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Reduction of lead times and optimization of inventory levels for meeting on time delivery (OTD) using value stream mapping

-A case study for the fast runner product in IMI Hydronic Engineering, Ljung.

Master's thesis in the Master programes of Supply Chain Management and Production Engineering

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Gothenburg, Sweden 2018, E2018:035

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Abstract

IMI Hydronic Engineering is the provider of hydronic components for Heating, Ventilation and Air Conditioning systems (HVAC) systems. The main vision for the company is to provide challenging innovative and sustainable energy efficient solutions for hydronic problems with high level of delivery accuracy, customer satisfaction and cost efficiency. Their product range includes various climate control products with integrated intelligent solutions. One of their facilities is located in Ljung. This facility produces many product families and product varieties out of which the product flow of their fast runner product, product SK is investigated in this thesis.

Due to the customer requirements, the company produces wide variety of hydronic components. This leads to substantial increase in the product variants which gets reflected in the product mix in the production. The complexity of the production flow increases as the number of variants and the production mix increase. This in turn affects the on time delivery (OTD). Currently the company is striving to keep up their delivery performance with lots of inventories in the production flow.

This thesis work mainly focuses on the enhancement of On Time Delivery (OTD) by providing suggestions for the reduction of production lead time with optimal inventory levels in the production flow of product SK. Since the demand is seasonal, keeping safety stock in the inventories and making the production system to reflect to the present demand is an important parameter.

The main purpose of this thesis is to reduce the production lead time with optimal safety stock and reorder points in the production flow of product SK in order to make the production system to produce in tune with the customer demand for that period of time.

Currently the production lead time is 9.5 days. After setting the optimal safety stock and reorder points, the planned production lead time is 2.17 days. However for running the production system with optimal stocks, this thesis work also suggests some other improvements on the production line. The improvement functions include placement of pacemaker and supermarkets in the production flow. The suggestions for the improvement are shown in the future state map.

Keywords: VSM, Safety stock, Reorder points, CONWIP, OTD.

Acknowledgements

This report is written as a master thesis in Chalmers University of Technology in collaboration with IMI Hydronic Engineering by the students from Supply Chain Management and Production Engineering master programmes.

First, we would like to thank our supervisor Peter Almström from Chalmers, for his splendid support and valuable time.

We would like to thank our industrial supervisors at IMI Hydronic Engineering, Ljung, Anna Ehn and Fredrik Johansson for entrusting us and for their great support. We would like to thank the people involved in this thesis project in IMI Hydronic Engineering, Ljung, for their timely help and support.

We like to like extend our thanks to our friends and family who have helped us a lot during this project.

Shashidhar Pai and Krishna Tamilselvam, Gothenburg, 2018

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1
Introduction

This chapter contains a brief description about the case study company, about the product SK, problem identification, aim and purpose of the thesis along with the scope and delimitation.

1.1 Background

IMI Hydronic Engineering is one of the pioneers in providing all types of hydronic components for the HVAC (Heating, Ventilation and Air- Conditioning systems). It was started in the year 1928 and it was acquired by a British manufacturing group, IMI Plc., in 1997. This group comprises of three brands that includes IMI Hydronic Engineering, IMI Precision Engineering and IMI Critical Engineering. Currently IMI Plc operates in more than 61 countries across the globe. IMI Hydronic Engineering has its headquarters in Switzerland and currently 400 employees are working in their facility in Ljung.

IMI Hydronic Engineering started adapting lean techniques and developed a strategy based on lean philosophy. They started practicing it under the name IMI way in 2010. Since then, they are training people and implementing various lean tools and techniques in their processes and in the production. They have altered their performance measurement indicators based on the IMI way. They have five KPI (key performance indicators) which includes OTD (on time delivery), IT (inventory turn), productivity, LTA (loss time accident) and COQ (cost of quality).

The facility in Ljung produces more than 100 product varieties and their main customers are in Nordic countries, in Poland and in Germany. Because of the rise in the number of product variants, there has been a significant increase in the complexity of the production processes and inventories in the production flow. This in turn gets reflected in the on time delivery (OTD) of the finished products.

AF product family is one of their fast running product family and it has several product variants based on the dimensions and minor functionality changes. All the variants of the product family AF follows the same production flow. This thesis focuses on the production flow of product variant SK, which is one of their fast running product for IMI Hydronic Engineering. The names of the product and the product family has been changed because of confidentiality reasons.

Product SK is a type of valve used for mixing the hot and cold fluids in the HVAC systems and it has more than 30 components in its bill of materials(BOM) and the major components are made of Brass. The dimension of the product SK is 74*110*54mm (length*height*width). There are three main elements of product SK, that is, the main body, the other metal parts and a few rubber components. The main body part is manufactured in the foundry and the other metal parts are manufactured in the bar machining area. Both the foundry and the bar machining are located within the facility and the rubber components are procured from external suppliers. Components for product SK are assembled to the casted body part in the final assembly in the production flow.

The company has categorized the product items based on the sales volumes and the delivery strategy is to ship their fast runner products within a day. The company follows 'make to stock' decoupling strategy for faster delivery of goods to their customers. The company strives to achieve on time delivery (OTD), in order to provide high service level to their customers. As a result, the company has large number of parts in the final inventory and also in many parts of the production flow. Production lead time and inventory management are important parameters, for achieving on time delivery (Ndubi, et. al., 2016) (Rother and Shook, 2009).

One another important cause for the huge inventories is the seasonal demand of the products. As the demand for the HVAC products are high in the spring and summer seasons, in order to satisfy the market requirements, the company ends up with the large inventories in most parts of the year. One such product is SK. It contributes nearly one third of the final sales volumes of the similar variants of the valves that are produced in their facility.

1.2 Problem Definition

In order to satisfy the customer requirements, IMI Hydronic Engineering developed its product portfolio to great extent in recent years. This in turn results in complex product mixes in the production flow. Since the company has a delivery strategy of shipping their fast runner products in one day, the current problem faced by the company is to meet the 'on time delivery' (OTD).

Currently the on time delivery for the product SK varies from 65% to 93% with the average of 84% for the past year. In their facility at Ljung, they are trying to ensure higher on time delivery rate of 96%.

1.3 Purpose

The purpose of this master thesis project is to find the improvement potentials for meeting the on time delivery (OTD) rate of product SK.

1.4 Goals and Deliverables

The goals and deliverables of this thesis project includes

- Using value stream mapping to understand and have an overview of the production flow of product SK.
- Analyzing the current state map to identify factors affecting OTD for product SK, in that production flow.
- Analyzing the identified factors and determine solutions for improving OTD
- Proposing future state map with the improvements for the product SK.

1.5 Scope and Delimitations

The scope of the thesis project is limited to the production flow of one particular product SK in the product family AF.

Value stream is only done for the body part which comes from the foundry as it takes the longer lead time when compared to the other parts in the bill of materials (BOM) of the SK. The thesis project is limited to the in-house flow of materials that is from foundry to final warehouse.

This master thesis focuses on improving the On Time Delivery (OTD). The interrelations between the OTD and other KPI's are not taken into account.

1.6 About the thesis

The structure of our thesis report is explained in this section. It also contains a brief insight of the contents covered under each chapters in this thesis.

chapter 2 - Theoretical framework
This chapter remains as a backbone of the thesis and it constitutes of the theory relating to the concepts discussed in this Master's thesis.

chapter 3 - Methodology
This part of the thesis report explains about the methodology in which the Master's thesis has been conducted.

chapter 4 - Current production
This chapter of the thesis describes about the data collected and the current production state of product SK along with the current state map.

chapter 5 - Analysis
This chapter of the thesis explains about the analysis of the current state with the theoretical framework as its base. This chapter also explains about the proposed future state map.

chapter 5 - Recommendations for the company
This part states the results of the analysis along with the improvements that are needed for the implementation of the proposed future state map for improving the production flow.

Chapter 7 - Discussions and conclusion
This chapter consists of discussions of the obtained results and the final conclusions of this master thesis project. This chapter also explains about the points to consider for the effective implementation of the proposed future state.

2
Theoretical framework

This theoretical framework consists of the relevant literature pertaining to the concepts used in this thesis along with the ways of improving On time delivery (OTD). The figure 2.1 explains about the framework used for this literature study, followed by literature about OTD and its importance along with the general concepts used. Since the project scope is limited to in-house production of product SK, we have limited our search to the factors affecting OTD in relation to internal processes. The literature relating to the above aspect, especially for in-house production, was limited. Therefore, two factors were selected and the process of selecting it is explained in later part of theoretical framework and as well as in methodology section. The two factors are, lead time decrement and ways of having effective control of buffers. Finally, the literature framework explains about value stream mapping, the tool used for performing the master thesis.

