.

Chapter 4: Results
The results chapter begins with a description of the current state and the identified problems in Plejd's production. Then it continues with a description of Plejd's current capacity requirements.

Chapter 5: Analysis
The analysis chapter begins with an analysis of the identified problems. Subsequently, improvements are proposed that aims to solve the identified problems with a focus on increasing production volume. These are then summarised in a future state map. Finally, an analysis of Plejd's capacity is presented with suggestions for measures to increase the capacity in order for Plejd to meet their production volume goal.

Chapter 6: Discussion
The discussion chapter begins with a discussion of the result and Plejd's ability to reach the production goal before proceeding to the method discussion. Lastly, sustainability at Plejd's production facility is discussed.

Chapter 7: Conclusion
The conclusion chapter answers the defined research questions and complete the aim.

2
Theory

In this chapter, the theory for the project is presented. This chapter aims to provide relevant theories and concepts, which will be the foundation of this project. This will help to create an overall knowledge of the topics and support further reading and understanding regarding the results and analysis.

2.1 Production systems

A production system should be designed considering the different parts of the system (Bellgran and Säfsten, 2005). These parts include the technical and physical aspects but also the people in the system and how the work is organised (Bellgran and Säfsten, 2005). To be able to design a production system, there is a need for a holistic perspective. The focus must be on the interaction between the different parts of the production system (Bellgran and Säfsten, 2005). Designing a production system is a challenging activity, and demands are placed on production both from the market and from employees (Jacobsen et al., 2001).

A production system contains several elements, such as facilities, people, machines, and equipment (Bellgran and Säfsten, 2005). However, it is essential to remember that different production systems may contain different elements depending on what is produced in the production. A production system can be adjusted differently depending on various parameters. There is no single form of production that will be successful for all types of products in all kinds of settings (Bellgran and Säfsten, 2005). It is about adapting production to the context, which will depend on more concrete factors such as the type of product and size of the investment, as well as factors such as company strategy, customer, needs and demand (Bellgran and Säfsten, 2005).

2.1.1 Production parameters

Measurements and various parameters can be used to visualise a process, identify potential problems, and increase the understanding of the flow to find improvements (Sörqvist, 2013). The following are some common parameters and terms used in a production system.

WIP
Work in process (WIP) is the accumulation of products currently in the production

process either stored between operations or processed in an operation (Martin and Osterling, 2013). The accumulation of products between operations leads to each operation are separate entities, which in turn makes the production process as a whole less affected by variation in cycle time and production disturbances (Jonsson and Mattsson, 2016). WIP influences the amount of tied-up capital and throughput time, where high WIP leads to more tied-up capital and longer throughput time (Sörqvist, 2013).

Bottleneck
The bottleneck is the resource that limits the available capacity in the production system (Olhager, 2013). The bottleneck machine should be fully utilised in order to maximise the output from production. Actions need to be taken to continually keep the machine running, for example, making sure the machine always has material available (Olhager, 2013).

Batch
When producing in batches, a group of identical or almost identical products is manufactured, without other types of products being manufactured in the same process on that occasion (Kiran, 2019). The whole group is processed before moving on to the next (Kiran, 2019). This leads to a large number of products that are in the same step of the production process. Large batch sizes can lead to extensive ques before each process (Sörqvist, 2013)

Process time
The process time is the time it takes to complete all activities associated with a single operation. If only one product is processed at a time, then the process time is equal to the cycle time (Rother and Shook, 2003).

Cycle time
The time it takes to complete all activities associated with a single operation for one product is known as cycle time. This is measured from the time the operator or machine starts working with the product to the moment work on the next product is initiated (Sörqvist, 2013). Equation 2.1 displays how to calculate cycle time from a known process time.

$$Cycle\ time = \frac{Process\ time}{Products\ processed} \tag{2.1}$$

Throughput time
Throughput time is the time from the moment the production of a product starts until it is finalised at the last operation in the process (Sörqvist, 2013).

Lead time
Lead time can be defined differently, but a common definition is that lead time is the time from the moment the customer places an order to the delivery of the product (Sörqvist, 2013).

Takt time
To produce products at a rate that meets customer demand while avoiding over producing is of importance (Luyster, 2006). The rate of production where customer demand and production speed match is called takt time (Luyster, 2006). Determining the takt time sets a pace for how often production should produce a product (Luyster, 2006). It is essentially how long time it is between the completion of consecutive units (Luyster, 2006). The takt time is calculated based on customer demand, as can be seen in Equation 2.2, and therefore, by matching production pace to the takt time, is it possible to produce enough products without overproducing (Luyster, 2006).

$$Takt\ time = \frac{Available\ production\ time}{Customer\ demand} \tag{2.2}$$

All operations need to be adjusted according to the takt time to be able to finalise products at the pace that matches the takt time (Petersson and Ahlsén, 2015). In practice, this means that the cycle time for each operation should be closely matched to the takt time.

Set-up time
When switching between tasks, it takes time to readjust whether it is a very time-consuming or a simple procedure (Sörqvist, 2013). The time it takes to change tasks is known as set-up time. Changing between tools or the settings on a machine are typical examples of set-up activities, but it also concerns the time it takes for the operator to adjust to the next task mentally (Sörqvist, 2013).

There are ways to reduce the set-up time where one method is Single Minute Exchange of Die (SMED), which aims to divide the set-up into the internal and external set-up (Sörqvist, 2013). The internal set-up is the set-up activities that can only be performed when production is stopped while external set-up actions can be made while production is still running (Sörqvist, 2013). By analysing the set-up, it can be possible to find unnecessary activities and identify internal set-up activities that could be made externally instead, which would reduce the overall set-up time, and the time production is stopped (Sörqvist, 2013).

2.1.2 Printed circuit board assembly

A central component in a production system that manufactures electronic products is the printed circuit board (PCB). A PCB is an insulated board with electronic components placed on conductive copper paths (Ho and Ji, 2007). An electrical current flows through the components on the PCB, which is the essential function of an electronic product (Ho and Ji, 2007). From a few hundred to thousands of components can fit on the board (Ho and Ji, 2007).

Components are mounted on the board by plated-through hole (PTH), surface mount technology (SMT), or both (Ho and Ji, 2007). Figure 2.1 shows the difference between PTH and SMT placement. With PTH placement is the component mounted through holes drilled in the board and soldered on the opposite side of the board. Assembling components with SMT consists of five operations; applying solder paste by screen printing, component placement, inspection, soldering by conveyor through an oven, and cleaning (Ho and Ji, 2007).

Figure 2.1: Electrical components placed with PTH and SMT.

The placement of SMT components is done automatically by a machine where the parts are placed simultaneously or sequentially (Yılmaz, 2008). If the components are placed simultaneously, all components are picked up and placed at once, whereas for sequential placement, each component is picked up and placed individually (Yılmaz, 2008). Each minuscule SMT component is delivered and feed to the machine taped on roles, which are called component feeders (Yılmaz, 2008). Several different components are placed on a PCB, where each component feeder delivers a separate component (Yılmaz, 2008). All separate component feeders are placed in a component magazine (Yılmaz, 2008). The component magazine is a kind of trolley that holds all these taped roles of components (Yılmaz, 2008). When a type of component runs out, the specific component feeder can be replaced in the component magazine, see Figure 2.2 for illustration. When it is time to switch between product variants, the entire component magazine can be replaced with another one that is already refilled with the correct components (Yılmaz, 2008).

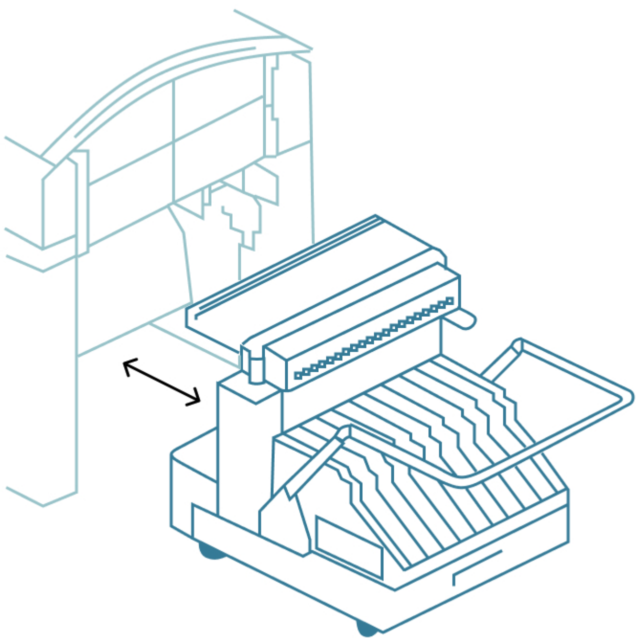

Figure 2.2: Component magazine.

The placement of the components on the board is a crucial step of the assembly and is commonly the bottleneck in the process (Yılmaz, 2008). How long time it takes to place components are affected by the programmed order in which the components are picked and where each component is placed in the component magazine. There are long setup times when changing the type of PCB manufactured. This is because it takes time to change the placement programming and switch the components that are feed to the machine (Ho and Ji, 2007). Optimising the setup times and the process of the component placement is a substantial part of creating efficient manufacturing of PCBs (Ho and Ji, 2007).

2.2 Lean production

Lean production is a company ideology that was introduced in the 1980s and began with Toyota's development strategy within Toyota Production Systems (Liker and Meier, 2006). Since then, lean production has evolved, and today it is a way of looking at and driving business, focusing on resource-efficient, flexible and fast processes (Sörqvist, 2013). The foundation of lean is to put the customer in focus and to try to produce and manage the business based on the customer's requirements and demand (Liker and Meier, 2006). Thus, neither produce more or less than what the customer wants. Mainly, it is about working efficiently to increase flow efficiency, reduce losses, and unnecessary work (Bergman and Klefsjö, 2012).

In all businesses today, there is great untapped potential, and large resources are being spent on things that do not create value for the company and its customers (Sörqvist, 2013). By using lean and its tools, companies can gain greater knowledge of their business and can thus save both time and money on things that would otherwise be put into defects, delays, and unnecessary work (Liker and Meier, 2006).

2.2.1 Value-added activities

A core concept in lean is that of value-added activities (Sörqvist, 2013). All activities performed at a company can be examined based on the value they can provide to the customer (Sörqvist, 2013). These activities can be divided into three categories: value-added, necessary but non value-added and non value-added (Sörqvist, 2013).

The first category is value-added activities, and these are the actions that create value for the customer and, thus, the activities that the customer is prepared to pay for (Sörqvist, 2013). For example, it may be, the actual production of the product in a machine or the assembly of the product (Borris, 2014). The aim of any organisation should be to optimise this part as far as possible (Borris, 2014).

The second category is necessary but non value-added activities (Sörqvist, 2013). These do not create any real value for the customer but are necessary in order to be able to perform the value-added actions (Sörqvist, 2013). For example, it may be when an operator sets up the machine, which is a fundamental step to manufacture the component. However, the activity on its own does not create any value towards the customer (Borris, 2014). Endeavours to minimise the effect of the necessary but non value-added activities should be conducted, which in the mentioned example would be to try to minimise the set-up time (Borris, 2014).

The third category is non value-added activities, which create no value for the customer and, thus, activities that the customer is unwilling to pay for (Sörqvist, 2013). For example, it may be the time that an operator waits for instructions or the wait for raw material (Borris, 2014). These activities are purely a waste, and these should try to be eliminated as quickly as possible (Sörqvist, 2013). According to Liker and Meier (2006), the non value-creating activities are usually divided into 7 + 1 kinds of wastes, and these are described in Section 2.2.2.

In a production setting, the concept of value-added activities can be applied for a single operation as well as for the entire production process of a product (Sörqvist, 2013). Figure 2.3 illustrates an example of how the proportion of value and non value-adding activities could be for a production process and one operation. For the single operation are all activities performed at that station represented and if that activity is value-adding or not. For a company that has not applied this concept before, it is common that only a few percent of the total time is spent on actions that create value (Sörqvist, 2013). A high proportion of activities that are entirely non value-adding results in the company spending plenty of resources, such as time and money, on completely unnecessary activities (Sörqvist, 2013).

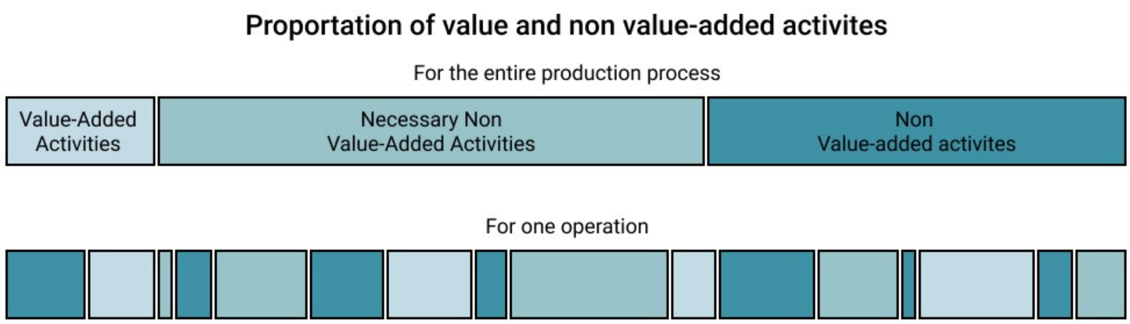

Figure 2.3: An example of the proportion of value-added activities.

Many companies usually focus on optimising value-adding processes. However, lean production focuses on the entire production system's complete flow and optimising the whole value flow from door to door. Not only individual processes are analysed and improved (Liker and Meier, 2006). A fundamental measure of the efficiency of the system is the total throughput time. The significant improvements can usually be achieved by focusing on eliminating the non value-added activities instead of optimising the value-adding activities (Sörqvist, 2013).

2.2.2 Wastes

In production, there are various types of wastes. Wastes are activities that add no value to the final product (Liker and Meier, 2006). Therefore, these different types of wastes can be removed without affecting the performance or quality (Blücher and Öjmertz, 2004). The wastes can be divided into eight different categories. Initially, only seven categories existed, which is why it is now called 7 + 1 wastes (Blücher and Öjmertz, 2004). The seven original wastes consist of overproduction, waiting, unnecessary transport, overprocessing, excess inventory, unnecessary movements, defects. The eighth and final waste is unused employee creativity (Liker and Meier, 2006).

Overproduction
Overproduction means producing more than customer demand (Liker and Meier, 2006). It may be the manufacture of too large batches, that the production takes place faster or earlier than is necessary for the next process. Overproduction is often classified as the worst waste since overproduction contributes to all other waste (Blücher and Öjmertz, 2004).

Waiting
Waiting is one of the most common waste. It may mean waiting for information or material (Liker and Meier, 2006). The wait can be both costly and frustrating for operators. Examples of activities that cause waiting time for operators can be when they wait for the material to be delivered to the work area, the wait for inspection, or to wait for equipment cycle time (Carreira, 2004). This waiting should ideally be used for something else, such as training, maintenance, or improvement work.

Unnecessary transport
Transport involves the movement of materials or products from one place to another (Carreira, 2004). Internal transport is all movements of the product regardless of where in the process the product is. The only transport that adds value to the customer is the transport of the finished product to the customer, and thus all other transport is a waste (Liker and Meier, 2006).

Overprocessing
Overprocessing means all the work that the customer is not willing to pay for (Carreira, 2004). For example, it may be too high quality, unnecessary work steps, or rework. These steps should be reviewed to strive towards creating value for the customer in all steps that are performed.

Excess inventory
Large stock causes tied up capital that could instead be used for other investments. Inventory can mean raw materials, WIP, and finished products (Liker and Meier, 2006). In many cases, the stock is needed, but the stock size should be reviewed (Liker and Meier, 2006). Excess inventory can create long lead times and substantial inventory costs. Surplus stock can also hide production imbalances, late deliveries from suppliers, long set-up times, and defects (Liker and Meier, 2006). In many cases, the inventory must be reduced to make visible the current problems in the flow.