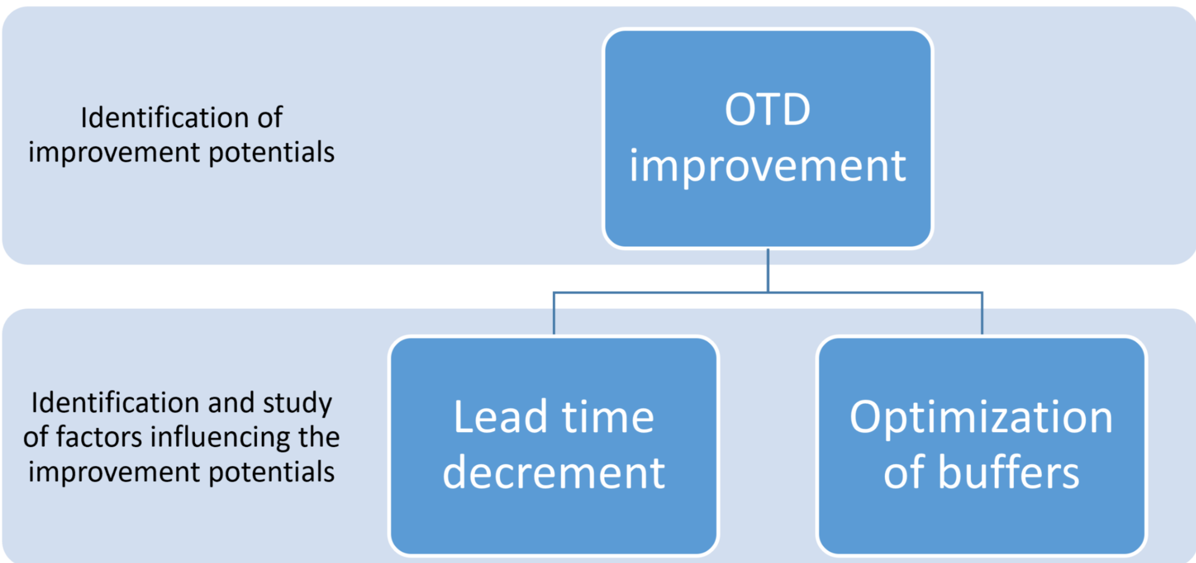

Figure 2.1: Overview of framework used for literature

The framework for this literature study consists of two phases that includes identification of improvement potentials and identification and study of factors influencing the preferred improvement potentials. In the first phase, the concept of OTD is explained along with its importance followed by the identification and selection of the improvement potentials. In the second phase of the literature study, various factors influencing the identified potentials is explained.

2.1 Customer order decoupling point and its types

Manufacturing companies can be classified by, the way the operations are carried out based on customer orders. The level of integration between the production operations and customer orders plays an essential role in managing an efficient flow. This is done by defining customer order point and customer order decoupling point (Jonsson and Mattsson, 2009). Customer order point refers to the point in products' bill of material from where the material supply is based on the specific customer order. All the production operations before that are usually generic and have the same processes. After the customer order point the products' appearance and characteristics are customer order specific. Furthermore, it also defines the delivery lead times which should be at least calculated from customer order point to the time it takes to complete the entire manufacturing operations (Jonsson and Mattsson, 2009) (Karim et al., 2009). Customer order decoupling point refers to the point in bill of material where the material supply and value added activities are based on customer order received. This is very essential as the material planning and delivery dates before this point are based on forecasts (Jonsson and Mattsson, 2009).

Based on the customer order decoupling point there are certain manufacturing strategies that can be implemented for better customer order integration. They are engineer to order (ETO), make to order (MTO), assemble to order (ATO), and make to stock (MTS) (Jonsson and Mattsson, 2009). ETO means that the products are made according to the specifications of the customers and the companies must try to be flexible and adapt according to the demand of the customers, possibly, at every stage of the production. The customer order decoupling point lies in the earlier stages of the production flow, in this case. MTO is also quite similar to ETO, the only difference is that certain parts, sub-assemblies, and semi-finished products are produced or procured from suppliers before customer orders are received. ATO means that the parts, sub-assemblies, and semi-finished products are produced without any relation to the customer orders. These are assembled together once the customer order is received. The semi-finished products usually have standardized items which are then assembled as per customer order. MTS means that the company is fully aware of the customer order specifications and then manufactures them to keep it in stock which is shipped as soon as the customer orders are received. This is also possible as the products are completely standardized with little or different operation along the flow. Furthermore, the forecasts, delivery schedules, resource availability, inventory levels, etc are the ones that dictate the initiation of manufacturing operations (Jonsson and Mattsson, 2009).

2.2 OTD - On Time Delivery

Manufacturing includes all the processes and activities from order receipt to final shipment of the product to the customer (Karim et al., 2009). For achieving competitive advantage, the firm must focus on improving one or mix of factors or parameters rather than concentrating on all (Tersine and Hummingbird, 1995). As mentioned earlier the five KPI's for the case company are OTD (on time delivery), IT (inventory turn), productivity, LTA (loss time accident) and COQ (cost of quality). Now, if we focus on improving OTD, the other KPIs such as inventory turns and productivity is also influenced positively when OTD is improved.

The firm should measure in terms of delivery performance, if their focus is on lead time and quality parameters (Tersine and Hummingbird, 1995). OTD (On Time Delivery) is one of the important measuring parameter for a manufacturing company's delivery performance and it should be measured based on the OPD (original promised date) to the customer (Ramachandran and Neelakrishnan, 2017). In other words, OTD can be improved by reducing the lead times and thereby delivering products to customers on time.

Karim et al. (2009) and Ramachandran and Neelakrishnan (2017), argue that for a sustained improvement of on time delivery (OTD), all the processes and functional units included in the manufacturing should be taken into account. Thorsen and Yao (2015), states that for maintaining higher service levels, it is important to calculate the optimal inventory ordering policies. On the other hand, Karim et al. (2009) confronts that inventory control and optimization of inventories alone have weaker impact over the On Time Delivery (OTD) performance when it is improved separately and it needs to be done with the improvement of a parameter or the mix of other parameters.

2.3 Why lead time decrement and buffer optimisation for OTD improvement?

Literature relating to the improvement of On time delivery (OTD) performance, for in-house production, is scarce. However, from the available literature, the stakeholders involved and from the authors' academic knowledge, the authors have narrowed down to lead time decrement and optimization of buffers. The motivation for selecting these two factors are also that they are much more related to the case study company and the product selected for the thesis.

Production lead time is one of the most important parameters for delivering products on time and a varying lead time leads to many consequences throughout the supply chain (Ndubi, et. al., 2016) (Wouters, 1991). For example, one of the issues of long or varying lead times is the cost related to expediting and fixing the problems caused in scheduling. Also, the planning horizons are made for longer periods and this leads to even more inventories, which again is an added expense to the company (Tersine and Hummingbird, 1995). Furthermore, Wouters (1991), states that, reducing the lead time, reduces the delivery lead time. If the customer order decoupling point lies downstream, the delivery lead time can be improved by both lead time reduction and optimization of buffers.As mentioned earlier, the case company works in a make to stock environment, which means the decoupling point lies downstream near the customer. Therefore, the delivery lead time in case company can be improved by both lead time reduction and optimization of buffers.

Excess inventories are a type of waste and it is one of the reason for the long lead times (Rother and Shook, 2009). It is considered as a waste as it does not add value and is, therefore, an unnecessary cost to the company. But at the same time, inventory might be required for products having high service level and then, in this case, it is not considered as a waste. Therefore, it is first necessary to understand what is considered as waste in perspective of the company or rather, in relation to the need of the company (Tersine and Hummingbird, 1995). Furthermore, optimizing the buffers helps in having effective control over the production flow. To summarize, reduction in the production lead time and excess inventories will help in enhancement of delivery performance by delivering products on time to the customers with higher service levels, thereby leading to higher On Time Delivery (OTD) rates.

The following chapters of the literature study explains about the lead time reduction and the ways of having effective control and execution in production systems.

2.4 Lead time reduction

As mentioned earlier, production lead time is one of the most important parameters for delivering products on time. Production lead time refers to the time from when a customer order is taken until it is ready for shipping (Ndubi, et. al., 2016) (Wouters, 1991). Lead time is divided into value added and non value added activities and in most of the companies, the difference between value added time (the actual time spent on the product) and non value added time is very huge. For example, the value added time can be 4 hours and the non value added time goes upto 4 weeks (Hopp, et. al., 1990). Therefore, lead time is an important parameter and reducing it is essential for having a competitive advantage. Furthermore, (Hopp, et. al., 1990) and Wouters (1991), states that lead time reduction helps in improving the quality, reducing inventories, reducing scrap, reducing the changes in production, having frozen horizons i.e. having a fixed schedule for immediate few days, so as to not depend on forecasts and all these lead to several economic benefits.