Unnecessary movement
Unnecessary movements refer to non value-creating movements that the operators make to postpone their work (Liker and Meier, 2006). For example, it may be that the operator goes and fetches material or that the operator reaches for tools. Walking is also regarded as unnecessary movement, and therefore the distances that the operator needs to walk should be reduced.

Defects
Production of defective products is about correcting mistakes that have not been right from the start. This may involve rework, more inspection, or scrap (Liker and Meier, 2006). It is important to identify and utilise resources to find the root cause of the production problem. It should be known where the error is created and what deficiencies in the process causes the error from the beginning (Carreira, 2004).

Unused employee creativity
Unused employee creativity is a waste that is created by not using employees' full competence (Liker and Meier, 2006). It arises by not listening to employees' suggestions for improvement or not engaging them in the improvement work. This can increase the risk of staff quitting and the failure of company improvements, which will reduce a company's development in the long run (Liker and Meier, 2006).

2.3 Value stream mapping

Value stream mapping (VSM) is a visual tool within lean that is used to map and analyse an organisation's material and information flows by following a product or family of products throughout its process (Rother and Shook, 2003). This is a developed work method for mapping production and for systematically identifying and eliminating waste and weaknesses in the value flow. The value stream mapping aims to produce a true-to-life image of production and to make suggestions on how production can function and look in the future (Rother and Shook, 2003).

According to Rother and Shook (2003), it is vital to understand and analyse the customers and their needs as well as analysing the value flow to create customer value. Figure 2.4 describes the process steps that form the basis for conducting a VSM (Rother and Shook, 2003).

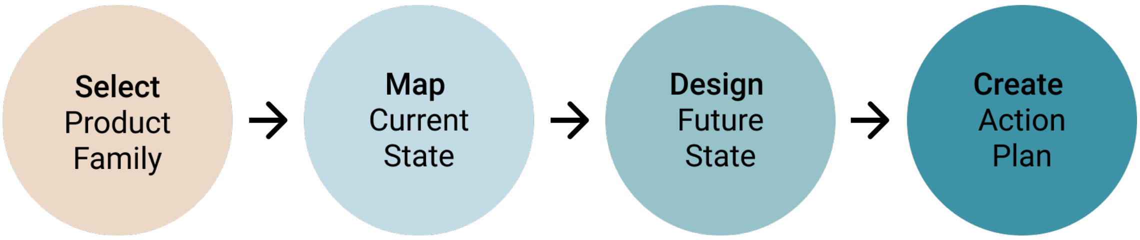

Figure 2.4: The four steps in the value stream mapping process.

The VSM tool can visualise the flow for more than just one process, for example, several different manufacturing steps in production (Rother and Shook, 2003). VSM also shows the linkage between materials and the information flow, which is unique to VSM since no other flow tool shows this relationship (Rother and Shook, 2003). It will also give a holistic perspective and a common language for the production process. (Martin and Osterling, 2013).

2.3.1 Select product family

The first step is to select a product or group of products that follow the same flow (Rother and Shook, 2003). The choice of a product family for the value flow analysis must be based on which product or products the company wants to investigate and which products the customer is interested in (Rother and Shook, 2003). According to Rother and Shook (2003), should not all value flows in a factory be mapped, because that level of complexity is not desirable when using the VSM tool. An important element that should be defined before the value stream mapping of the current state is a clear aim (Martin and Osterling, 2013). This helps to ensure that the right people are included in the team that will carry out the value stream mapping, while also reducing the risk that the team will spend valuable time on unnecessary activities (Martin and Osterling, 2013).

2.3.2 Map current state

The second step is to map the entirety of the process, considering both material and information flow to have an accurate representation of the current state (Rother and Shook, 2003). Material flow is how the material will flow through the factory to produce a finished product (Rother and Shook, 2003). However, it also concerns the material from the suppliers and the product's delivery to the customers. All operations relevant to making the product and the sequence the product moves through these operations are documented when mapping the material flow (Rother and Shook, 2003). It is also necessary to document all the surrounding factors such as where in the process material accumulates, how many operators are needed, and how long process time the operation has (Rother and Shook, 2003).

Figure 2.5 shows an example of a VSM where the middle layer represents the material flow. Beneath the material flow is the time ladder, which displays the process times and the production lead time. It demonstrates the difference between the processing time to produce a finished product and the actual time it takes for the product to move through the factory from the first operation to the last.

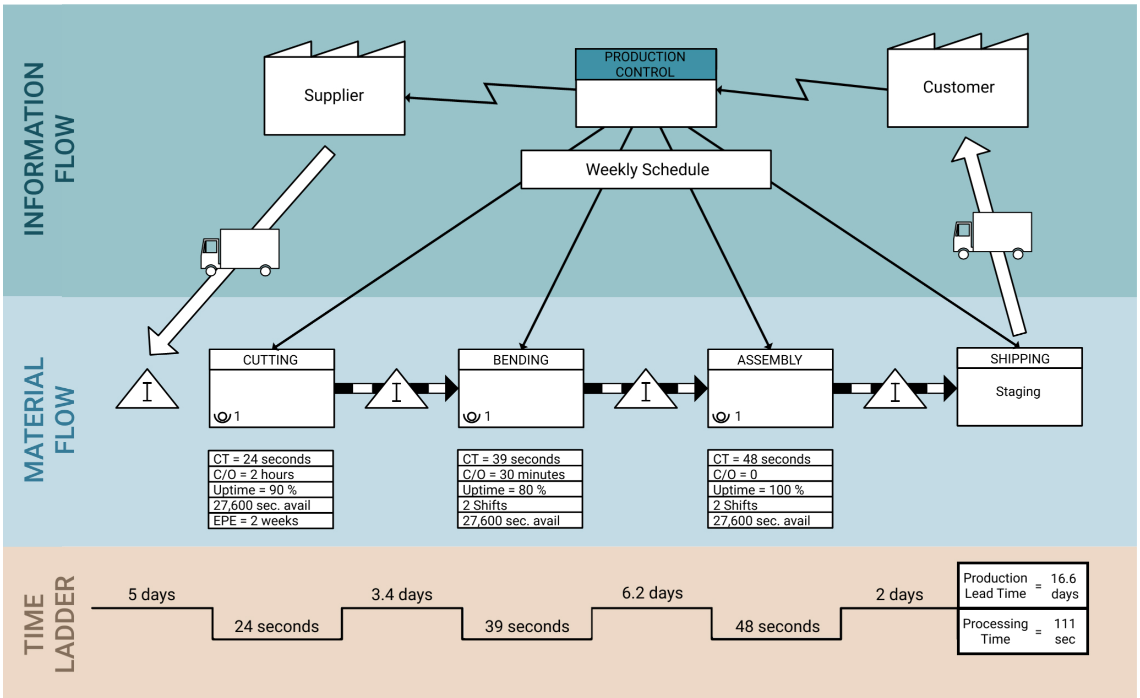

Figure 2.5: An example of a value stream mapping.

In the top layer of Figure 2.5 is the information flow displayed. The raw material does not spontaneously move from the supplier to the factory, and operators do not just start making something without directions. For this to happen is an information flow required. The information flow is the way to communicate orders and instructions that control the process, which can be done more or less efficiently (Rother and Shook, 2003). The information flow within the factory can be a planning system that indicates electronically what to manufacture and when but it can also be a manager planning and directly talking to the operators or a mixture of both (Rother and Shook, 2003). The information flow outside the factory can also have different characteristics. Information such as orders and forecasts can be made by a phone call or sent electronically either by mail or directly from the planning system (Rother and Shook, 2003).

To design the map of the current state, are there standard symbols to use (Rother and Shook, 2003). Utilising standardised symbols support the intent that the VSM can act as a way to have a common language and view of the process. These symbols represent various factors related to production, such as flows, activities and processes, transport, warehouses, manual, and electronic information flows (Rother and Shook, 2003). A selection of standard symbols is shown in Figure 2.6.

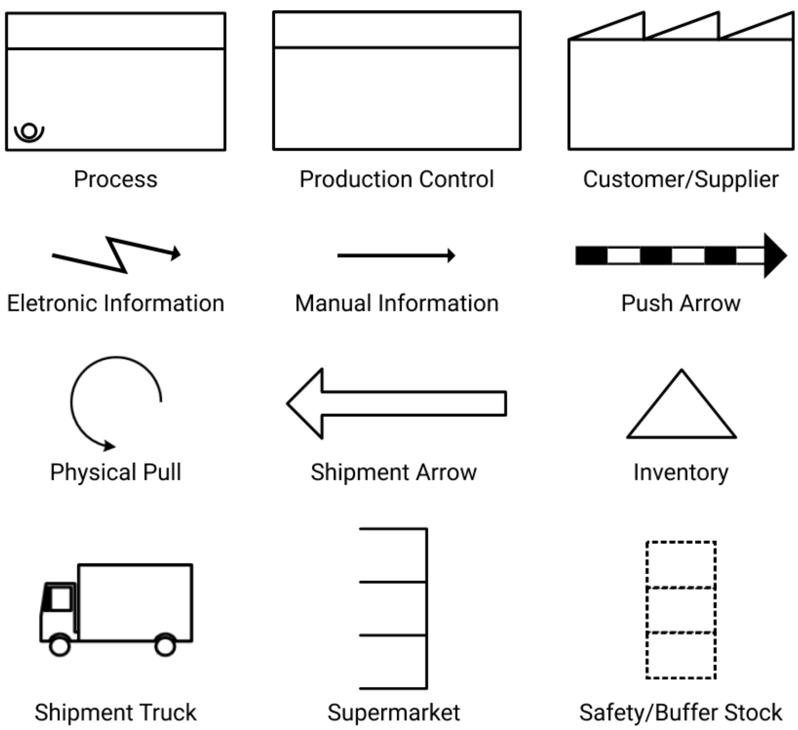

Figure 2.6: A selection of standard symbols used for value stream mapping.

The description of the current state will provide the foundation for improving the process. Having a correct understanding of the process is a vital part of implementing solutions that are actual improvements and not implement solutions that will aggravate production or are merely short-term fixes (Martin and Osterling, 2013). Without mapping the current state, it will be misconceptions since people make assumptions and do not always have the correct information or complete facts about every situation without necessarily realising it (Martin and Osterling, 2013). By mapping the entire process, would misconceptions diminish, and build an understanding of how all processes are connected, enabling solutions that are beneficial for the entire flow and not just optimising specific operations (Martin and Osterling, 2013).

Since value stream mapping is a tool used within lean, which has significant customer focus should the process of mapping the current state also reflect on customer centred thinking (Sörqvist, 2013). The customer is the one who receives the final product, and the manufacturing processes are there for that purpose (Sörqvist, 2013). Even if an operation is inherently ineffective, it is still a step in the making of the final product. However, the customers need is only the specific actions that create the final product (Sörqvist, 2013). For example, it may aid the making of the product to get a necessary component in the warehouse. When looking closer at this action, it is noticeable that this does not actually bring any value to the customer. Instead, if the component was already stored at the work station, the operator could perform the same action without spending time walking to get the component. The customer is only interested in value-adding activities, regardless of where in the process they happen (Sörqvist, 2013). Therefore should the customer always be kept in mind throughout every step in the process when mapping the current state.

2.3.3 Design future state

With a clear understanding of the current production, it is possible to create an improved future state (Rother and Shook, 2003). An ideal state is not what sought after, instead the future state should be an improved but feasible version of the current production, which can be achieved in the near future (Martin and Osterling, 2013). The future state is not a fix-all solution. Instead, it should be designed to fulfil the defined aim of the VSM, for example, improving quality or increasing production volume (Martin and Osterling, 2013). The customer is still a vital part, and it is no use to invest energy and money in solutions that are not beneficial from the customer's perspective.

Creating the future state map is a shift from the previous fact-finding activities to creative and innovative thinking (Martin and Osterling, 2013). Nevertheless, even in this phase, are there concepts that can be applied to aid the design of a better future state. One of the conventional concepts to apply is to eliminate waste in the process (Sörqvist, 2013). Some waste might be easy to eliminate and could be eliminated at once, while others require more effort to identify and to eliminate. If not possible to eliminate them, they aim should instead be to reduce or control it (Sörqvist, 2013). It is vital in this step to not just focus on the individual manufacturing process but to see how it would affect the entire process.

2.3.4 Create action plan

The final step is to create an action plan and to implement the future state solution (Rother and Shook, 2003). It is necessary to make an action plan on how to implement the changes (Rother and Shook, 2003). An action plan should describe what improvements and actions should be made and when they should be done (Rother and Shook, 2003). The action plan is a living document that needs to be updated frequently (Martin and Osterling, 2013). When the action plan is implemented, it will be revised, and new improvements and discoveries should be added (Rother and Shook, 2003).

2.4 Capacity

There are many measurements to calculate capacity. Two of the most common measures are machine-hours or man-hours (Jonsson and Mattsson, 2016). Other common measures are volume or number of manufactured products. Capacity is usually calculated per product family or production groups. How much capacity is needed is mainly determined by the demand the company's products have (Olhager, 2013). When talking about capacity, it is important to keep in mind and take into account that there is always a loss of capacity (Jonsson and Mattsson, 2016). The concept of capacity is usually divided into four different categories, with different types of losses, which are described in Figure 2.7.

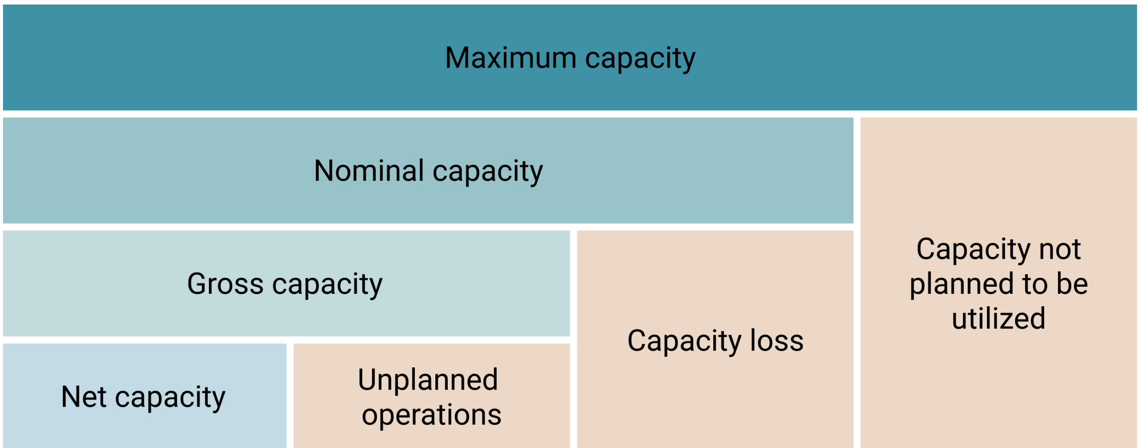

Figure 2.7: Capacity levels and capacity losses at different levels.

Maximum capacity
Maximum capacity is the highest capacity level, which symbolises the capacity the resource would have if production produced products around the clock, every day of the year (Jonsson and Mattsson, 2016). Maximum capacity is usually not interesting as it is not usually physically possible to produce 24 hours a day, every day of the year (Jonsson and Mattsson, 2016).

Nominal capacity
Nominal capacity is usually the first level calculated because it is based on what times the resources are estimated to be utilised (Jonsson and Mattsson, 2016). Nominal capacity can be calculated by multiplying the number of working hours per day by the number of machines and the number of days per planning period (Jonsson and Mattsson, 2016).