The need for lead time reduction needs to be defined as well. Mainly because, it could vary from one company to other. It could be that the lead time needs to be reduced to reduce inventory, thereby saving on inventory carrying costs. Another reason could be to reduce the delivery lead time in order to fulfill customer order or gain competitive advantage (Hopp, et. al., 1990).

According to (Hopp, et. al., 1990), lead time is affected by three major aspects. First is the waiting time and queuing time, second is the WIP and finally the variability in the lead time. The waiting time and queuing time are directly proportional to the lead time and therefore, it must be dealt accordingly. Similarly, WIP and lead time are directly proportional for a given throughput. This helps in understanding the causes of excess lead time by identifying places with large inventories. Finally, the variability in lead times need to be considered as it is easy to reduce the average lead time and not keep in mind the former aspect. But in situations when there is high or low lead times, it causes shortage or excess of products or materials, thereby creating unnecessary issues.

(Hopp, et. al., 1990), further states certain general strategies to reduce lead times taking into consideration the above mentioned causes, they are: analyzing the WIP, keeping the products moving, and synchronizing the different production activities.

As mentioned previously, increased WIP leads to increased lead time and that is the reason the WIP needs to be analyzed. But at the same time, keeping stock in buffers might be necessary for avoiding bottlenecks or depending on the need of the company, for example if high service level is needed for a high runner product. This will be explained later in the section 2.5. Once the places with large buffers are identified, it needs to evaluated if those are really needed (Hopp, et. al., 1990). If it is in excess, then steps must be taken to ensure reducing the buffers. Now, the question arises, as to what level it needs to be reduced to or rather what is the optimal level of inventories that needs to be maintained. This will be explained in section 2.6.

(Hopp, et. al., 1990) states, if it is ensured that the products are moving towards the completion of manufacturing, then the lead time and buffers will decrease. The main reason is that, 90%-95% of the time the product is in waiting period. Therefore, improving the production by having new machines or investing time and resources in setup reduction will not be of much help in reducing lead times. Instead, the focus should be on reducing the waiting times. Waiting times can be, waiting for parts or sub assemblies, the queue time of a product. However, (Hopp, et. al., 1990), state that setup time reduction is important for increasing capacity, but if reducing lead time is the main focus, then reducing waiting times is essential. This is also supported by (Wouters, 1991), who states that increasing machine utilization, increases waiting time and queue time, resulting in longer lead time. One of the ways to reduce queue time is to directly control the WIP by using tools such as Kanban or CONWIP systems (Hopp, et. al., 1990). Furthermore, these tools also help in synchronization of production (Hopp, et. al., 1990) and these two concepts will be explained in the further sections.

In a pull system, the material planning, execution and control are not separate functions but rather are initiated based on the consumption of units in the subsequent operations (Jonsson and Mattsson, 2009). This means that the individual control of various functions and departments is not necessary, since all of the above mentioned parameters are integrated at a single point. The main idea here is to create a smooth production flow which is based on the customer demand but at the same time it is kept as simple as possible with fewer inventories and without much communication of information at every process. It differs from the traditional production in the sense that there are no production orders for every department. It is the material planning that directly initiates production (Jonsson and Mattsson, 2009). For example, the material consumed downstream initiates production upstream. Similarly, the order sequence in the upstream process will be matching the replenishment signals from the downstream process. The degree to which this process is possible is dependent on the size of the inventory. The reason is, there are situations where lead times are too long for immediate delivery, setup times are too high, higher batch sizes, ordering costs are high, etc which leads to higher inventory and restricts direct demand delivery (Jonsson and Mattsson, 2009).

It can be seen that even in pull systems, it is not possible to function stockless. The intermediate stock levels are also very essential mainly because, the time for a product to go through from the first operation to the last would be very long if there were no stocks in the middle (Jonsson and Mattsson, 2009). For example, when material consumed at a downstream operation, it initiates production in the preceding operation. Now, there might be a situation where there is no input material from that preceding operation, and the reason might be because of high setup times, higher batch sizes, etc. As this situation can occur anywhere in the flow, it is necessary to have stocks, but at optimal levels. Another reason to have intermediate stock levels is that it balances out the minor variations in the production line between any successive operations (Jonsson and Mattsson, 2009). For this purpose intermediate buffers can be used, as sometimes there cannot be continuous flows between all the processes (Rother and Shook, 2009).

Furthermore, these buffers should be linked to the downstream processes instead of individually scheduling them (Rother and Shook, 2009). Linking them with the downstream processes creates a pull based system, as it will depend on the consumption of the downstream process. Whereas, in a push system, the order are scheduled to the upstream process directly, without considering the consumption of the products in the downstream process.

By using buffers in a pull based system, the upstream production can be controlled from this point and this point is called the pacemaker (Rother and Shook, 2009). In a traditional push based system, the production scheduling of each department is controlled individually and thereby having a greater task of coordinating it. Having only one production control point, in a pull based system, will reduce this need of coordination and it is even more beneficial when there is mix model based production. The pacemaker, therefore, sends signal to the upstream process based on the demand and only then will the production start, thereby creating a pull flow (Rother and Shook, 2009). The downstream process from the pacemaker process needs to be in a continuous flow, up until the finished product (Rother and Shook, 2009).

Although, there is justification for keeping stock, the main idea here is to keep it at a very minimal level by leveling the production, minimizing the setup times and batch sizes as much as possible. Therefore, for a pull system to work, it is first necessary to have a proper planning environment where visibility and control can be established. Furthermore, traditional planning methods can also be implemented in parallel to the pull systems as in some cases it is not possible to fully implement pull systems (Jonsson and Mattsson, 2009).

As explained earlier, for a smooth production flow the preceding operations are initiated based on respective subsequent operations. To keep this running in an efficient way it is, therefore, very essential to have the downstream operations leveled which means that there needs to be necessary production schedules, along with smaller batch sizes and every variant of the items should be scheduled at regular intervals. This creates a smoother flow with leveled production and higher the demand volume, the better it is for the material flow. Determining the demand volume is another essential factor as these pull systems can manage +/- 10 % demand variation (Jonsson and Mattsson, 2009).

2.5 Reorder point

To balance the supply and demand, there can be many planning methods which can be implemented based on the manufacturing environment. It needs to answer two questions i.e. when the orders start and when the delivery will take will place (Jonsson and Mattsson, 2009). One of the methods is reordering point where a comparison method is used to initiate a manufacturing or a procurement order (Jonsson and Mattsson, 2009). The comparison is made between the available stock and a reference level of stock (i.e. the reorder point). If the available stock goes below the reference stock level a manufacturing or procurement order is initiated to replenish the respective quantity of stock. Furthermore, if any planned orders results in quantity of stock going below this reorder point, a replenishment order can be initiated. The reorder point is calculated taking into consideration the lead time required for replenishment of the respective stock. Also, certain levels of safety stocks are calculated, taking into consideration the variations in demand, lead times and any other unpredictable events (Jonsson and Mattsson, 2009).

It might be seem that, since material flows are managed by planning and scheduling, this is a push flow. But at the same time, if the downstream process consumes a unit from the buffer and then the signal is sent to the preceding process, it is a pull flow. Another aspect to look at is whether the planning and control takes place from a central unit or not (Jonsson and Mattsson, 2009). If manufacturing orders are given out to each and every functions/departments it is clearly a push flow. If it is customer order initiated or centrally controlled it is a pull flow. Therefore, the material planning methods cannot be classified as push or a pull flow; it is their way of use and application of it, which makes it a push or a pull flow (Jonsson and Mattsson, 2009).

For example a reorder point may be used to order material, initiated by the subsequent operation after consumption of the same; which makes it a pull environment. Similarly, the planning department can order to fill up stocks, which is needed for future sales; and this makes it a push environment.

The ideal way to calculate reorder point is to add the safety stocks and demand during lead time. The formula used is R.O.P = Safety stock + (D*L) (Jonsson and Mattsson, 2009). The demand during lead time is the units that will be consumed during the replenishment of the stock. This helps to distinguish between the variation of demand that is dependent on lead time or on other uncertain aspects. By collecting the information on demand, consumption, variations, quantities in stock an average value for reorder point can be obtained. Furthermore, this can be used to maintain optimal tied up capital and delivery schedules (Jonsson and Mattsson, 2009). A fixed reorder point can be used if there is some random variation expected with respect to demand and lead times in the future. Similarly, if there is seasonal demand, then the reorder point must be calculated accordingly by adjusting the deviations and safety stock. In this way, the finished goods stock can be maintained using the reorder points.

This is used to efficiently and effectively manage inventory even when the demands and lead times vary, as it provides a structure for how much to order and when to order (Coyle, Bardi and Langley, 2003). Furthermore, the four ways to use reorder point are: fixed quantity with fixed interval, fixed quantity with irregular interval, irregular quantity with fixed interval and irregular quantity with irregular interval. If the demand and the lead time is known then the fixed quantity with fixed interval can be used. If the demand varies and the lead time varies then either the fixed quantity with irregular interval or the irregular quantity with fixed interval is used (Coyle, Bardi and Langley, 2003).

2.6 Safety stock

Determining safety stock is an essential part of calculating reorder point, as explained previously. Companies usually keep it to prevent stock outs and as a buffer against variations in demand. Safety stock optimization, therefore, leads to savings and better inventory turnover. Most of the companies have a perspective of stocks as an added cost, but it should be rather seen as an element that actively contributes towards developing or maintaining specific market through high levels of service. The main objectives of stock management is, therefore, not only reducing inventory related costs, but also, retaining customers and acquiring new market shares through improved service level thereby providing better service and product availability, as per the requirements of the customers (Jonsson and Mattsson, 2009).

Having a better service level, to avoid stock outs and losing sales during a replenishment cycle, means having higher safety stock levels. These higher safety stock levels is considered as a value, as the company needs to provide high service levels to customers (Tersine and Hummingbird, 1995). At the same time it should not be very high that the company loses money on inventory carrying costs, but should have an ideal balance. Therefore, companies have a trade-off between opportunity costs and operation cost, with respect to maintaining the service level (Jonsson and Mattsson, 2009). Reducing inventory frees up money but at the same time the company might lose on customer satisfaction and it is complex to measure on such intangible factors. This also depends on a lot of other factors such as customer sensitivity to stock outs, the risks involved in maintaining high level of stocks such as storage costs, products getting expired, the prices of the products getting lower, etc. Therefore, optimizing stock levels is complex and specific to the type of market environment the company is functioning in (Jonsson and Mattsson, 2009).

One of the approaches to this dilemma is the ABC analysis where the products are classified based on the revenue they generate (Jonsson and Mattsson, 2009). The more essential products, which generate more sales, are assigned higher service level. Therefore depending on the revenues generated the service level is assigned. The top 20% of the products which are of strategic importance to the company are classified as items ‘A’ and they are assigned with a high service level of 96%-98%. The next 20%-30% of the products which are of intermediate importance are classified as items ‘B’ and they are assigned a medium service level of 91%-95%. The last 50%-60% of the products which are of relatively lower importance are classified as items ‘C’ and they are assigned a lower service level of 85%-90% (Jonsson and Mattsson, 2009). Furthermore, if required, the service level for each individual product can be determined, but at the same time the company must have the required technological infrastructure to achieve this aspect. Therefore, for a company to decide on the target service level there is a trade-off between cost of the inventory and cost of the stock outs. The company needs to find a balance between the two and decide in which way to optimize their inventory, keeping in mind the costs involved (Jonsson and Mattsson, 2009).

Based on the consumption pattern of the products, there are two ways of determining safety stocks. The first one is based on manual calculations and estimations and the second one is based on scientific calculations and collecting maximum possible information about the uncertainty (Jonsson and Mattsson, 2009). In manual calculations the results are not aimed at a specific parameter to optimize safety stocks, for example, like service level, inventory carrying costs, stock out costs. It is quite resource consuming in creating such a system and even more complicated when revising the same. For calculating safety stocks using scientific calculations there are various options such as calculating safety stocks based on lead times and safety stocks based on demand.

For safety stock based on lead times, it is calculated as a percentage of demand during lead time (Jonsson and Mattsson, 2009). In this the quantity in the safety stock is determined by the size of the demand and the duration of the lead time. In this way the safety stock can be determined when the demand or the lead time changes. But the main disadvantage is that this method does not take into consideration the variation in demand or the forecast errors. For example, the calculation requires average demand throughout the entire lead time in consideration giving the same safety stock for that entire period. But it might be the case where the demand variation is very high for a particular product and that safety stock calculated for the average demand might not be sufficient or would be too high (Jonsson and Mattsson, 2009).

For safety stock based on demand distributions, the above mentioned demand variations are taken into consideration by using normal distribution (Jonsson and Mattsson, 2009). The normal distribution is defined by a mean value and standard deviation which gives a symmetric distribution. Since these two factors are taken into account, safety stock can be calculated based on demand data, average demand during the lead time and standard deviation of demand during this lead time (Jonsson and Mattsson, 2009). There are possibilities that the lead times can also vary, and similar to demand, the lead time has a normal distribution which can be taken into consideration. Hence, the required safety stock and based on it the required service level can be much better controlled using this method.

To further enhance the reliability on the above method, 'service factor' (Z) is used as a multiplier along with the standard deviation, as shown in the formula below (Constantin, 2016).

$$Safety\ stock = Z * \sqrt{(\frac{LT}{T} * \sigma_D^2) + (\sigma_{LT} * D_{avg})^2}$$

Where,
Z is the service factor
LT is the maximum lead time
D avg is average demand
σ_D is the standard deviation of demand
σ_{LT} is the standard deviation of lead time
T is the total time taken for calculation (1 day)

This is done to calculate the specific required quantity which relates to the desired service level. Constantin (2016) shows in table 1, the relation between the service level in percentage and the corresponding service factor.

It can be seen that it is non linear in nature, which means that, the higher the service level, the safety stock level will get exponentially higher. Therefore, instead of having a fixed service factor for all products, it can be assigned on basis of the ABC analysis of the products as mentioned earlier. For example, if the 'A class items' are assigned to have service level of 96%, then based on table 1, a service factor of 1.75 will be used in the calculations for the safety stock. Once the safety stock is determined, it should be reviewed in regular time intervals to check if it is, what is needed or if any adjustments is required or performing root cause analysis if any problems occur, etc.

Table 2.1: Relation between desired service level and service factor (Constantin, 2016)

Desired service level	Service factor
50%	0.0
60%	0.3
70%	0.5
80%	0.8
85%	1.0
90%	1.3
93%	1.5
95%	1.6
97%	1.9
98%	2.1
99%	2.3
99.90%	3.1

2.7 Kanban systems

As explained in the previous section, the authorization of movement of materials is initiated when the operation, consuming a unit of the material, more or less gives a production signal to the preceding operation. The degree to which this is possible depends on the size of the inventory which is used for various reasons such as lead times are too long for direct delivery, high set up times, ordering costs are too high, etc. This is one of the main reasons that an inventory buffer needs to be kept to cover for these direct needs. These type of methods are called direct call offs methods as, in this material planning method, ordering takes place directly from the consuming operation to the supplying operation which is same as the reorder point system (Jonsson and Mattsson, 2009). Another variant of this reorder point system is called Kanban system, and the physical form of this is called the two bin system. The word 'Kanban' means card or sign in Japanese, which is a method for authorizing movement of materials based on this visual signals (Jonsson and Mattsson, 2009).

In the two bin variant of the reorder point system, as the name suggests, there are two bins. One of which is a bigger bin and the other one is a smaller bin. From the bigger bin, withdrawals of material takes place and from the second bin a replenishment amount is withdrawn which is equal to the corresponding consumption unit from the larger bin plus the safety stock. The consumption from the second bin continues until the quantity is replenished in the first bin. This is again an example of pull system where the downstream consumption of material initiates replenishment order to the upstream process (Jonsson and Mattsson, 2009).

As explained in the previous section, the reorder point is calculated by adding safety stocks and demand during lead time. This lead time is the total lead time and can be split into two, mainly production lead time and moving lead time (Jonsson and Mattsson, 2009). The production lead time is the time taken for the actual manufacturing process on the material such as set up time, changeover time, run time, waiting time, maintenance time, etc. The moving lead time is the time it takes to send and order upstream from the consuming operation and also the time required to physically moving the material from the upstream operation to the downstream operation that initiated the replenishment order. Similarly, production Kanban is a visual signal for a manufacturing unit to start the operation and a move Kanban is a visual signal to move the materials from upstream to downstream replenishment manufacturing unit.