Gross capacity
Based on the nominal capacity, it must then be assumed that some capacity loss will occur due to, for example, short-term absence, maintenance, and machine

breakdowns (Jonsson and Mattsson, 2016). When these factors have been taken into account, gross capacity remains (Jonsson and Mattsson, 2016).

Net capacity
The remaining capacity must then be adjusted to for the time when no production can occur, such as waiting time for materials, breaks in work, and staff meetings (Jonsson and Mattsson, 2016). Activities that are not planned, such as rework, also occupy capacity and must be taken into account (Jonsson and Mattsson, 2016). As all the above factors are included in the capacity calculation, the net capacity remains. It is this capacity that can be calculated to be available for the planned production (Jonsson and Mattsson, 2016).

2.4.1 Changing the capacity

By monitoring the different production capacity levels, it is possible to see if the capacity supply corresponds to the need for capacity (Jonsson and Mattsson, 2016). This means that there must be sufficient capacity to produce the products the customer requires. Over-dimension of capacity is to be avoided because much of the capacity will not be utilised, but it will still entail high costs for the company, no matter if it used or not (Jonsson and Mattsson, 2016). If the availability and need for capacity does not match, Jonsson and Mattsson (2016) mention four actions that can be taken:

- Increase/decrease the availability of capacity
- Redistribute the current capacity asset between different departments
- Increase/decrease the capacity requirement
- Redistribute the capacity requirement between different periods

If production requires an increase in capacity assets, it is primarily personnel, machines, or working hours that can be adjusted. (Jonsson and Mattsson, 2016). Examples of these actions are investing in new machines and production equipment, increasing the staff, changing the number of shifts, and utilising overtime (Olhager, 2013). Situations, where the company manufacturing more products than usual, is the introduction of a new product or a drastic increase in customer demand (Jonsson and Mattsson, 2016). These situations may cause the company to increase its capacity.

Capacity is not always a matter of just increasing capacity it is also a matter of decreasing and varying capacity (Jonsson and Mattsson, 2016). A company experiencing seasonal variation has varied capacity requirements, which can be adjusted by adapting the production (Jonsson and Mattsson, 2016). This can be done by adjusting delivery times or stock levels, which means that the company can build up stock during the low season to meet the high season requirement (Jonsson and Mattsson, 2016). Another alternative is to introduce longer delivery times in the high season to level out the need (Jonsson and Mattsson, 2016).

2.5 Sustainable production

Manufacturing companies must strive towards becoming sustainable (Olhager, 2013). Sustainable production includes three different aspects of sustainability: economic, environmental, and social (Olhager, 2013). Economic sustainability means counteracting poverty without adversely affecting social or environmental sustainability (UNDP, 2015). Environmental sustainability is about managing the earth's resources so that it is sufficient for the future generations. Social sustainability means, in the long term, protect all fundamental human rights (UNDP, 2015).

Regulations, laws, and requirements drive this development of sustainable production, but today, customers also demand greater awareness from the companies they buy products from. Customers now place higher demands on environmentally conscious products and for companies to take responsibility for their production and emissions (Olhager, 2013). When a company shows that they work with sustainable production, it can lead to new competitive advantages (Olhager, 2013).

The United Nations Development Program (UNDP) works with Agenda 2030 and the 17 global goals to achieve sustainable development (UNDP, 2015). Goal 12 involves sustainable consumption and production, where the aim is to reduce our environmental footprint by changing the pattern of how we produce and consume goods and resources (UNDP, 2015). Sustainable production benefits both the local and global markets with, for example, increased employment and improved health among the employees. Achieving sustainable production will reduce the negative impact the industry has on the climate and the environment (UNDP, 2015). Some examples of aspects that contribute to a more sustainable production are energy efficiency, good quality of products from the beginning, and short distances from production to customer (Olhager, 2013).

2.5.1 Production in Sweden

According to both Tillväxtverket (2011) and Teknikföretagen (2008), the Swedish industry and particularly small and medium-sized enterprises (SME) are facing considerable challenges. Growth and expansion for a company are a constant challenge, but necessary to meet increased competition or adapt the company to its customers. Some of the challenges that producing SMEs face linked to expansion can be production development, scaling up operations quickly enough, and broadening or deepening production (Tillväxtverket, 2011).

With these challenges, there are many reasons why a manufacturing company chooses to change or design new production systems (Bellgran and Säfsten, 2005). The primary causes of change are the manufacturing of a new product or family of products, where the old system cannot be used, needs to be renewed or expanded for various reasons. In the event of a major change or expansion of production, many companies usually see it as an opportunity to, at the same time, improve other things in production in order to achieve better results and a better working environment for the employees (Bellgran and Säfsten, 2005). Some of the things that companies usually take the opportunity to do during another significant change are to improve the working environment, automate parts of production, and get a better order of production flow (Bellgran and Säfsten, 2005).

For the Swedish manufacturing industry to be able to compete successfully globally, production must be world-class (Teknikföretagen, 2008). To succeed in this, Swedish companies need to change constantly and have a desire to improve and develop. Production development is a key competence to renew the Swedish industry, partly to develop domestic production and partly to increase Sweden's attractiveness as a development base for the global companies (Teknikföretagen, 2008).

Productions in Sweden must be competitive with productions in the rest of the world (Teknikföretagen, 2008). Therefore, Swedish industries must take advantage of the opportunities with sharply increased globalisation. Effective choice of product strategies and develop production strategies for optimised distribution of domestic and localised production strengthen Sweden as an attractive production country (Teknikföretagen, 2008). To make sure that companies do not choose to outsource or place their production in other countries.

Sweden has, for a long time, had a long tradition of production, and it has been a strong production country (Teknikföretagen, 2013). Teknikföretagen (2013) has a vision that in 2030, Sweden will be the first choice for the development of production of advanced products and that the Swedish industry will be a world leader in customising and advanced industrial services. To achieve this, it is required that all producing companies work with the future production challenges described above. Above all, this must be done in order to be competitive with the rest of the world. However, it must also be done because production in Sweden is a fundamental basis for employment and economic growth. According to Teknikföretagen (2013), production and industrial services employ over one million people in Sweden.

3
Methods

In this chapter, the method for the project is presented. In addition to this is the reliability and validity of the research evaluated and research ethics are described.

3.1 The project's process

Figure 3.1 describes the process of this project and the steps taken to fulfil the aim. It began with gaining an understanding of Plejd's current production. The process was then divided into two parts, where the first part analysed how to make the current production more efficient, and the other part analysed how Plejd can reach their production goal. Value stream mapping and capacity calculations were performed to accomplish this. A triangulation between a literature study, qualitative and quantitative methods was conducted to complement the value stream mapping and the capacity calculations.

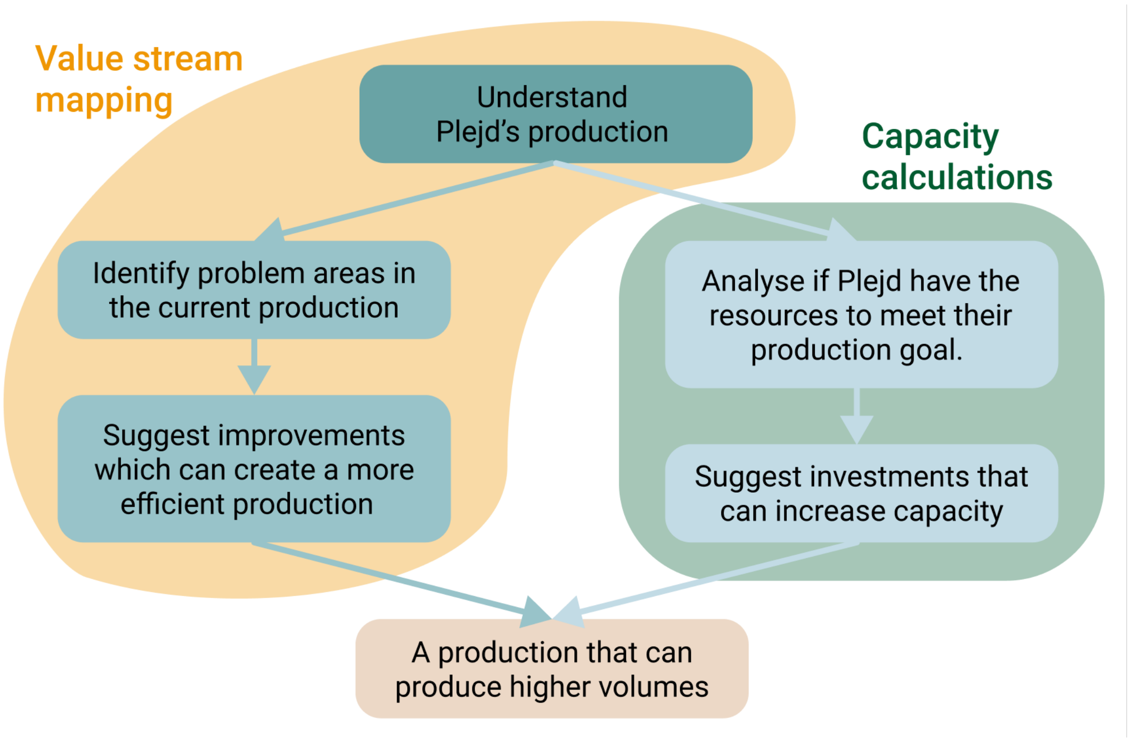

Figure 3.1: Illustration over the projects process

3.2 Literature study

The literature study is a process that is ongoing during the project and is a direct determinant of how the project will result (Friberg, 2006). A literature study can look different depending on the aim of the project, but it is about structurally creating an overview of the area of interest (Friberg, 2006).

The literature study followed the process described by the author Friberg (2006) and includes two phases: the initial literature study and the actual literature study. The first phase is the initial literature study, and this phase aims to provide an overview of the area to be studied (Friberg, 2006). The initial literature study helps to delineate the area into a reasonably large area within the given time frame. The objective is also to get enough background information to move on to phase two, the actual literature study (Friberg, 2006).

The actual literature study is the phase that takes the most time (Friberg, 2006). All literature the project will be based on is collected during this phase. It is necessary to make both systematic and unsystematic searches to find all the literature relevant to the project (Friberg, 2006). These two working methods are intended to be used in parallel during the project. Both working methods are equally important, and in order to achieve a proper information search, both searches must be applied (Friberg, 2006).

Systematic information search is the method that takes the most time. However, this method helps to create structure and to handle the variety of different types of information and sources of information (Friberg, 2006). While unsystematic information search requires less time and planning, it is a method where the purpose is to complement the systematic information search with inspiration and ideas (Friberg, 2006). For example, by looking around the library for books and articles or through simple database searches without any actual plan.

The purpose of the literature study was to find relevant information and gain useful knowledge from available research articles and books. In this project, the literature study was carried out to gain a deeper understanding of primarily lean production, value stream mapping, printed circuit board assembly, and other related topics that may be relevant to the project. The primary databases used were the Chalmers Library and Google Scholar.

To find relevant literature, which forms the basis of the theory, where searches performed with some of these following keywords which were used individually and in combination with each other:

- Lean
- Value stream mapping
- Capacity
- Printed circuit board
- Batch
- Production
- Electronics production
- Increase production volumes

3.3 Qualitative methods

Qualitative methods intend to collect data that are not numerical but instead stems from the social environment. The aim is to capture people's actions and why they do it in the defined context (Nationalencyklopedin, 2020). Observations and interviews are conventional methods to gather qualitative data.

3.3.1 Observations

Observation is a method to collect information by observing the situation (Kuada, 2012). Observing can yield different results from merely describing the situation to gather a more in-depth understanding of people's behaviour and attitude towards the situation (Kuada, 2012). There are two basic types of observation: nonparticipant and participant (Kuada, 2012). In this project were both types of observation used. The difference between these is the degree to which the observer is involved in the activities (Kuada, 2012). A nonparticipant observer watches the activities without engaging, which is a faster approach to observing but at risk that the participant deviates from their normal behaviour (Kuada, 2012).

Being a participant observer is a more extensive approach where the observer takes part in the activities which could span over several days or months (Kuada, 2012). The observer gains first-hand impressions and could gather vital information by observing how employees truly work but also by engaging in small talk or partaking at meetings (Kuada, 2012). This would give greater insight into the observed activities. However, there is a risk that the observer gets socially and emotionally attached to the observed group, and as a consequence, it is no longer unbiased(Kuada, 2012). To lessen the bias should notes be taken frequently, and the observer should reflect over the situation (Kuada, 2012). Observations as a method have to be extensive to gather the information that is representative of the situation. Still, the observer cannot be at all places and once and therefore, should be careful with generalising the situation (Kuada, 2012).

In this project, many days of observing the production have been made, to gain a deep understanding of how production works and what potential problems may arise during some ordinary days. The nonparticipant observations have mainly concerned measuring times in production and observing the functions of each machine. The participant observations have been made while working at the production office where it could be observed how the employees actually worked.

3.3.2 Interviews

Interviewing is a data collection method that can be used to gather information about what people think and feel, but also to obtain people's lessons and experiences (Osvalder et al., 2015). An interview can result in both qualitative and quantitative data depending on the structure of the interview (Osvalder et al., 2015). Interviews are often time-consuming and take a long time to complete, but if they are conducted in a structured and proper way, the interviews' results tend to be valuable to the project (Osvalder et al., 2015). Interviews are usually divided into three different categories: unstructured, structured, and semi-structured interviews (Osvalder et al., 2015).

In an unstructured interview, the interviewer asks open-ended questions, and thus the person being interviewed can talk freely about their thoughts and opinions (Osvalder et al., 2015). The interviewer can steer the discussion in the direction that is considered important. In an unstructured interview, it is good to inform the interviewee about the areas that the interview will deal with in advance. The advantage of an unstructured interview is that the interviewer can ask follow-up questions and go into depth on specific questions (Osvalder et al., 2015).

In a structured interview, the person interviewed answers predetermined questions (Osvalder et al., 2015). A structured interview is often a short interview that can be conducted on the telephone. The advantage of a structured interview is that the number of people who can be interviewed is often much higher because each interview does not take that long.

A semi-structured interview is a mixture of an unstructured and structured interview (Osvalder et al., 2015). The interviewer often decides some questions in advance to be addressed, but there are also opportunities to ask follow-up questions and more open questions. A semi-structured interview is less formal than a structured interview (Osvalder et al., 2015).

In this project, semi-structured interviews have been used. Before each interview, several questions have been prepared, but other questions and more in-depth questions have also been discussed during the interviews.

3.4 Quantitative methods

Quantitative methods are data collection methods where measurements are used to collect data of statistical nature (Denscombe, 2014). Quantitative data is data based on numbers. This data can be collected through surveys, observations, measurable values, or experiments (Denscombe, 2014).

In this project, quantitative data were collected in the production facility through measurements of the machines and manual stations. Measurements of different times have been measured with the help of a stopwatch. The data that has been measured is cycle times, process times, and WIP. Each measurement was measured three times to give a mean value of the data expect for WIP, which has been counted once.

3.5 Value stream mapping

The value stream mapping tool has two central parts which have been used in the project. These are; map the current state and design the future state. However, before these can be performed, the scope of the VSM has to be narrowed. This is achieved by selecting an appropriate aim for the VSM and decide which product family to focus on. The aim should reflect the desired outcome of the VSM, which can, for example, be to improve quality, increase production volume or to shorten lead time. To reduce complexity, a product family that is deemed significant to the company or customer is chosen. A product family is a group of products that undergo the same or similar manufacturing process, for example, the same process steps, similar machines, quality control and packaging steps (Rother and Shook, 2003). From the start, the company might have grouped its products in product families; otherwise, analysis of the process steps for all products should be made to find products that have similar processes.