In a pull system, there is high repetitiveness and a specific item is produced and moved around frequently. But it does not mean that there is high volume production (Jonsson and Mattsson, 2009). It might be the case where there are large variants of products produced and some of them are infrequently produced, like in a make to order or assemble to order manufacturing environment. In this case it is very challenging to implement the traditional Kanban system mentioned above; instead a generic Kanban or CONWIP card (explained further in the next section) is issued (Jonsson and Mattsson, 2009). Generic Kanban is the same as the traditional Kanban system, which is used as a visual authorization to start production to the upstream process; but with the only difference being that it does not specify which particular product to produce. Instead it specifies by the product family and not about the exact model or variant in it. The information regarding the specific product, with its corresponding configuration and processes, and the sequence of products, has to be generated and sent out separately, which is based on historical consumption. This can, therefore, work in a mix model production environment. Also, there is a mix of pull and push systems, in the sense that the pull mechanism of Kanban and push mechanism of sending out the product plan is both implemented in this generic Kanban method (Jonsson and Mattsson, 2009).

2.8 CONWIP system

CONWIP stands for constant work in process. A CONWIP system is the same as generic Kanban system wherein the signal for production is sent upstream by the consuming downstream process, without any specifications of the product, but only the product family (Jonsson and Mattsson, 2009). The only difference being that, in a generic Kanban system the upstream process receives order signals from the successive downstream process, whereas in a CONWIP system the last process sends order signals to the very first process in the production flow. As shown in the fig. 1, this process, thus, secures a constant work in process and can handle mixed model variations as well (Jonsson and Mattsson, 2009).

A CONWIP card can be used instead of a Kanban card and the last operation in the process will send it to the first process in the operation for authorization of production (Jonsson and Mattsson, 2009). The CONWIP card needs to be supported with a list of product specifications, configurations and sequence, which is based on the future expected demand compared to the historical consumption used in the case of Kanban systems (Jonsson and Mattsson, 2009). Now, the sequence of

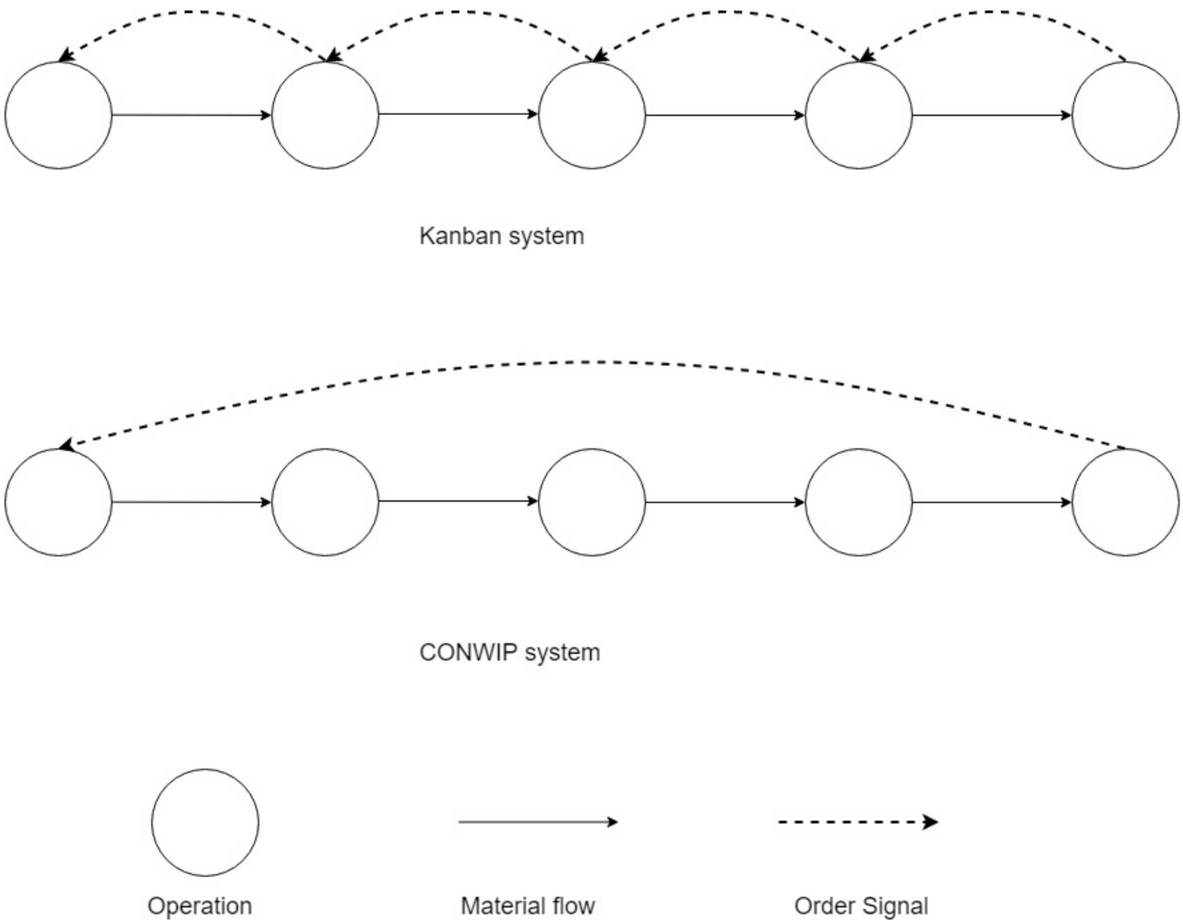

Figure 2.2: Kanban system vs CONWIP system (Jonsson and Mattsson, 2009)

operations is decided on the basis of first come first served and when the CONWIP card is received at the first operation, it is produced and pushed through the next process and so on. Also, in this system it allows to have mix model variations to be included in the processes in between as it secures a constant work in process. The main reason is that the signal is received from the last operations to the first, there can be various individual operations included in between; which is the main difference between a CONWIP and Kanban system (Jonsson and Mattsson, 2009). The only aspect to consider in this case is the sequence of the received order should be followed, even if there are various individual operations, as the items are pushed through from first operation till the end.

2.9 Value stream mapping

Value stream is mapping of all the processes, irrespective of whether it's value adding or non value adding (Rother and Shook, 2009). It relates to the flow of products from raw material stage to the final customer, based on customer demand (Abdulmalek and Rajgopal, 2007). Rother and Shook (2009), further mentions the importance of creating a value stream map as it is an essential tool which helps to visualize the various processes in the production system, for example, casting, sand blasting, machining, assembly, etc. The path of a product is followed from the start till the end i.e. from the raw material stage to the finished product reaching the customer, recording all the value adding activities and the non value adding activities (Liker and Hoseus, 2007). As mentioned by Rother and Shook (2009), if the components for the chosen product comes from many sources, the component which is having the maximum lead time should be taken for value stream mapping first. Furthermore, it helps in decision making, in the sense that, it helps in visualizing the effects of a decision over other processes connected to it. Having a broad view like this, helps to avoid cherry pick situations that seem right at a particular moment.

Within the production flow, apart from the material flows explained above, the information flow is also of equal importance. The linkage between the two can also be visualized through a value stream map. As the name suggests, the information flow tells each process as to what to do next. The main idea is to have a flow of information such that one process makes exactly what is needed by the next one, nothing more and nothing less (Rother and Shook, 2009).

The initial step is to define a product family for the value stream mapping (Rother and Shook, 2009). This is essential as otherwise it would be highly complicated and difficult to map the flows of all product families of a manufacturing plant. It is also necessary from the customer point of view, as they care only about certain products and not the entire range of products that is manufactured in a plant. A product family is a group of products going through similar processes and machine equipments in the downstream processes. Establishing a product family from the upstream processes might lead to grouping of many products, for example, they might be produced in batch mode in fabrication, casting, or similar processes. A product family must be clearly selected, the different finished part numbers in that selected family must be defined, the quantity required by the customer, the frequency of the requirement, etc should all be decided in the early stages of value stream mapping. (Rother and Shook, 2009)

The next step is to continuously improve the identified issues in the value stream map. This process of continuous improvements is known as Kaizen. There are essentially two types that is flow level Kaizen and process level Kaizen (Rother and Shook, 2009). Flow level Kaizen refers to the continuous improvements done for the entire value stream, trying to create value from the flow. Process level Kaizens refer to the continuous improvements done at the shop floor level by eliminating or reducing waste. Flow level Kaizens are usually done at a senior management level as it focuses more on material and information flow. Process level Kaizens are done at shop floor level which means more focus on processes and people.

As companies are usually organized in terms of functions and departments, it is difficult for a person from any department to focus on the entire value stream. This is mainly because; they tend to look more into their own functions for identifying improvements and thereby leading to process level Kaizens. This is good in a way, but looking at a bigger picture, for the development and improvement of the entire flow, one should focus more on flow level Kaizen (Rother and Shook, 2009).

3

Methodology

This section contains information about the methodology by which this master thesis was performed. This section includes a short description about the strategy, data collection for the value stream map and finally about the study and analysis.

3.1 Overall research strategy

As shown in fig. 3.1 the thesis study was followed in 7 stages. As mentioned earlier, the current problem of the company was to meet the on time delivery (OTD) requirements. Once the focus for the study was decided as exploring solutions for meeting OTD requirements, the related background study was done. Field observations and collecting information, through various literatures, was done to understand the basic factors related to OTD. For the literature framework, more specific articles related to OTD and factors affecting OTD were collected. In relation to the literature, the required qualitative and quantitative data was collected. Using the literature and the data available the current state map was drawn. This map was analyzed and redrawn a few times for the future state map. Based on the future state, recommendations related to system level and other improvements were proposed to the company, to improve OTD.

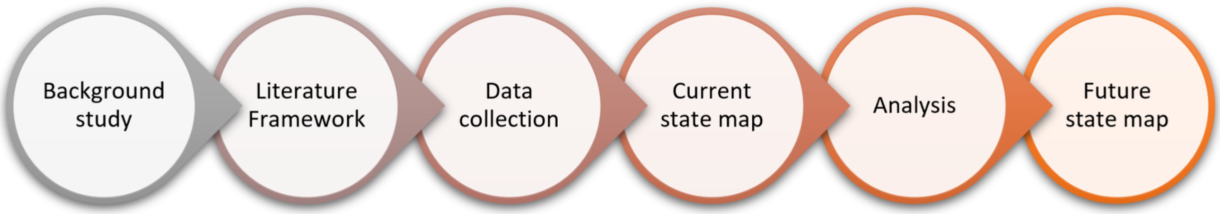

Figure 3.1: Overall research strategy for the thesis project

3.2 Background study

As mentioned earlier, the background study was done to understand the issues related to OTD. In this, the shop floor processes of various departments in the manufacturing plant were observed. The observations were done directly by the authors while going through the processes and taking down notes. Furthermore, information was also collected by interacting with the shop floor team leaders, supervisors and workers. The main aim here was to understand the process flow. The next step was to get to know about the information flow and the ways in which the production was controlled. This was done by having some initial unstructured interviews with the managers and department heads. Throughout this process, various literature relating to OTD were referred to and accordingly the background study was carried out. Once the process flow and the information flow was known, the next step was to have in depth literature study.

3.3 Literature study

The main purpose of the literature study was to provide an academic framework and base for the thesis project. Continuing from the background study, literature relating to factors affecting OTD were taken into consideration. It was found that literature relating to the improvement of On time delivery (OTD) performance, for in-house production, was scarce. However, from the available literature, the stakeholders involved and from the academic knowledge of the authors, the scope for literature study was narrowed down to lead time decrements and optimization of buffers. The motivations for selecting these two factors were explained previously in the literature framework. The next step was to find literature relating to lead time and buffers and the way in which it can improve OTD. Furthermore, literature regarding control and execution of the production system was included as it further supports improvement of OTD. These articles were collected from various databases and sources that include Science direct, Web of science,IEEE, Scopus and chalmers library.

3.4 Data collection and validation

All the relevant data for the thesis work was collected from the company's ERP (enterprise resource planning) system, through interviews and also through direct observations. The data collection is divided into two parts, that is collection of qualitative data and the collection of quantitative data.

3.4.1 Qualitative data

The main aim of the qualitative data collection was to collect all relevant data and valid information about the problems in the production flow of product SK, in relation to OTD. Qualitative data was collected via 6 interviews from the employees at the company. Interview time was one hour per interview and the questionnaires were formulated with the help of the literature framework. Interviews were conducted with the supply planners, industrial engineers, team leaders and with the procurement head of the company. The motivation for selecting supply planners was that they have direct influence over the control and execution of information flow of product SK. They are responsible for placing the orders, taking into consideration the capacity and demand. The reason to interview industrial engineers was that they are responsible for the production flow of SK. Furthermore, the team leaders were also interviewed as they work closely with the production flow. The rubber and plastic components are procured from the external suppliers, the authors interviewed the procurement head in order to understand the impact of the supplier lead time on the production flow.

All the interviews were semi structured and the questionnaires were sent to the respective people well before the interview. The focus of these interviews was to collect as much information as possible regarding the production and information flow of product SK. The aim was to narrow down and to find the factors affecting OTD through these interviews. The questionnaires are shown in the appendix A.

Since all the interviews were semi structured, the interviewees explained about the problems and its consequences in their perspective. But at the same time, the interviews gave the authors insights about the root cause of the problem which in turn helped us a lot in the analysis part.

3.4.2 Quantitative data

The main idea behind the collection of quantitative data is to collect all the empirical data pertaining to the production flow of product SK. The current state map should be a snapshot of the existing production system (Rother and Shook, 2009). The data is collected by walking along the production flow of product SK. The data relating to few inventory levels is collected as an aggregate of all the snapshots taken from ERP system for one particular year (2017). Snap shots for those inventories are based on the average time spent by the products in that particular inventory. Few empirical data relating to the forecast and the past sales data are collected from the planning department.

3.4.3 Data validation

Sometimes the data available in the ERP systems might not be up to date, so manual collection and verification was necessary (Rother and Shook, 2009). After collecting all the required quantitative data of the current state value stream map, we validated the data by checking with the people who are involved in the production of SK. This validation ensures the reliability of the data collected through the field observation and from the ERP systems.

3.5 Current state map

Plant level Value stream mapping was done for product SK from the raw material to the final warehouse. The authors used value stream for visualizing the current production and also to visualize the future state with the proposed improvements. Data for the current state map includes the data pertaining to both the information and material flow (Rother and Shook, 2009).

Current state map was drawn with the help of the manually collected qualitative, quantitative data and from the ERP system. Usually when the components for the selected product comes from multiple ways, the flow which comprises of maximum lead time is taken into account for drawing the value stream mapping and analysis (Rother and Shook, 2009). For product SK, since the body part is having maximum lead time, it is considered for drawing the current state map. The data for current state map is collected by walking through the production line and by asking questions to the people who are involved in the production (Rother and Shook, 2009). But since it is a batch production, the production is not continuous and the production for product SK is performed on different days, according to the production schedule, in different departments. Therefore, the data was collected on different days.

The data collection for the current state map was collected from the warehouse to the starting point of the production flow. During data collection phase, current state maps were drawn in an A3 paper by hand first. Then after collecting all the empirical data for the current state map, it was validated with the people in the production flow. Then again the map was further analyzed for improvements and the above mentioned procedure was repeated, Finally after number of iterative maps, the final current state map was digitized.

3.6 Approach for Analysis

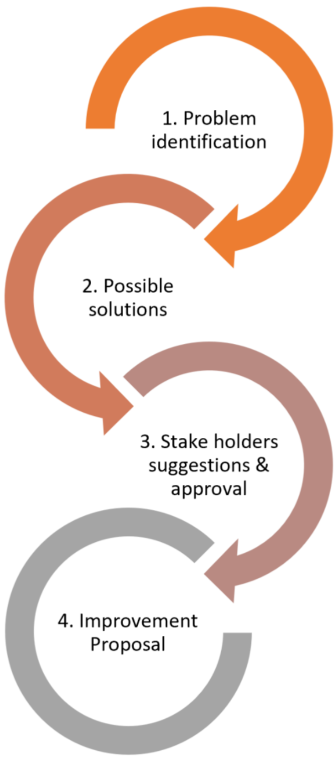

Figure 3.2: Approach used for analysis

Rother and Shook (2009) state that the value stream is done to identify and eliminate sources of waste by implementing a future state value stream. Rother and Shook (2009) further state that one of the ways to draw the future state is through a list of questions mentioned in section 3.7. Therefore, after drawing the current state map, the approach for analyzing the current state map was to follow the steps as shown in fig. 3.2. The problems were identified using the future state questions, which will be explained in the next section. Once the problems were identified, the possible related solutions were found using literature. These solutions were then discussed with the stakeholders for their suggestions and approval. The focus was also to consider the feasibility of the solution in relation to OTD and as per the availability of the resources. Once a solution was decided, the entire process was repeated and then the final future state map was drawn and digitized.

3.7 Future state map

Future state map is drawn with the aim of eliminating the wastes and also to produce according to the customer requirements in future (Rother and Shook, 2009). Future state map was drawn after the analysis of the current state with the scientific data collected from the literature study. Analysis was done with the aim of producing product SK according to the customer demand and also to deliver it on time by eliminating the wastes such as excess lead time and excess inventories in the production flow of SK. Future state map was drawn by consulting with a team of Industrial engineers, supply chain planners and the lean manager and also by answering the following questions from Rother and Shook (2009). The procedure followed for drawing the future state map is described in the previous section 3.6. The analysis of the following questions is explained in section 5.2.