3.5.1 Current state

The goal with current state mapping is to get an accurate representation of the material flow and information flow (Rother and Shook, 2003). To do so, it is not possible to rely on given data or information about the situation. In order to achieve a real understanding, it is a requirement to follow the production process and all its steps (Rother and Shook, 2003). The people involved in the value stream mapping must understand the entire process and not just specific operations. Therefore should all involved follow along with the complete process and not just specific sections and operations (Rother and Shook, 2003).

The mapping process should start with a quick walk that follows the operations in the order the product is processed to get an overview of all the steps involved (Rother and Shook, 2003). This part of the mapping process was done along with the production manager to gain increased knowledge of the functionality and purpose of the different operations. In this step, it should also be decided which parameters should be measured, such as cycle time, process time, and availability for all operations.

The next step in the mapping process was to walk the flow again and gather more in-depth knowledge of each operation (Rother and Shook, 2003). Since VSM aims to create value for the customer should the walk starts at the final step before delivery to the customer instead of the first step in the production process (Rother and Shook, 2003). This is done to naturally focus on the customer and analyse all operations based on the value it creates for the customer. The decided production parameters are measured in this step, along with the amount of inventory between the different operations (Rother and Shook, 2003). Knowledge of the operations comes not only from parameter data but also from impressions and observations of the situation.

Due to the nature of Plejd's production, which does not have a continuous flow through the process, has it not been possible to measure all operations consecutively. During the mapping process, was each determined parameter measured mainly using a stopwatch, and relevant observations were written down.

Much information can be obtained from the walk through the production process, but to have the full picture of the situation is additional information required. It should be complemented with data of customer demand, knowledge about planning system is utilised, and how the communication works to the customer and from the supplier. A mix of semi-structured interviews and observation of the workplace can be conducted to collect this information. The semi-structured interviews with relevant production personal gave a general understanding of the practice in use from their perspective. At the same time, the observations of the workplace shined a light on the actual practice used. With this data, it was possible to start the drawing current state map.

3.5.1.1 Drawing the current state map

The process flow is drawn by hand on A3 paper or post-its on a whiteboard. The first step is to illustrate the material flow within the factory by drawing a box for each operation in the sequence the product is processed. Each box should have a label with the type of activity and the number of operators that perform the tasks. Beneath each box should the parameter data be displayed. The inventory levels are illustrated with a triangle symbol between the boxes. Figure 3.2 shows the beginning of a current state map where the factory's material flow is drawn utilising the standard symbols used in VSM.

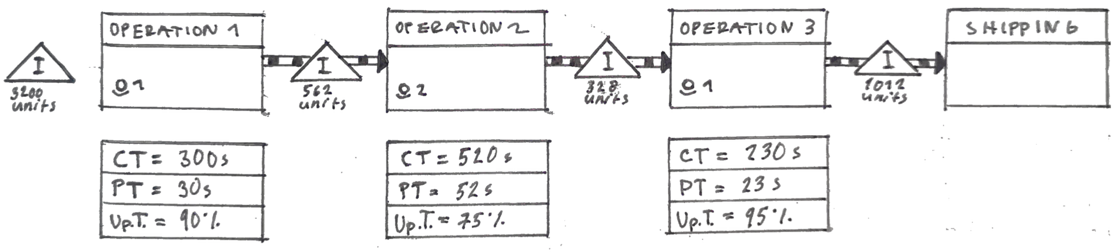

Figure 3.2: Example of how material flow within the factory should be illustrated in the current state map.

Material moving from the supplier and finalised products moving to the customer is part of the material flow and should be illustrated on the current state map. A product rarely has a single material supplier. Instead of displaying every single supplier on the map is one supplier that is deemed significant chosen. Figure 3.3 shows the current state map of the complete material flow with the supplier and customer added.

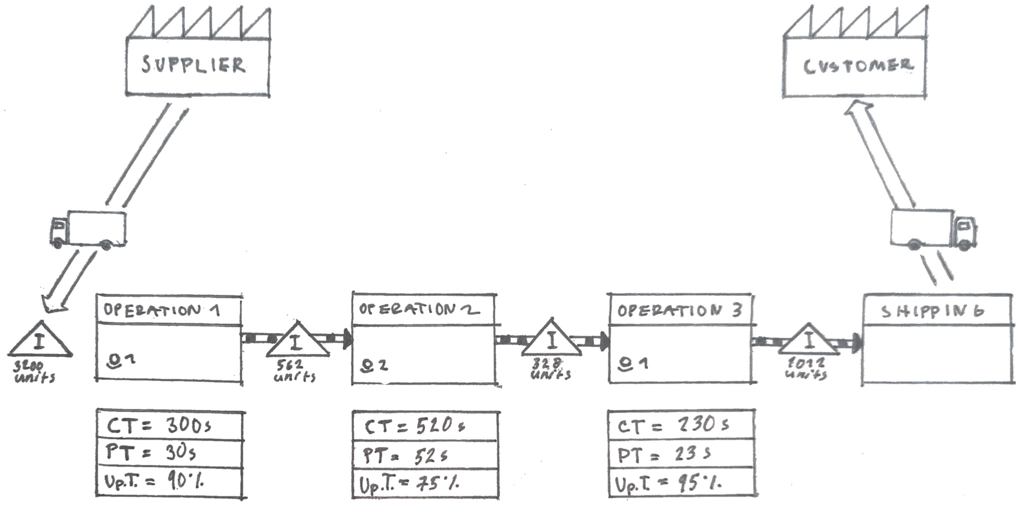

Figure 3.3: Example of how a complete material flow should be illustrated in the current state map.

How long it takes to make the product is also of interest and, therefore, is a time ladder drawn beneath the material flow, which 3.4 demonstrates. The time ladder demonstrates both processing time and production lead time for the separate operations and their total. The lower part of the time ladder displays the processing time for each operation measured earlier. The top part of the time ladder shows how long time it would take to produce the inventory, which summed up gives the total production lead time. This is calculated utilising by multiplying the number of inventory times the takt time.

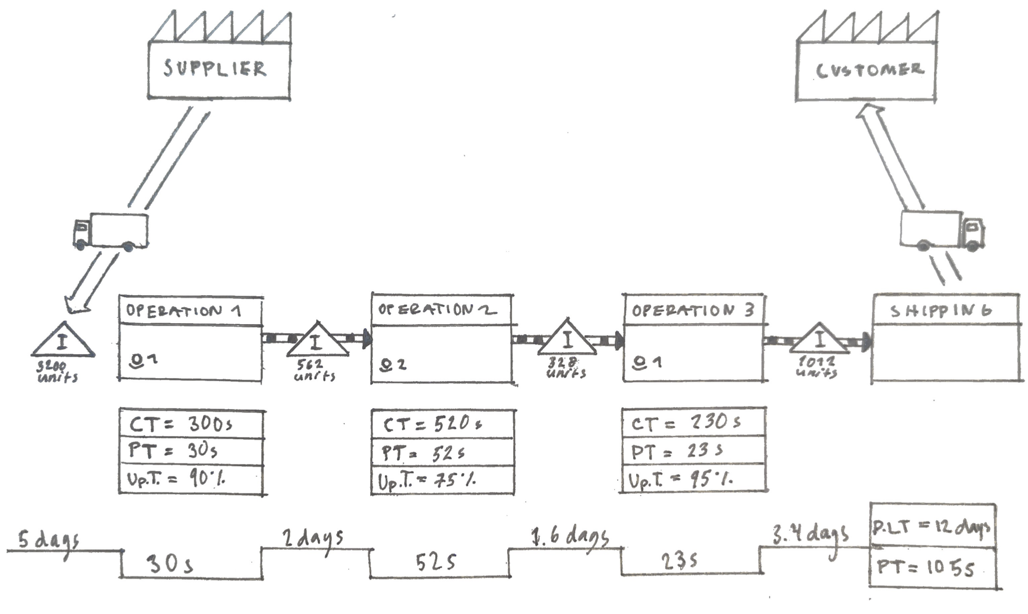

Figure 3.4: Example of how the material flow and timeline should be illustrated in the current state map.

To complete the current state map, should the information flow be illustrated. The information flow shows how information is exchanged, how often information is exchanged, and in what way the information is transmitted. The information flow includes communication within the factory as well as information to and from the supplier and customer (Rother and Shook, 2003). For example, it can be sending a three-month prognosis to a supplier, but it can also be communicating to an operator what type of product should be made that day. It also makes a difference whether the information is sent electronically or not. If the company has a planning system in place, more of the information will be sent electronically than if it did not. Figure 3.5 presents an example of a completed current state map with the information flow in place.

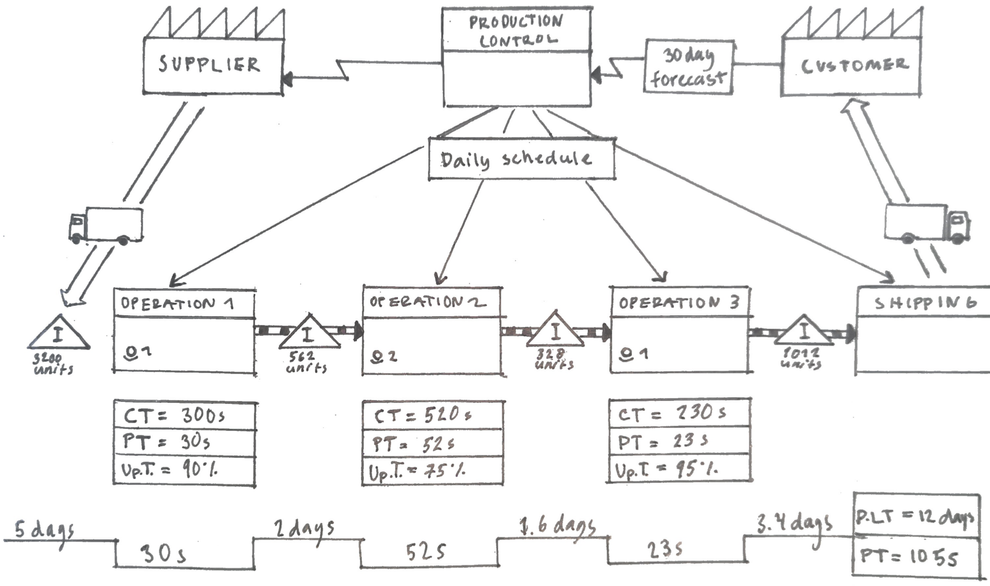

Figure 3.5: Example of how the material flow, timeline and information flow should be illustrated in the current state map.

The finished current state map should give an accurate description of the current set-up and present all relevant information (Sörqvist, 2013). Based on this, problem areas in the current state map can be identified and evaluated in order to create a better future state.

3.5.2 Create future state

The goal for the future state is to find improvements to current state's identified problems and solve these problems to achieve a better production (Rother and Shook, 2003). The design of the future state was initiated by following the authors' Martin and Osterling (2013) approach. They describe a set of about 35 questions in different categories that can be used as a starting point for shaping the future state (Martin and Osterling, 2013). Some of the categories that Martin and Osterling (2013) describe are quality, labour effort, technology, and variation management. All categories and questions can be seen in Appendix A.

After these questions have been reviewed and answered, which can be seen in Appendix B, it is, in some cases, possible to know clearly what the future state will look like. However, if it still is unclear, brainstorming may be useful for thinking of additional ideas of how future state will be achieved. When the future state map is created, the same procedure used to create the current state map can be applied (Martin and Osterling, 2013). It is allowed to make assumptions to create the future state, and these assumptions can change over time (Tapping et al., 2002).

3.6 Capacity calculations

Evaluating capacity gave an indicator of the existing production set-up limits. As mentioned in Section 2.4, are there different levels of capacity calculations and nominal capacity was selected to be a suitable capacity level for this situation. Nominal capacity is restricted to the planned production hours without considering losses such as maintenance and machine breakdowns (Jonsson and Mattsson, 2016). Since the manufacturing of the selected product family recently started, there is a risk that the amount of unplanned stops is disproportionately large compared to what it will be later. Considering the unplanned stops in this stage of the production is, therefore, not entirely representative. The stops could also be considered negligible when the present capacity level is compared to Plejd's ambition for future production volumes since its several times larger than current production volume.

Nominal capacity, Equation 3.1, is determined for a machine or a group of machines that perform the same actions by multiplying the number of products produced per hour and the planned production time (PPT) for a chosen period, for example, a month.

$$Nominal\ capacity = (Number\ of\ products\ produced\ per\ hour) \cdot (PPT) \tag{3.1}$$

The planned production time is calculated by Equation 3.2 (Jonsson and Mattsson, 2016).

$$PPT = (Shifts) \cdot (Length\ of\ shift) \cdot (Number\ of\ machines) \cdot (Time\ period) \tag{3.2}$$

When considering the production capacity, it was of interest to calculate capacity for the bottleneck machine (Olhager, 2013). The bottleneck in the production system is the machine that sets the pace of the production and limits the possible output because even if other stations work faster is not possible to exceed the output of the slowest station (Olhager, 2013). The bottleneck, therefore, limits the production capacity (Olhager, 2013).

3.7 Validity and reliability of results

Validity is a measure of whether the project examines what is intended to be investigated (Denscombe, 2014). In order to ensure high validity, a triangulation of three different methods has been used. Triangulation has been chosen to look at the research problems from different perspectives and thereby gain a more accurate and comprehensive control of the study (Denscombe, 2014). It is considered more valid to mix methods than to use only one method in a study (Denscombe, 2014). The methods chosen are literature study, qualitative methods with interviews and observations, and quantitative methods such as measurements of data. This way, validity has been ensured, and results obtained have been in line with the theory, which indicates high validity.

Reliability is the project's trustworthiness (Denscombe, 2014). This means that it is important that, for example, measuring instruments are reliable, and measurements are made correctly. In order to achieve good reliability, it is essential to be accurate and record the result obtained correctly (Denscombe, 2014). If the study is carried out again, the same measurement values should be obtained. Each measurement has been performed several times and then compared to ensure high reliability. This ensures that the results obtained are reliable and real. In this project, all measurement values were documented and presented in the appendix. The mean value of these measurements has been used in the calculations.

The people interviewed for the study were the ones who have had the most expertise about Plejd's production, while the observations have been conducted to see which areas of the production can be improved. Several suitable methods and theories have been used to develop proposals for solutions, including value stream mapping and production capacity calculations.

3.8 Research ethics

Within the research ethics, there are four general research requirements. These are; information requirement, consent requirement, confidentiality requirement, and use requirement (Vetenskapsrådet, 2002).

The first requirement, the information requirement, means that the researcher must inform those who participate in the study about the purpose of the study and why the study is conducted (Vetenskapsrådet, 2002).

The second requirement, the consent requirement, means that those who participate in the research or study have the right to decide their participation (Vetenskapsrådet, 2002). This means that the participants can terminate their participation at any time during the study without consequences.

The third requirement, the confidentiality requirement, means that the participants of the study must be given the highest possible confidentiality, and the personal data must be kept in such a way that unauthorised persons cannot access them (Vetenskapsrådet, 2002).

The fourth and final requirement, the use requirement, means that data collected about individuals can only be used for research purposes (Vetenskapsrådet, 2002). This means that information may not be used or lent for commercial use or other non-scientific purposes.

In this project, all four general research requirements have been used and taken into account throughout the observations of the production. The authors of the project have informed the operators of the observations, why they were carried out, and explained the project's purpose. The operators have also been asked if they approve that the authors observe them and measure the time it takes to perform the various tasks in the manual operations. The confidentiality requirement is fulfilled by making the employees anonymous and mentioning no names in the project (Vetenskapsrådet, 2002).

4
Results

In this chapter, the result of the empirical findings in the project is presented. It begins with a selection of the product family that should be mapped through the production. Next, a description of Plejd's current production and its identified problems are described. Then it continues with a description of Plejd's current capacity requirements.