1. **What is the real customer demand?**
   This question is really important for the company to manufacture according to customer demand. Producing to real demand within the available time helps in eliminating most of the wastes in the production. Knowing the present demand and altering the production rate accordingly ensures on time delivery and reliability of the production flow.

2. **Will the produced goods be delivered directly to the customer or produced to final warehouse? From where the customer pulls the finished goods?**
   Many factors needs to be considered before answering this question. However company's on time delivery strategy is one among the main factor to be considered. The other factors such as demand variation, ability to react to the demand and the production lead time are need to be considered while answering this question.

3. **Where can the continuous production flow be implemented?**
This question is about having the continuous production flow without buffers in between the processes. But as mentioned earlier, if buffers are needed, then it should be optimized so as to have continuous production flow. The production rate of different processes and the layout needs to considered as well. Order replenishment systems and the order releasing and the receiving points, should also be considered.

4. **Where can the supermarkets and buffers can be placed in the flow?**
This question is about the need for having the supermarkets and buffers in the production flow. Placing the supermarket in the production flow helps in regulating the complete flow downstream. Factors such as lead time, ability to deliver it on time, delivery policies, safety stock and reorder strategies needs to be decided while answering this question.

5. **Where should the pacemaker be placed to control the production flow?**
This question describes about having the control point in the production with which the production control will place the order based on the current demand. The order for the upstream processes will be placed from the pacemaker process. Many factors such as type of production (batch, line etc.), ability of the production system to reflect to the demand and traceability needs to be considered. The answer for this question also explains about the level of inventory control and the safety stocks needed as the demand is seasonal.

6. **What are the process improvements needed?**
This question is about the process improvements that are needed for implementing the future state map. Answer for this question justifies the feasibility of achieving the future state and also allows the value stream team of the company to make implementation plans.

Number of iterations for improvements, were done in the current state map to create the future state map, and for which the above process was followed. For example, when a future state map was drawn, the improvements were discussed with the team in terms of its feasibility and practical implications. The feedback from the team was noted down and was used to create a new future state map. Similarly, the future state map in this report has been finalized by the continuous improvements and feedback from the team.

4 Current production

This section contains information about the current production state of product SK. This section includes the brief explanation about the product itself and the current production and information flow along with the current state map.

The case company started to implement pull systems for material replenishment in order to produce to the customer demand. Kanban is suitable with only smaller fluctuations in demand (Jonsson and Mattsson, 2009). Since the demand and the production lead time are fluctuating, the company needs its production system to react to the customer demands quickly in order to ensure the higher on time delivery rates. For implementing the pull system, they started using kanban cards between the production processes. However, because of the unpredictable lead times and the lack of frozen horizon for production orders, using kanban cards for material replenishment did not give proper results in the initial testing stage itself. One another reason for that is the lack of modern electronic tools for material replenishment and traceability. Currently, the material replenishment is done by 3 planners, who have to, sometimes, physically go to the shop floor, to check the material in the inventory. They have to check in the ERP system as well and verify if the data matches with what is actually available at the shop floor. Since the departments are not connected to each other, the departments behave as isolated islands resulting in piling up of inventory in many places.

4.1 Current production flow

As mentioned earlier, product SK comprises of more than 30 components which comes from three different sources. All the metal parts are manufactured in-house, whereas the rubber and the plastic components are procured directly from external suppliers and supplied to the various parts of the production flow by the internal logistics department. The metal parts for product SK comes from two different sources.

The body part of SK which has the maximum production lead time is die casted in-house in the facility at Ljung. All other metal parts are manufactured in the bar machining area. The parts for the bar machining area are manufactured by machining bars which are procured from the suppliers. The parts from the bar machining area are sent to the 4 sub assembly stations before being used in the final assembly. The parts from the bar machining area are manufactured in large numbers, in a batch size of approximately 12000. This is mainly because of the large setup and changeover times of the machines at the bar machining facility. Another reason for such huge batch size is that the components from bar machining area are relatively small and the cost for storing such small parts are negligible when comparing to the body part.

If the components for the chosen product comes from many sources, the component which is having the maximum lead time should be taken for current stream value stream mapping (Rother and Shook, 2009). The body part for the product SK has the maximum production lead time, so the production flow of body part is followed and the value stream for the body part is drawn.

Figure 4.1 shows the process flow map followed by the body part. The process flow of Body part of product SK starts in the foundry where it is been die casted and sent to the sand blasting process. The simplified layout of the path travelled by the body part is shown in fig. 4.2. The sand blasting machine is also located in the foundry area. After sand blasting the casted body parts are sent to either the Brother machines or the Riello based on the planners decision and machine availability. The Riello machine has a longer lead time, compared to the Brother machines, and reasons for that is explained later. After machining, either from the Riello or the brother machine, the part is washed as shown by process 'washing 2'. After washing, the machined body part is stored near the final assembly until the next order for final assembly of product SK is placed. In the final assembly the body part is assembled with the other parts and the final finished product SK is stored in the warehouse.

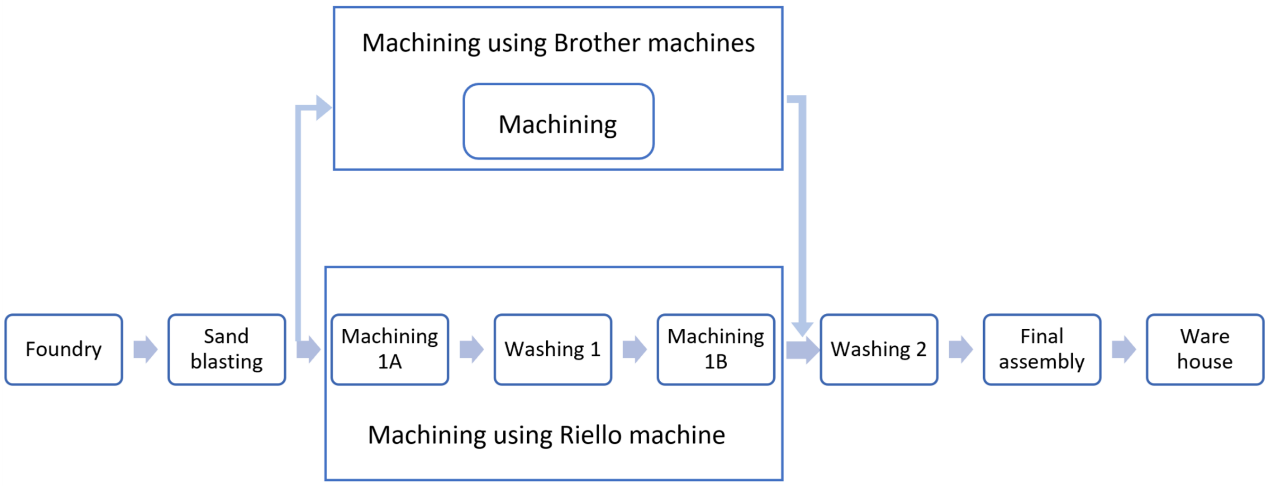

Figure 4.1: Process flow map for product SK

As shown in the current state map, in figure 4.3, the production flow of the body part starts from die casting, in machine number 15. The molten metal is fed into the casting machine with the help of the forklifts from the melting furnace when it