4.1 VSM: Product family

Plejd's ambition to produce products in higher volumes at the new Mölndal factory primarily concerns the products REL-02, REL-01-2P, and DIM-01-2P. Therefore, the first step in the value stream mapping was to identify if these products were in the same product family. Table 4.1 was created to see which products have the same or similar process steps as other products.

Table 4.1: The productions steps required to produce the different products.

		Production steps											
		A	B	C	D	E	F	G	H	I	J	K	L
Products	REL-02	x	x	x	x			x	x	x			x
	REL-01-2P	x	x	x	x			x	x	x			x
	DIM-01-2P	x	x	x	x	x		x	x	x			x
	WPH-01	x		x				x			x	x	x
	BAT-01		x	x		x	x	x	x	x			x

Analysing the products production steps confirmed that REL-02, REL-01-2P, and DIM-01-2P are a product family with no related products. These three products have almost the same product step, except that DIM-01-2P has one different product step. It is evident from the table that WPH-01 and BAT-01 have many process steps that are different from the product group that has been identified, and therefore were these products not mapped.

4.2 VSM: Current state

In the production, usually, 5-7 people work with monitoring the SMT assembly line, loading the selective solder machine, or at the manual stations. Plejd's current production set-up for the product family consists of six different operations, which are presented below and illustrated in Figure 4.1.

Operation 1: SMT assembly line
The SMT assembly line is loaded manually with PCBs in racks. The PCBs are then transported on a conveyor belt through the line. The first step is traceability marking with QR code. Solder paste is then applied, and the solder paste is checked for the correct application by an automated optical inspection. Subsequently, all SMT components are mounted on the PCB, and finally, the PCB is transported through an oven to fuse and attach the components which are then placed in racks. This whole process is repeated one more time to do the same steps on the top of the PCB, which cannot be performed simultaneously as the bottom of the PCB is processed. At least one operator is required to monitor the SMT assembly line.

Operation 2: Inspection SMT
This is a manual station where an operator inspects what has been done in operation 1. The operator inspects that everything is attached correctly and that all components are placed in the right place, called human optical inspection. If something is wrong, it is noted in a computer programme, and the operator corrects the error if possible, by manual soldering. There are two stations for this operation were two operators can work simultaneously.

Operation 3: Selective solder
The inspected PCBs are loaded into a robot cell where a robot places the PTH components. Then a camera inspects that the PTH components are placed correctly, and finally, the PCBs are transported through the selective solder machine where these components are soldered onto the board.

Operation 4: Encapsulation
This is a manual station where an operator first starts by breaking apart the PCB's plates to singles. Of each PCB plate, holds ten single PCBs. Then, the QR codes on both the single PCB and the corresponding plastic cover is scanned so that each finished product can be traced. Finally, the PCB is encapsulated with the plastic cover.

Operation 5: Final test
This is a test station where the encapsulated products undergo an examination and are installed with the software. An operator manually loads the test.

Operation 6: Packaging
This is a manual station where an operator first packages a small batch of products in product boxes, which are then packed in a shipping box that will be sent to the customer.

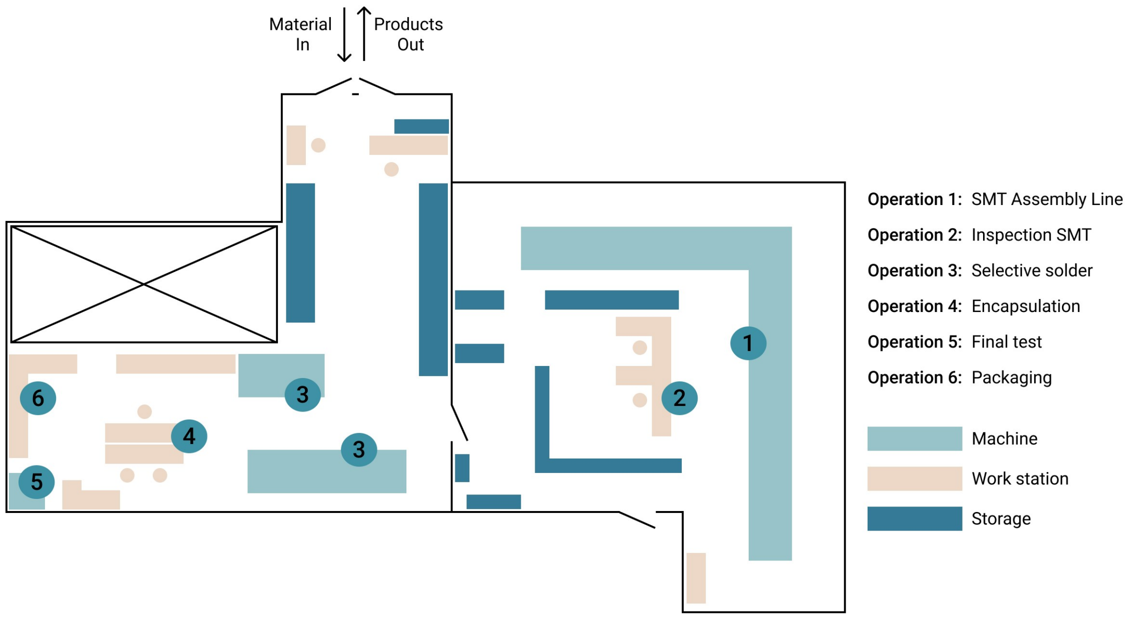

Figure 4.1: An illustration of Plejd's current production layout, not to scale.

All operations and their position related to each other can be seen in Figure 4.1. From the layout, it can be seen that the current production consists of two spaces with a wall and door in between. Based on the interviews and observations, it has emerged that the production area is too small and narrow, which is one of the reasons why Plejd will move its production to a larger production facility. The various operations and storage of materials are not close to each other. This means that the operators have to go unnecessarily long distances to retrieve materials or when they have to transport products from different operations.

4.2.1 The current state map

The second step in the value stream mapping process was to draw the current state map of Plejd's production, see Figure 4.2. In Appendix C, the original drawn current state map can be seen. The current state mapping was done for REL-02. Since that product was about to be manufactured when the measurements were planned to be performed. The measurements of cycle and process times can be seen in Appendix D, and the mean value of those measurements are presented in Figure 4.2. WIP was counted when the operations SMT assembly line and SMT inspection were ongoing, which can be seen in Appendix E and illustrated in the current state map. Plejd works with batch production, which is why some of the operations and buffers have zero WIP, while other buffers are very large WIP.

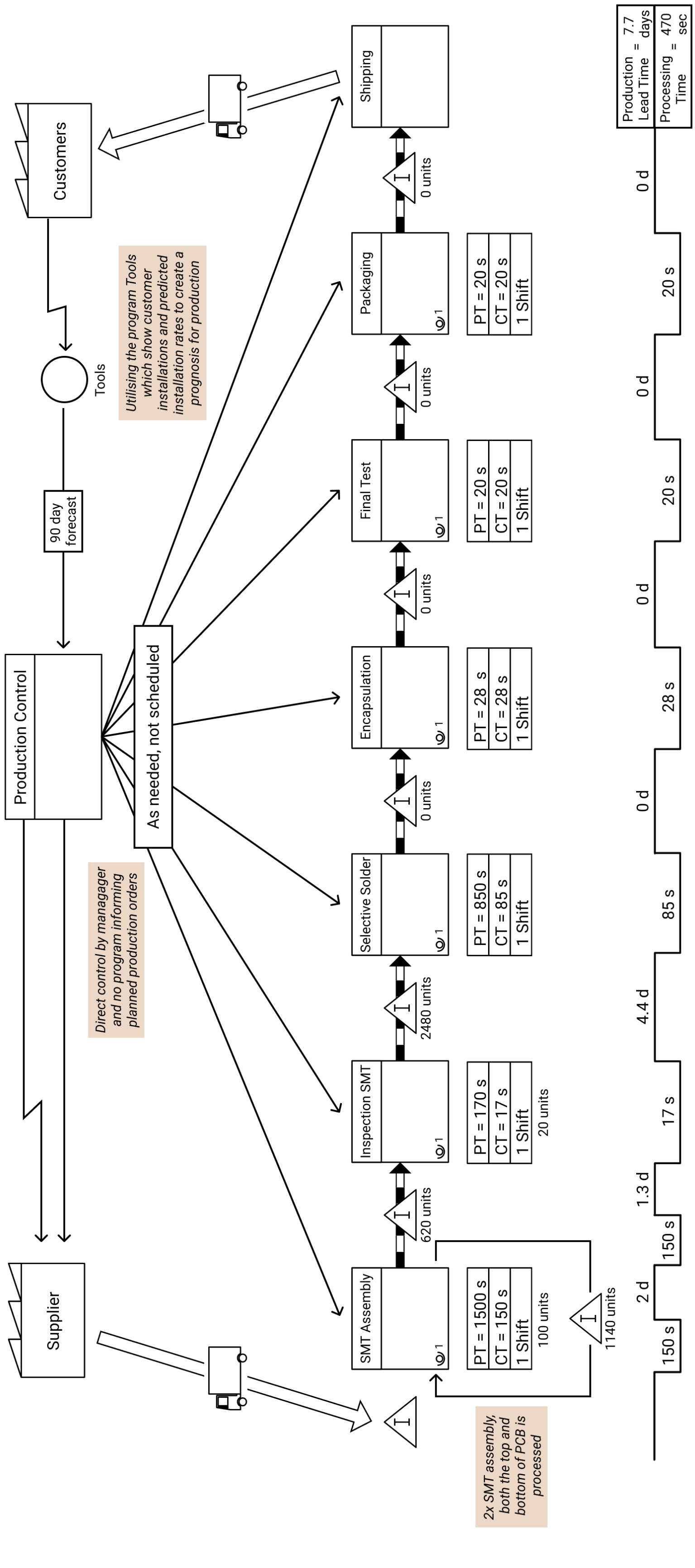

Figure 4.2: Value stream map for current state.

The information flow consists of some different elements. Plejd uses a program, Tools, to see how many products are installed each day at the end customer. Based on this, a forecast for 12 months is made. The production manager receives a forecast for 90 days ahead, and then plans which product should be produced and when. Plejd has just started using an enterprise resource planning (ERP) system, Monitor. When implemented, it can plan the production, but at the moment, it is not fully utilised. Therefore, the production manager informs the operators what they should do and which products should be produced, but not with the use of any schedule. Based on the forecast, components are also ordered 90 days in advance.

The material flow begins with Plejd receiving raw material from their suppliers. Then the material flow consists of the six operations described above, and between each operation is a buffer. The products are pushed to each new operation, and Plejd has no specific limitation on how many products there may be in each buffer between operations. When all operations are completed, the products are shipped to the customers. The products are first shipped to wholesalers in the electronics industry, who then deliver the products to the end customer, who installs them in their home with the help of an electrician.

The time ladder in Figure 4.2 shows the calculated processing time and production lead time. Processing time was calculated by summing the cycle times for all operations. The processing time is 470 seconds, which is displayed in the current state map. The production lead time was calculated by multiplying the inventory with the takt time. The takt time is determined by dividing available production time by customer demand using Equation 2.2. Plejd works with forecasts and therefore was the forecast used instead of customer demand. It was planned to produced 6500 products of the product family to meet the forecast the month when the mapping was performed. Plejd manufactures an additional product family at their production facility in Mölndal, it was necessary to calculate what proportion of the available production time would be used for the selected product family. This calculation was based on the products planned to be manufactured that month and the product processing time. The product family analysed in this project theoretically utilised 51 % of the total available production time of 180 hours in March. Equation 4.1 was used to calculate takt time given the mentioned inputs. This means that every 50 seconds should one product come out of the process.

$$Takt\ time = \frac{Available\ production\ time}{Forecasted\ demand} = \frac{(180\ h \cdot 60 \cdot 60) \cdot 0.51}{6500\ products} = 50.8\ s \quad (4.1)$$

Multiplying this calculated takt time with the inventory for each buffer and the ongoing operations gives a value for how many days it should take to consume the buffers and finish the operations. These were then summed up and gave a production lead time of 7.7 days.

4.2.2 Identified problems in the current state

Based on the value stream mapping for the current state, five problems have been identified in the production and presented in Table 4.2. These will be further analysed in Section 5.1.

Table 4.2: Identified problems in the current production.

Identified problems	**Description**
Long cycle time for SMT assembly line	*Operation 1 is disproportionate to the other operations, which is creating an unbalanced production.*
Many small operations	*Short operations at different locations cause disproportionate long transportation time for the value added at each operation.*
Build-up of material between operations	*Not a continuous flow, processing the complete batch before moving on to the next operation.*
Insufficient dedicated space	*There are few dedicated areas for material, tools and unfinished products.*
Lack of resource planning	*ERP system not fully implemented, which cause inefficient use of resources.*

4.3 Current production capacity requirements

Nominal capacity is calculated for the bottleneck machine, which is the operation SMT assembly line since that is the operation with the longest cycle time. The planned production time is calculated for a month, with five working days a week of one 8 hour shift per day. Using Equation 3.2 gave a planned production time of 180 hours per month. However, for the selected product family, the same SMT assembly line is used to mount components on both the top and bottom of the printed circuit board, which cannot be performed concurrently. The planned production time was, therefore, cut in half and would be 90 hours per month.

To get the nominal capacity specified in products, the planned production time needs to be multiplied with the number of products the SMT assembly line can produce per hour. The SMT assembly line produces a finished PCB plate every 2.5 minutes. This yields 24 finished plates per hour, which is equivalent to 240 finished single PCB per hour. With these numbers, it was possible to calculate the approximate nominal capacity of 21.600 products per month. Plejd has customer demands around 5000-7000 products per month for the chosen product family. The current capacity is, therefore, enough to meet current customer demand with quite a margin. To keep in mind, nominal capacity does not consider any unplanned stops, which means that the nominal capacity will be higher than possible. How long time it is possible to keep the current set-up depends on the expected future customer demand.

5
Analysis

In this chapter, the analysis of the project is presented. It begins with an analysis of the identified problems that lay the foundation for improvement proposals. Furthermore, Plejd's potential to meet their goal of increasing production volume is evaluated, and changes that can increase capacity are proposed.

5.1 Identified problems in current production

Based on the result of the value stream mapping for the current state, five problems have been identified, which are presented and analysed below.

5.1.1 Long cycle time for SMT assembly line

Based on measurements of process times and cycle times, it has emerged that the different operations have very various cycle times that can be seen in Figure 5.1.

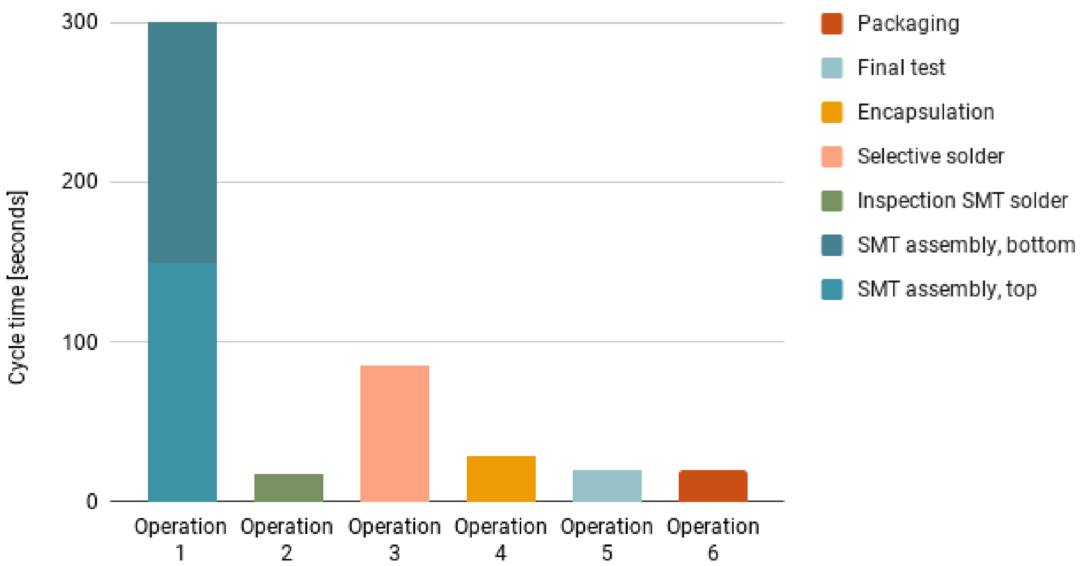

Figure 5.1: Cycle times for all operations.

Operation 1 consists of a two-part operation, the first SMT assembly is done for the bottom, and the second SMT assembly is done for the top. Operation 1 is extensive and thus has a much longer cycle time than all the other operations, and therefore operation 1 is the bottleneck in the production. Due to the various cycle times, the production becomes unbalanced. Some operations have to wait for the operation before being able to run, which creates waiting, queues, and high WIP, which are some of the 7 + 1 wastes (Blücher and Öjmertz, 2004).

5.1.2 Many small operations

In Figure 5.1, it can also be seen that many of the operations, especially operation 2, operation 5, and operation 6, have short cycle times, about 17-20 seconds. A consequence of the short cycle times is that the products have to be moved often because the operations are performed at different places in the production. This takes unnecessary time, and transportation of material and products is one of the 7 + 1 wastes. The time it takes for transport products is non value-adding for the customers and should be minimised or eliminated (Sörqvist, 2013).

5.1.3 Build-up of material between operations

When Plejd is manufacturing, it is not a continuous flow of products moving between the operations. An operation process all or most of the products in a batch before the products are moved to the next operation, which creates a build-up of material between operations. This results in a high WIP, which is associated with longer throughput times and more tied up capital.

The procedure on how to handle the products between the operations is not optimised. From the SMT assembly line is the finished PCB plate placed in a SMT magazine racks automatically by the machine, which can only hold a set amount of PCB plates. There are not enough racks to contain and store the entire produced batch. Therefore an operator needs to repackage the PCB plates from the SMT magazine racks into PCB holders and plastic boxes to have a place to store all the products before they are moved onto the next operation, see Figure 5.2. The repackaging is an action that takes unnecessary time and creates no value for the end product or the customer.

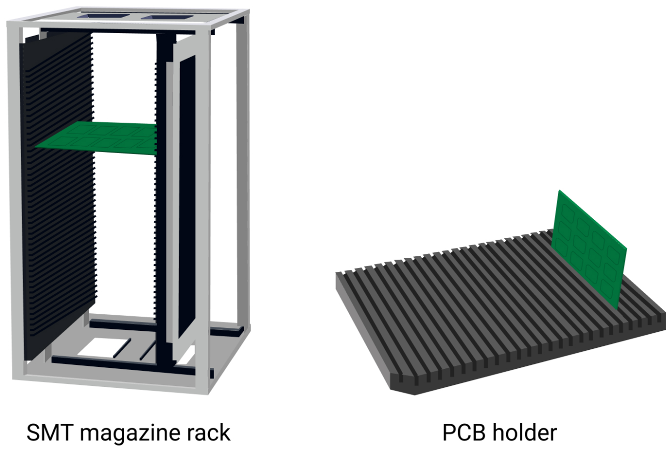

Figure 5.2: Illustration of a SMT magazine rack and a PCB holder.

Transportation is an activity that is considered as a waste (Sörqvist, 2013). By moving the products from an operation first to storage and then to the next operation, an unnecessary amount of time is spent on transportation and, therefore, unnecessary time on wasteful activities.

5.1.4 Insufficient dedicated space

During the observations, it was observed that there are no dedicated spaces for where products should be placed when stored between two operations. There are also few dedicated areas where tools and raw materials should be placed. This is a problem because it takes time for the operators to find products and materials that should be processed in the next operation, and thus there can be confusion and disorder in the production. There is also no procedure to ensure that no box or rack with products has been forgotten when the products are moved to the next operation, leading to more WIP and deficits of products. This can lead to that the operators get less control and knowledge of which products are manufactured in the production.

5.1.5 Lack of resource planning

Plejd manufactures products without defined times for when to start and finish producing. If there is no direct and clear goal to work towards, it can be harder to determine the required level of efficiency. This affects how the resources are utilised in production. From the observations, it was noticed that the operator did not have a production plan to follow and, therefore, did not have the conditions to work as efficiently as possible. Daily production meetings with the operators that bring up what type or how many products are supposed to be manufactured do not occur, nor do they have a precise schedule for the week.

They still have low customer demands for the selected product family, and therefore the capacity does not have to be fully utilised yet. However, they have some difficulties delivering products on time, and therefore, it is a problem that the resources are not utilised adequately. There is not sufficient planning on how to utilise the machines and operators while regarding the product mix. Based on interviews and observations, it emerged that Plejd is implementing an ERP system that is not yet fully utilised.

5.2 VSM: Future state

The present production system functions for the current customer demands, but Plejd's ambition is that customer demand will steadily grow and increase production volume. As mentioned earlier, is the takt time a function of available production time and customer demand. With increased customer demand but the same available production time, the takt time will be shorter, setting pressure on the production system to produce faster. To enable higher volumes is a requirement, therefore, a more effective production system. Ideas on how to solve the identified problems that today hinder production from achieving higher volumes have been developed by answering the authors' Martin and Osterling (2013) questions. The answers are presented in Appendix B. Below are suggestions based on these answers and brainstorming for improvements that aim to create a more effective production presented. The future state map is then displayed, which compiles these improvements in one solution.

5.2.1 Combine operations

One improvement is to combine the many different operations described in Section 4.2 into a few stations. The stations and the division of the operations are described below.

Station 1: SMT assembly line
This station is the SMT assembly line, which is operation 1 from earlier. This station will not be merged with any other operation since operation 1 is the bottleneck in production. Therefore, should the station not include any other operations to prevent prolonging the bottleneck (Olhager, 2013). Station 1 thus consists of two sub-operations; SMT assembly for the bottom of the PCB and SMT assembly for the top of the PCB. This means that station 1 is run twice and has a cycle time of 150 seconds for each time, as shown in Figure 5.3.

The two sub-operations being both processed in the same machine creates an issue since it is only possible to process either the one or the other, they cannot be processed simultaneously. Since these operations have to be processed in sequence, it is impossible to move on to the other stations before both sub-operations have been processed in the SMT assembly line. Therefore no work can be done at any other station when the first sub-operation is running because the products still have to go through the second sub-operation at station 1. There is also a set-up time between the switch, so switching between the two frequently is not ideal. Due to these reasons, there cannot be a continuous flow of products moving from one station to another.

Station 2: Inspection SMT solder and Selective solder
This station is a merge of operation 2: inspection SMT solder and operation 3: selective solder. This means that an operator first performs the inspection of the SMT solder and then immediately after, instead of placing the product in a buffer between these operations, feed the product into the selective solder machine. The inspection has a shorter cycle time than the machine performing the selective soldering, which should leave the operator enough time to perform the inspection while also making sure that the machine is running.

Station 3: Encapsulation, Final test and Packaging
This station is a merge of operation 4: encapsulation, operation 5: final test, and operation 6: packaging. This means an operator first encapsulates the product, then the product is tested in the final test, and then the product is packed without the

product being placed in a buffer between each operation.

Based on the measured data from the current production, an approximate cycle time diagram for each station has been created and shown in Figure 5.3.

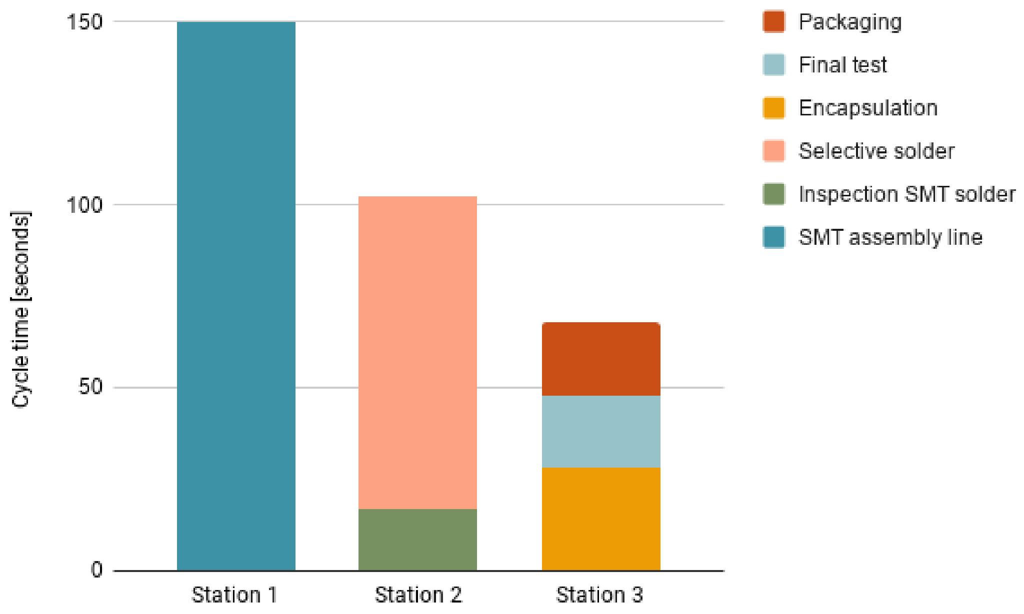

Figure 5.3: Cycle times for the stations.

When the first sub-operation on station 1 is ongoing, the batch of products cannot move on to the following operations. So the hours it takes to process all products in the first sub-operation of station 1 is time not utilised by any other station. Consequently, the operators working at the other stations are not utilised at that time since only one operator is needed to run the SMT assembly line. This is something that should be addressed, and side activities or remaining work on other products should be planned in that time where the operators are available. With the current production system, this break in the production flow is inevitable. The first sub-operation at station 1 affects the total throughput time. However, it can be considered disconnected from the rest of the operations, and therefore do Figure 5.3 not demonstrate both sub-operations at station 1.

From the cycle times shown in Figure 5.3, the different stations are not perfectly balanced, but it is more balanced than what it was in the current state, which can be seen in Figure 5.1. The reason for this division of stations is to avoid creating a new bottleneck in the production process. Table 5.1 displays the cycle times for the stations, and an initial reaction could be to create only two stations where station 1 remains the same, and station 2 and station 3 are merged. This would be more efficient if station 1 had a cycle time of 300 seconds, but since there are two sub-operations performed in batches, the cycle time at station 1 is considered to be 150 seconds. The division into three stations does not create a new bottleneck in the process while also keeping a reasonable amount of tasks at each station.

Table 5.1: Cycle times for the stations.

	Station 1	**Station 2**	**Station 3**
SMT assembly, top	150 s		
SMT assembly, bottom	150 s		
Inspection SMT solder		17 s	
Selective solder		85 s	
Encapsulation			28 s
Final test			20 s
Packaging			20 s
Total cycle time	**300 s**	**102 s**	**68 s**

The purpose of merging operations into fewer stations is to minimise many wasteful activities in the current production facility, thus not bringing unnecessary waste and non value-adding activities into the new production facility. Another advantage of combining operations is that products do not need to be transported between operations as often as in the current state, which will save time. The distances that operators must take to retrieve the products will also decrease. These changes should generate a shorter throughput time, making it possible to produce more in the available production time.

5.2.2 Optimise the bottleneck

Even when combining several operations into new stations, it is clear the SMT assembly line is the process that takes the longest time and is the bottleneck of the production system when looking at Figure 5.3. The bottleneck is the process that limits the pace of which the production system can manufacture products and, therefore, in order to maximise the output of products should the bottleneck machine be running as frequently as possible (Olhager, 2013).

One occasion when the machine cannot be operated is during the switch between two product variants due to the set-up time. It is an inevitable task, but there are ways to reduce the amount of time the set-up takes, such as utilising SMED (Sörqvist, 2013). To reduce the set-up time with SMED is the aim to turn internal activities to external to keep the machine running as much as possible (Sörqvist, 2013). An activity Plejd performs for every set-up is to load the component magazine with the SMT components that will be assembled on the PCB. All product variants have many SMT components, and loading the trolley with every component needed takes time. Today, this activity is performed when production is stopped. The task of loading the component magazine could be performed externally and thus shortening the internal set-up time if Plejd where to invest in a second component magazine. This would make it possible to have the machine running more often and generate a higher output of products.

A second improvement to increase production volume by optimising the bottleneck is to shorten the cycle time of the bottleneck machine. Since Plejd started their production recently, they still have room for improvement in the programming of the SMT assembly line. If they were to put in the time to find the optimal programming for every type of product, it would save time every occasion the SMT assembly line was running. Reducing the total throughput time and thus improve the possibility of producing higher volumes per shift.

5.2.3 Overlapping operations

One improvement that Plejd, to some extent, already uses is the overlapping of operations, but it could be utilised further and in a standardised procedure. This means that partial quantities of a batch are transported to the next operation and allowed to start before the whole batch is finished on the previous operation (Olhager, 2013). Overlap of operations usually leads to a reduction in the total throughput time of the order (Olhager, 2013).

A situation where overlapping of operations does not work is between the sub-operations on station 1. Nonetheless, between the other operations and stations, the overlapping of operations works. Therefore, Plejd should introduce a standard for how many should be finished before the products can move to the next station. Today, there is no routine on how this should be done. Through observations, it has been noticed that there is no consistency for when to start the next operation, sometimes the whole batch has passed through the previous operation, and sometimes only a few products.

If Plejd creates a procedure for overlapping of operations throughout the production, except between the sub-operations on station 1, the flow of products would be more continuous, and the WIP in the buffers would be reduced. Also, the product's throughput time would be reduced, and thus Plejd can produce in higher volumes. There is one disadvantage as this would require more frequent transportation of products between operations. However, if this improvement is used with the change to merge operations to stations, it will work better, and the negative effect would be less prevalent.

5.2.4 Invest in more SMT magazine racks

A simple but effective improvement that would save time is to invest in more SMT magazine racks. After the PCBs have gone through the SMT assembly line, they are automatically stored in an SMT magazine rack. In today's situation, Plejd has a problem with this because they do not have enough PCB magazine racks for a complete batch of products. Therefore an operator needs to re-position the PCBs into PCB holders, which takes unnecessary time and is an activity that is non value-adding for the customer. By investing in more SMT magazine racks, the time it takes for an operator to place PCBs into PCB holders could instead be spent on the other stations. Thus products can pass through the different stations more quickly, which would shorten throughput time and enable higher production volumes.

5.2.5 Create more standards

One improvement that would benefit and facilitate Plejd in their daily work is to introduce more standards. Today Plejd has some standards, for example, how the products should be assembled and packaged, but for almost all these standards, there are no instructions or visual aids. The importance of standards is to create conditions for the work to be conducted systematically and uniformly and to ensure that the determined working method is applied (Sörqvist, 2013). Since Plejd's production is relatively new, it is vital to create more standards to achieve a uniform working method to prevent unnecessary incidents that lead to losses and waste. Having standards and a standardised working method is the basis for future improvements (Sörqvist, 2013).

However, it is not always easy to introduce standards because people do not want to become standardised and follow given procedures and processes (Sörqvist, 2013). Therefore, it is crucial to involve the people who will be affected by the standards, in Plejd's case, the operators. They should be allowed to create and develop standards and routines for how the work should be conducted. Standards also form the basis for detecting deviations, which is vital to minimise or eliminate waste (Petersson and Ahlsén, 2015).

One problem identified in Plejd's production was insufficient dedicated space. This problem could be solved by standards that regulate where products should be placed between stations and how many products may be stored in each buffer. By having standards, operators would know exactly where to place the products, and thus the flow of products would be more efficient as it saves time and reduces the disruption in production.

This, together with the fact that Plejd is implementing an ERP system, would make it possible to plan production in more detail and allocate resources more efficiently. With more efficient production, it becomes easier to produce higher quantities of products. Another advantage of having both standards and a well-implemented ERP system is that production can be planned according to a weekly schedule. Thus all operators will know exactly what is needed to be produced that week and how they are scheduled in advance.

5.2.6 Design of future state map

The future state map has been created to illustrate the changes that would enable Plejd to increase its production volumes. In Appendix F, the original drawn future state map can be seen. By combining the improvements described above and considering that Plejd is currently implementing and learning how to work with the ERP system, many of the wastes in the current production process could be minimised or eliminated. Also, much of the non value-adding time will be minimised, which means more time will be available to produce products.

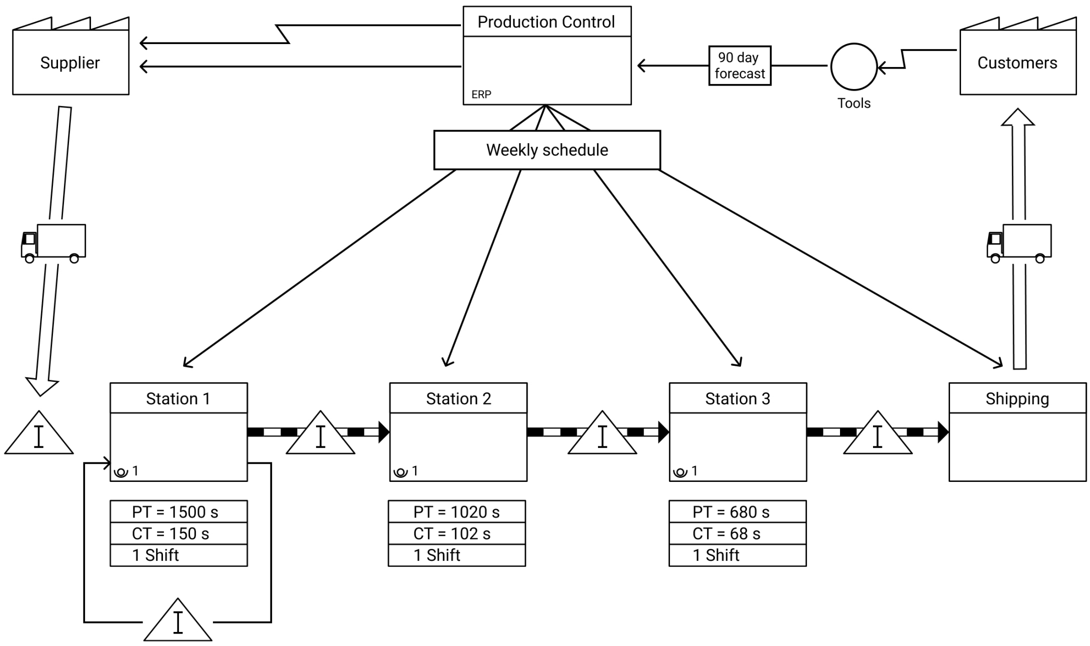

Figure 5.4: Value stream map for the future state.

The information flow in the future state has more structure than before. With the implementation of an ERP system can the production be better planned and lead to greater use of resources. For example, weekly scheduling can facilitate planning for everyone working in production.

The material flow has changed a lot. Instead of the six operations illustrated in the current state map, have these operations merged into three stations. Station 1 is run twice, illustrated in Figure 4.2, since both the bottom and the top of the PCB must run through the SMT assembly line. As can be seen, the number of buffers has also been reduced from eight to five.

The time ladder illustrated in the current state has deliberately been excluded from the future state map. The reason for this is that the time ladder depends on takt time, which is related to customer demand and available production time. As customer demand will increase, a change in takt time will occur. Since the future customer demand is unknown is, therefore, a future takt time also unknown. However, the processing time for production in the future state will be the same as in the current state if no improvements or optimisations of the machines are made.

5.3 Future production capacity requirements

Plejd wants to increase its production volume and, in the future, be able to produce 100.000 products per month. When comparing this number to the current capacity of 21.600, it is clear that the current set-up will not be enough. The difference between the two is prominent. Even though the proposed improvements would create a more efficient production that can produce higher volumes, it will most likely not be sufficient. Investments in increased capacity will be required in the future.

There are different options for possible solutions that can be implemented on their one or together in order to reach a higher capacity. As mentioned earlier is primarily personnel, the number of machines, or working hours that can be adjusted. It is the bottleneck machine, which in this case is the SMT assembly line, that has to increase its capacity. That machine will not change its production speed, depending on how many operators are working on it. Investing in a second SMT assembly line or increase the number of shifts would affect capacity.

5.3.1 Invest in machines

Investing in additional SMT assembly machines would have a significant impact on available capacity since it is currently the bottleneck in the process. To reach Plejd's goal capacity, the current capacity would have to be increased with a factor of five, which is a substantial upscaling. As the company grows, the SMT assembly line might not continuously be the bottleneck. Future investments in machines should start with an investment in a second SMT assembly line, but after that, the present situation has to be analysed. Investment in new machines could also, in turn, lead to an increased requirement in personal and resources.

The desired state is to have a balance between every operation because if one operation cannot meet the required capacity, it will hinder the rest of the operations. In practice, this does not have to mean that each operation has an equal capacity level. Instead, there has to be a balance between operations when conditions such as process times and break downs considered.

5.3.2 Invest in more shifts

Investment in more shifts is a way to utilise current resources without investing in new machines (Jonsson and Mattsson, 2016). If production can run for more hours of the day, it is possible to produce more without changing the current set-up of machines and layout. The cost of the investment is the personnel cost for the additional operators who would work the extra shifts.

5.3.3 Levelled capacity

Plejd has some seasonal variation in their customer demand. They can exploit this variation to mitigate the need for higher capacity. If it is possible to produce products more even over the year, the need to increase the capacity would not be as imminent. Some of the customer orders received in the peak season could be produced in periods with lower customer demand, which Figure 5.5 demonstrates.

Plejd manufactures a small product range, and therefore it should be feasible to forecast customer demand.

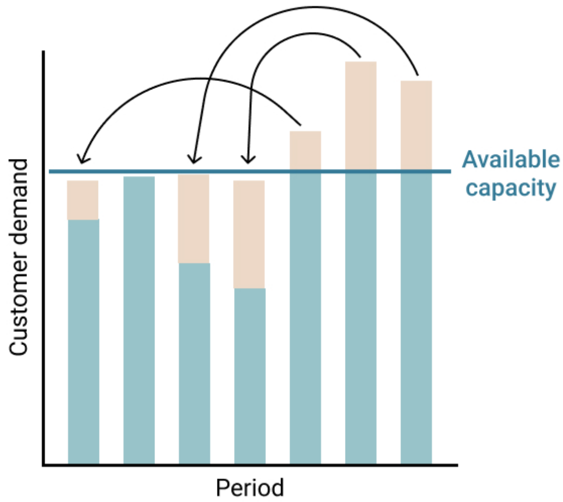

Figure 5.5: An illustration of levelled capacity.

6
Discussion

The discussion chapter begins with a discussion of the result and Plejd's ability to reach the production goal, then the methods used in the project are discussed and the effects of Covid-19. Lastly, sustainability at Plejd's production facility is discussed.

6.1 Future production

Plejd wants to increase its production volume and, in the future, be able to produce 100.000 products per month. One could suggest that they only should invest in capacity and not bother to implement the changes in the current production since they do not have the same effect on increasing production volume. However, if they were to invest in capacity without implementing any production improvements, they would have a lower utilisation grade of the production system and thus have to invest even more in capacity. As mentioned earlier, capacity entails a high cost for the company. Therefore, it would be beneficial to implement the changes to create a more efficient production that can better utilise the investment in capacity. The identified problems in the current production would not be solved by investing solely in more capacity. Instead, they would probably be even more prominent. To lay the foundation for a stable production system in the future should the solutions to these problems be implemented. Creating an efficient production and investing in capacity should not be considered separate solutions; instead, they can be seen as a complement to each other.

It is clear from the result that with today's productions set-up that the SMT assembly line is the bottleneck in the process. Since the products have to go through twice in that machine, will it not be possible to create a balanced production even with the combined stations. Developing on the approach of complementing solutions for Plejd's future production could an investment in a second bottleneck machine drastically reduce the negative effects the bottleneck has on the production. The bottleneck process is not constant, and it will shift with changes made in the production system, and future investment should reflect those changes.

6.1.1 Future studies

The process of implementing the improvement proposals is not part of this thesis. However, the implementation process could be a start for future studies where an action plan for the implementation of improvements and more substantial investments are planned in an optimal order. The process should be iterative, and further improvements should not be based on the old current state map. Instead, a new map should be created that reflects the present current state to identify relevant improvements.

6.2 Method discussion

The method chosen for mapping the production was value stream mapping. The advantage of this method is that it presented a good picture of the production. However, this method only gives an overview of what it looks like at the moment. Value stream mapping should be seen as an iterative process, and several analyses should be performed to give a better picture of the production. In a production like this, it would be interesting to perform value stream mappings at regular intervals to see if the lead time changes as improvements are introduced and because the takt time will change when the production volumes increase. A disadvantage of value stream mapping is that it does not take into account variations over time, and the information gathered comprises mean values for the time the data was collected.

The mapping of the current state took a longer time than first planned. This was mainly because the product group that had been identified for the project was relatively new, and there were some errors in the production, which caused the mapping to take longer than expected. Other factors that caused the value stream mapping to take longer were the lack of some materials and components which delayed production and also that operation 5: the final test was a new operation, which took a long time to start up.

One difficulty with using VSM as a mapping method was that Plejd does not produce in a continuous flow but produces in batches. VSM is generally easier to use if a company produces in a continuous flow. Since Plejd does not have a continuous flow, it made it quite difficult to map the flow of materials and products. With this, there is a source of error regarding the calculated WIP on each operation because the mapping took a very long time, and there were other similar products at the same time in the production flow.

Another source of error that can be discussed is the reason why nominal capacity was the one calculated. Gross and net capacity are on a more detailed level where different capacity losses and unplanned operations are included in the calculations. These parameters were very varied at Plejd, so a calculation of gross or net capacity would not be entirely representative of the level of detail they should represent. Nominal capacity, which had a more overall calculation of capacity, was deemed better suited for the situation. Given that the estimated nominal capacity was so far from the future target of 100,000 products per month, the margin of error can be considered irrelevant.

6.2.1 Effects of Covid-19

From the beginning of the project, it was intended that the authors would work from Plejd's production throughout the entire period of the project in order to get as much understanding and knowledge about their production as possible. However, this was not possible due to Covid-19 and Plejd's restrictions that all employees and students should work from home to the greatest extent possible. Consequently, the authors have not been at Plejd from March 12th until the finalisation of the project at the end of May.

One positive thing was that the value stream mapping of the current state was almost complete at this time and could be finalised with the supervisor's help at Plejd conducting the final cycle time measurements. However, this can be considered a source of error because it means that the same person did not measure the cycle times for all operations, and the measurements may not be performed in the same way. However, letting the supervisor measure some cycle times was the only way to continue working with the VSM for the current state. Nevertheless, this is not considered to affect the result of the VSM because the suggested improvement proposals were held at an overall level. Detailed improvements proposals for specific operations were not evaluated in this project. Another way that Covid-19 has affected the project is that the proposed solutions and value stream map for the future state could not be discussed and analysed together with the employees at Plejd in the same way as if the authors had been at Plejd's production.

The study visits planned at the beginning of the project could not be carried out because other companies did not want to receive visitors due to Covid-19. The study visits were intended to be used as benchmarks to compare how other productions in the electronics industry and similar industries have built up their productions. Since these study visits could not occur, the authors could not compare Plejd's production with other companies and, therefore, could not get inspiration on how other productions work. Unfortunately, the study visits could not be carried out as the authors believe that it had provided a good input to the project and to the solutions that have been proposed for increasing the production volumes.

6.3 Sustainable production

Expanding a company is a challenge. Plejd is a company that chooses to expand and continue to have its production in Sweden, instead of outsourcing it to another country. Keeping the production in Sweden and increasing production contributes to both economic sustainability and social sustainability. It contributes to economic sustainability because it gives people in Sweden job opportunities thus contributes to lowering unemployment. It also contributes to social sustainability because Sweden has better work conditions for its employees than other countries have.

Expanding production and developing the organisation can also contribute to environmental sustainability. However, this is something that has not been investigated in this project. If Plejd chooses to make the new production facility energy and resource-efficient, it can contribute to environmental sustainability.

7 Conclusion

In this chapter is the aim of this project fulfilled by presenting the conclusions to the defined research questions. The research questions are: ***how is the current production flow structured****, and* ***how can changes in the current production accomplish a higher production volume?***

A broad understanding of their current production was required to provide relevant solutions to Plejd on how they can increase their production volumes. By conducting a value stream mapping on their production site and carrying out observations and interviews emerged an understanding of how the current production flow is structured when it comes to material flow as well as information flow. This acted as the foundation of which problem areas could be identified, and improvements could be proposed.

Plejd can accomplish a higher production volume and the goal of 100.000 produced products per month by creating a more efficient production and investing in capacity. Creating a more efficient production is done by implementing solutions to the identified problems in Plejd's current production. With more efficient production, they should be able to produce higher volumes in the same available time as earlier. However, these changes will not be sufficient on their own. For Plejd to reach their production volume goal, they have to complement these improvements with investments that increase production capacity.

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A

Appendix 1 - Future state questions

Questions from Martin and Osterling (2013).

General Questions

- What are the business issues (service quality, product quality, speed, capacity, cost, morale, competitive landscape, impending regulations, etc.) we wish to address?
- What does the customer want?
- What measurable target condition(s) are we aiming for?
- Which process blocks add value or are necessary non-value-adding?
- How can we reduce delays between processes?
- How can we improve the quality of incoming work at each process?
- How can we reduce work effort and other expenses across the value stream?
- How can we create a more effective value stream (greater value to customers, better supplier relationships, higher sales conversion rates, better estimates-to-actuals, lower legal and compliance risk, etc.)?
- How will we monitor value stream performance?

Specific Questions

Touch points

- Are there redundant or unnecessary processes that can be eliminated (e.g., excessive approvals)?
- Are there redundant or unnecessary hand offs that can be eliminated or combined?
- Are there processes or hand offs that need to be added?

Delays

- Is work being processed frequently enough? Can we reduce batch sizes or eliminate batching completely?
- Do we have adequate coverage and available resources to accommodate existing and expected future workloads?
- How can we create more capacity or reduce the load at the bottleneck?

Sequencing and Pacing

- Is the work sequenced and synchronised properly? Are processes being performed too early or too late in the value stream?
- Are key stakeholders being engaged at the proper time?
- Can processes be performed concurrently (in parallel)?
- Would staggered starts improve flow?
- How can we balance the workload to achieve greater flow (via combining or dividing processes)?
- Do we need to consider segmenting the work by work type to achieve greater flow (with rotating but designated resources for defined periods of time)?

Variation Management

- Is there internally produced variation (e.g., end-of-quarter sales incentives)?
- How can we level incoming workload along the value stream to reduce variation and achieve greater flow?
- Can we reduce variation in customer or internal requirements? How can necessary variation be addressed most effectively?
- Are there common prioritisation rules in place throughout the value stream?

Technology

- Is redundant or unnecessary technology involved?
- Is the available technology fully utilised?
- Are the systems interconnected to optimise data movement?

Quality

- How can higher-quality input be received by each process in the value stream (to improve the
- Is there an opportunity to standardise and error proof work?

Labour Effort

- How can we eliminate unnecessary non-value-adding work?
- How can we reduce the labour effort in necessary non-value-adding work?
- How can we optimise value-adding work?

Value Stream Management

- Do policies need to be changed to enable improved performance?
- Are there organisation / departmental / reporting structures that can be changed to reduce conflicting goals or align resources?
- Do existing performance metrics (if any) encourage desired behaviours and discourage dysfunctional behaviour?

- What key performance indicators (KPIs) will we use to monitor value stream performance?
- Who will monitor the KPIs? How frequently? Who else will results be communicated to?
- What visual systems can be created to aid in managing and monitoring the value stream?
- Are the key processes within the value stream clearly defined with their own KPIs, standardised appropriately, and measured and improved regularly?

B

Appendix 2 - Answers to future state questions

General Questions

- What are the business issues (service quality, product quality, speed, capacity, cost, morale, competitive landscape, impending regulations, etc.) we wish to address?
  - Increase production volume
- What does the customer want?
  - Get the product they order in time
- What measurable target condition(s) are we aiming for?
  - No concrete measures. Achieve a higher production volume that will match future customer demand
- Which process blocks add value or are necessary non-value-adding?
  - SMT assembly, selective solder, encapsulation packaging
- How can we reduce delays between processes?
  - Reduce the number of components placed in storage between every station, start processing at the stations earlier
  - Combine stations
- How can we improve the quality of incoming work at each process?
  - SMT assembly
    - Order components that function properly with the programming and don't require extra tasks
  - Selective solder
    - Program the SMT assembly in order to minimise errors
    - Order components that function properly with the programming and don't require extra tasks
  - Encapsulation
    - Program the selective solder in order to minimise errors
  - Packaging
    - Have standards on how the encapsulation should be performed
  - Shipping
    - Have standards on how the packing should be performed
- How can we reduce work effort and other expenses across the value stream?
  - Plan weekly production in detail
  - Every person should know what their tasks are for the day in order to minimise wait time and people aimlessly wandering around

- How can we create a more effective value stream (greater value to customers, better supplier relationships, higher sales conversion rates, better estimates-to-actuals, lower legal and compliance risk, etc.)?
  - Plan production in more detail
  - Improve communication between functions so that every part of the production is on the same page and can plan their work accordingly
- How will we monitor value stream performance?
  - Measure the ratio of products delivered on time number of complaints on each product type

Specific Questions

Touch points

- Are there redundant or unnecessary processes that can be eliminated (e.g., excessive approvals)?
  - No processes can be removed
- Are there redundant or unnecessary hand offs that can be eliminated or combined?
  - Every process has a short cycle time compared to SMT assembly. Those stations could be combined in some manner to have a more balanced production
- Are there processes or hand offs that need to be added?
  - No processes need to be added

Delays

- Is work being processed frequently enough? Can we reduce batch sizes or eliminate batching completely?
  - To maximise production volume should the bottleneck machine be running as frequently as possible. The SMT assembly is the bottleneck of the process (takes the longest time) and this machine is not running continuously in the current production
  - Batch sizes can be reduced
- Do we have adequate coverage and available resources to accommodate existing and expected future workloads?
  - It depends on the size of the future workload. In the short future, it could be possible to meet higher demands by having more effective processes but with higher demand, the current resources are not enough
- How can we create more capacity or reduce the load at the bottleneck?
  - It's not possible to reduce the load at the bottleneck. The full capacity is not used today. If they want to increase capacity they could "upgrade" the machine or by a second one

Sequencing and Pacing

- Is the work sequenced and synchronized properly? Are processes being performed too early or too late in the value stream?
  - The work is sequenced and synchronised properly
- Are key stakeholders being engaged at the proper time?
  - Yes
- Can processes be performed concurrently (in parallel)?
  - No
- Would staggered starts improve flow?
  - No
- How can we balance the workload to achieve greater flow (via combining or dividing processes)?
  - All stations except SMT assembly have short cycle time and can, therefore, be combined into one or two stations that better match the SMT assembly cycle time
- Do we need to consider segmenting the work by work type to achieve greater flow (with rotating but designated resources for defined periods of time)?
  - No

Variation Management

- Is there internally produced variation (e.g., end-of-quarter sales incentives)?
  - No
- How can we level incoming workload along the value stream to reduce variation and achieve greater flow?
- Can we reduce variation in customer or internal requirements? How can necessary variation be addressed most effectively?
- Are there common prioritisation rules in place throughout the value stream?
  - No

Technology

- Is redundant or unnecessary technology involved?
  - No
- Is the available technology fully utilised?
  - No. There some machines that could be utilised more and the ERP system as well
- Are the systems interconnected to optimise data movement?
  - No

Quality

- How can higher-quality input be received by each process in the value stream (to improve the %CA metric)?
  - Utilise standards, improve the programming of machines and order appropriate components
- Is there an opportunity to standardise and error proof work?

  - Yes. Manual work by operators is common and that work could be standardised and have instructions on how it should be performed. Standards could also be for the set-up of the machines

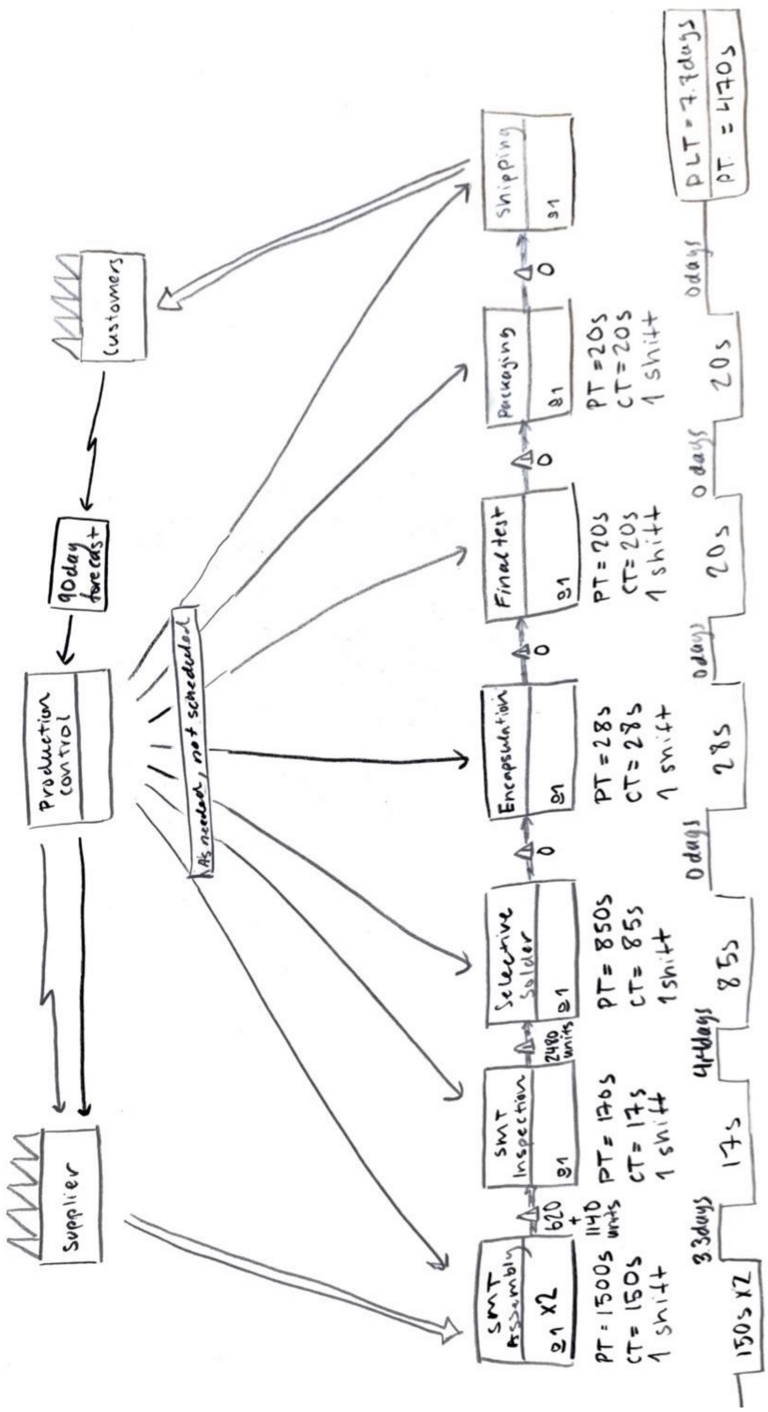
Labour Effort

- How can we eliminate unnecessary non-value-adding work?
  - Minimise uncertainties in what and when a task should be performed
    - Have a more detailed schedule
  - Minimise unnecessary transport and repacking of product/component
    - Can combine stations
    - Purchase more racks
  - Minimise wait for components from supplier
  - Each component and tool should have its dedicated space so everyone knows where the components and tools are located
- How can we reduce the labour effort in necessary non-value-adding work?
  - Optimise and standardise the set-up and match the product mix after optimal set-up
- How can we optimise value-adding work?
  - Optimise component placement so it goes faster in the SMT assembly

Value Stream Management

- Do policies need to be changed to enable improved performance?
  - There are no policies
- Are there organisation / departmental / reporting structures that can be changed to reduce conflicting goals or align resources?
  - No
- Do existing performance metrics (if any) encourage desired behaviours and discourage dysfunctional behaviour?
  - There are currently no performance metrics in place.
- What key performance indicators (KPIs) will we use to monitor value stream performance?
  - The percentage of products delivered on time
  - The percentage of reclaims from customers
  - The percentage of reworked products compared to the total produced
- Who will monitor the KPIs? How frequently? Who else will results be communicated to?
  - Production management, monthly, communicated to operators and higher-ups
- What visual systems can be created to aid in managing and monitoring the value stream?
- Are the key processes within the value stream clearly defined with their own KPIs, standardised appropriately, and measured and improved regularly?
  - No

C
Appendix 3 - Current state map



D

Appendix 4 - Measurements of CT and PT for REL-02

REL-02

Process time	PT 1	PT 2	PT 3	PT Mean
SMT Assembly Line *(seconds)/(minutes)*	1467	1554	1484	1502
	~24.5 min	~26 min	~25 min	25,2
Inspection SMT *(seconds)*	162	169	180	170
Selective solder *(seconds)*	851	-	-	851
Encapsulation *(seconds)*	28			28
Final test *(seconds)*	20			20
Packaging *(seconds)*	20			20

Cycle time	CT 1	CT 2	CT 3	CT Mean
SMT Assembly Line *(seconds)/(minutes)*	146,7	155,4	148,4	150
	~2.5 min	~2.5 min	~2.5 min	2.5 min
Inspection SMT *(seconds)*	16,2	16,9	18	17
Selective solder *(seconds)*	85,1	-	-	85
Encapsulation *(seconds)*	28			28
Final test *(seconds)*	20			20
Packaging *(seconds)*	20			20

(yellow)	Measured correctly by the authors at the production facility
(pink)	Machine broke down after first measurement. Further measurements could not be perfomed due to Covid-19
(blue)	Measured by supervisor at Plejd due to Covid-19

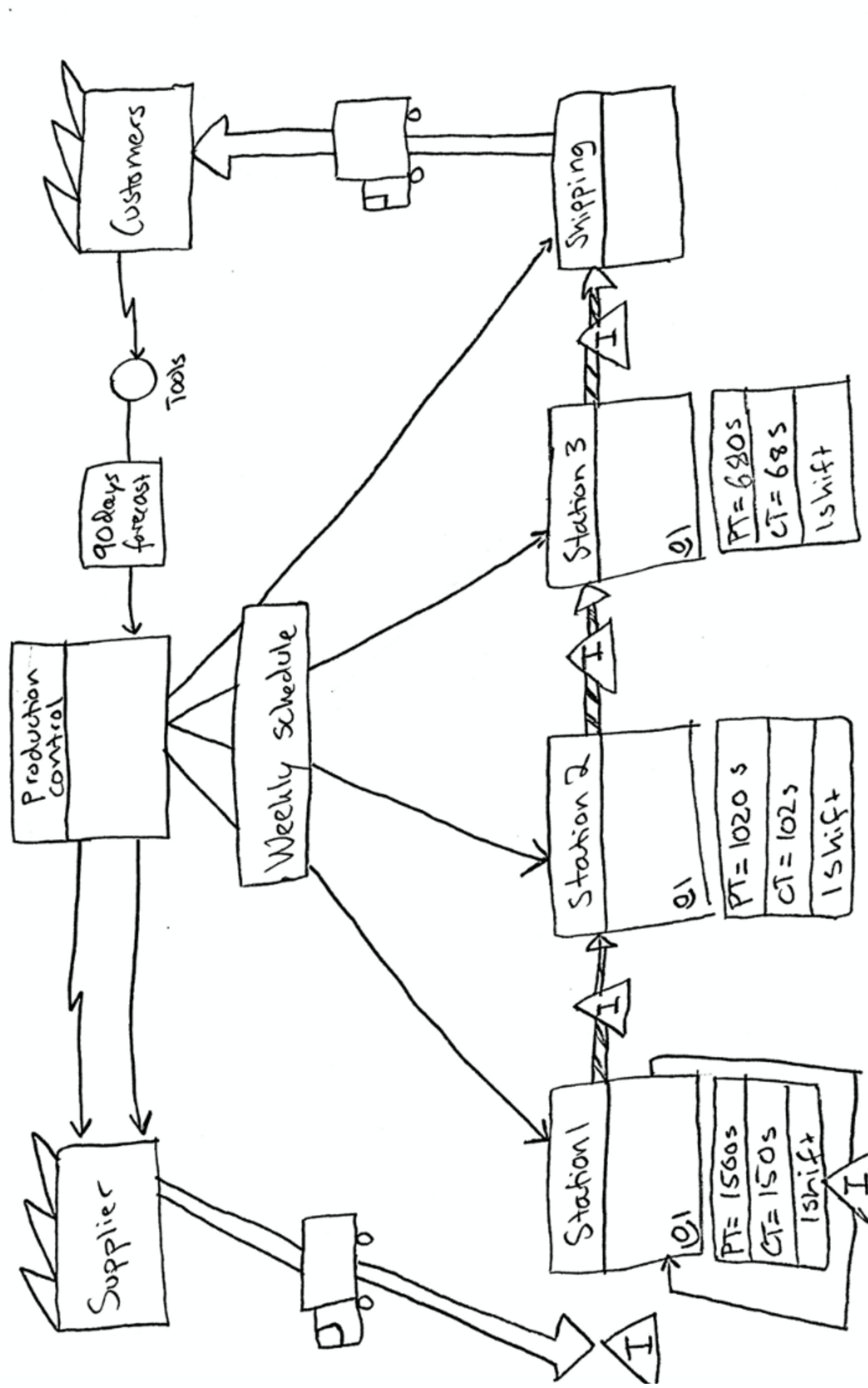
E
Appendix 5 - Counted WIP for REL-02

REL-02

Processes	Operators	WIP (PCB plate)	WIP (PCB single)
Inventory between operations		0	0
SMT Assembly Line Top		0	0
Inventory between operations		114	1140
SMT Assembly Line Bottom	1	10	100
Inventory between operations		62	620
Inspection SMT	2	2	20
Inventory between operations		248	2480
Selective solder		0	0
Inventory between operations		0	0
Encapsulation		0	0
Inventory between operations		0	0
Final test		0	0
Inventory between operations		0	0
Packaging		0	0

(yellow)	Operation running during measurements

F
Appendix 6 - Future state map



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