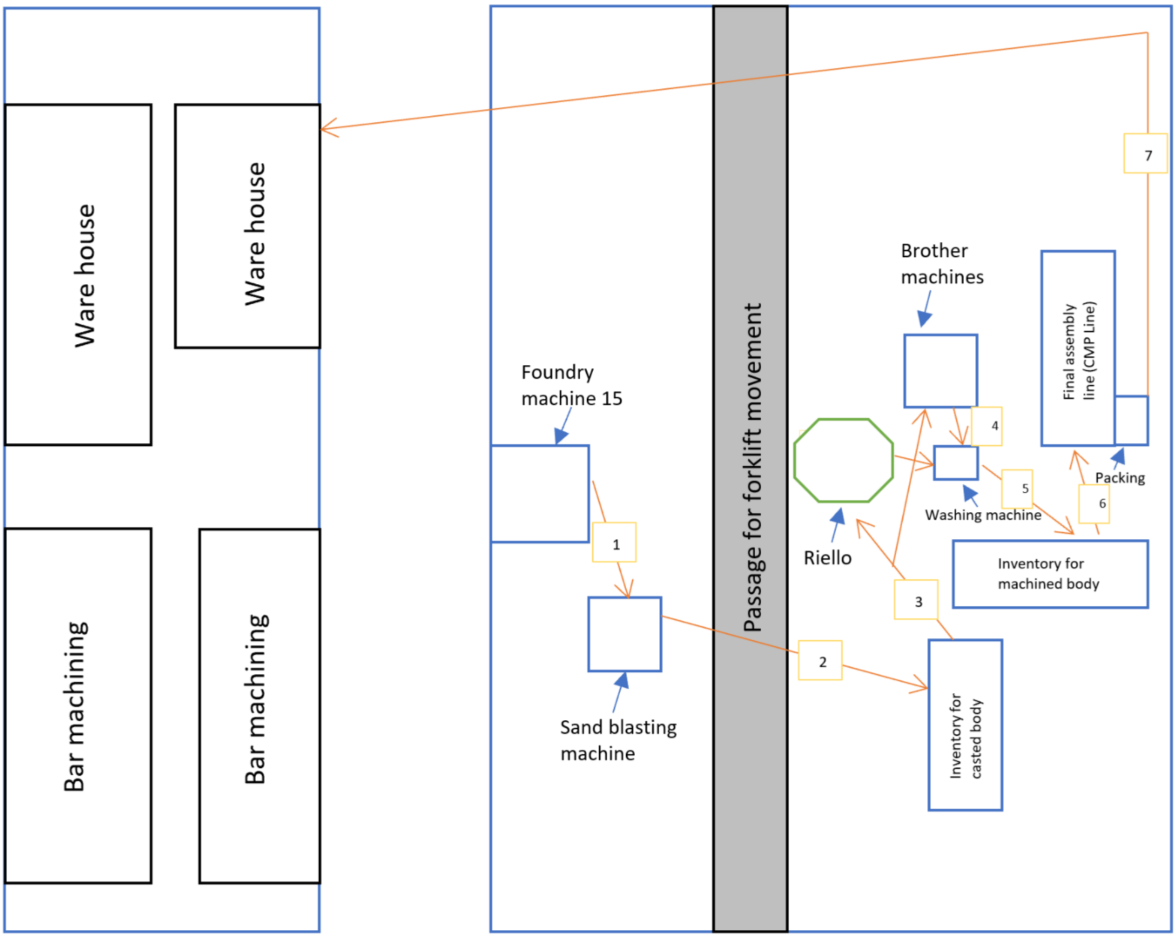

Figure 4.2: Layout of the production system

is needed. This machine is dedicated for the product family AF. However, during seasons of high demand, few varieties of AF will be casted in machine number 24 for satisfying the demand. However as far as the product SK is considered it has been casted in machine number 15. The quality of the product SK is very good compared to the other variants of AF. The casting machines are running all the three shifts for satisfying the demand.
After die casting, the products are collected in the pallet and it is sent to the sand blasting process in a batch of 600 products. The sand blasting machine is also located inside the foundry department. Even Though the setup time and the cycle times are relatively small, since the sand blasting machine is not dedicated for AF family, the batches have to wait in the queue for more than half a day to get sand blasted.

After sandblasting process the parts are sent out of the foundry and stored in the inventory before the machining process. From the inventory it is routed to two machines that is to the Riello or to the brother machines based on the availability.

The reason for this is the availability of the Riello. Even though the Riello is really fast, it is used by more than 70 product varieties. One more reason is the complexity of the machining process steps. In the Riello, the machining is done in two steps, that is operation 30 and operation 50. Once the casted body is sent into the Riello, operation 30 is carried out and after that a batch of 200 is collected and washed in the washing machine near the Riello machine and it is stored temporarily near the Riello machine till the complete batch is machined and washed in the washing machine. Then the entire batch is sent again to Riello and the operation 50 is carried out and the products are washed again and stored in the supermarket before final assembly. Even though the machining operation in Riello is really fast, as two operations are carried out in the same machine, the parts after finishing the operation 30 have to wait for approximately 1.3 days for carrying out its finishing operation that is operation 50.

The Brother machines only need one operation and the finished products are just washed once. One of the major drawback was the high cycle time. The capacity of the brother machines is approximately 32 products per hour whereas Riello is able to machine nearly 200 products per hour but it has a waiting time of 1.3 days between its two operations. Recently, Industrial engineers at the company have worked on the improvement of cycle time of the Brother machines and it is now in the testing phase. Once the change has been implemented completely, the new capacity of the machines will be 60 products per hour with a set up time of 2 hours. The engineers claim that, after the implementation of the improvements, the Brother machines can accommodate all the product variants of AF to be machined in brother machines without being machined in the Riello. Machined parts from both the Riello and the Brother machines, are washed and randomly checked for quality and stored in the inventory before the final assembly. Since the quality for product SK is really good, it is stored directly in the inventory before final assembly. For the other product variants of AF, its been sent to the visual inspection area and collected in the supermarket before final assembly.

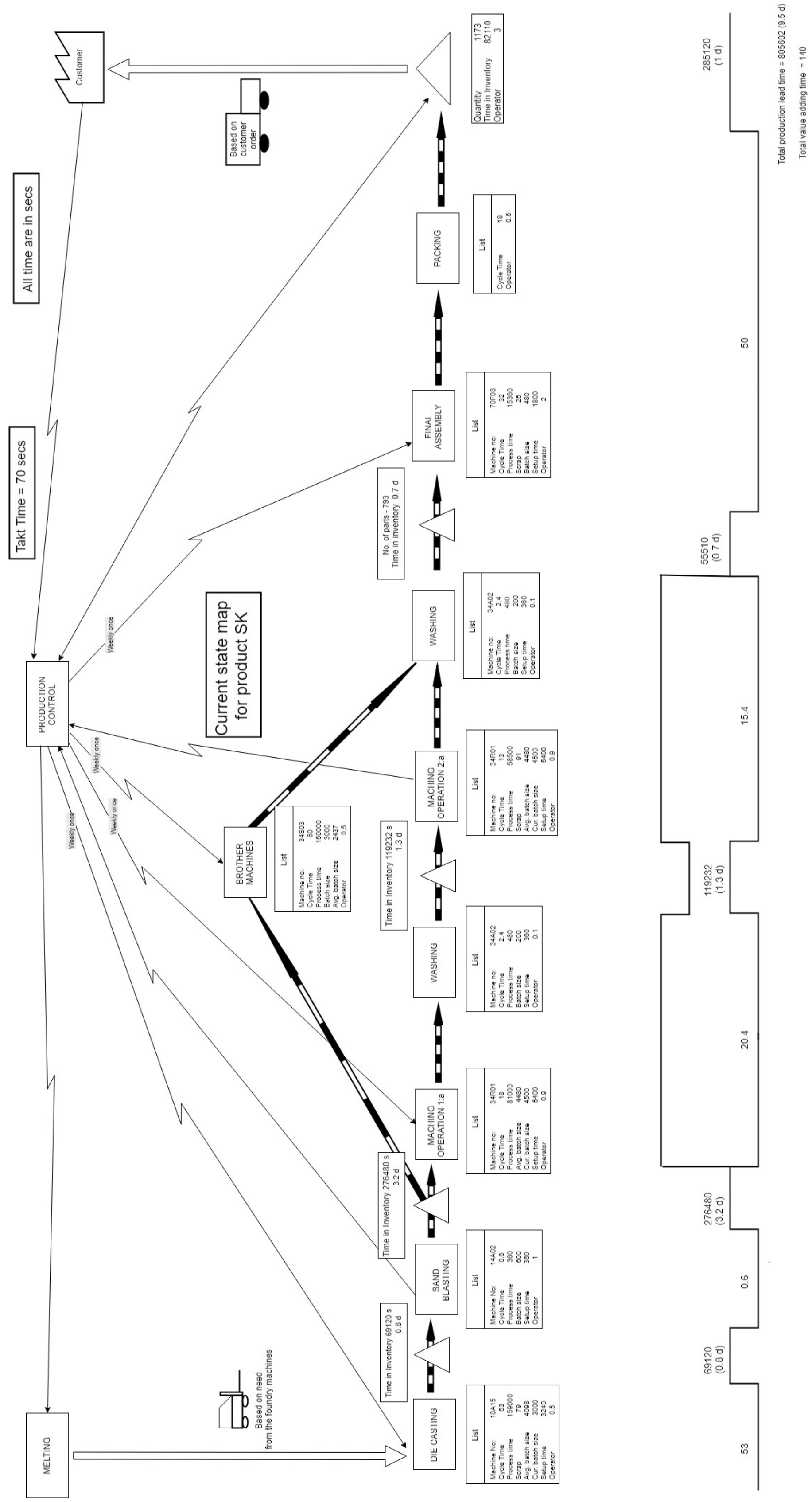

Figure 4.3: Current state value stream map of product SK

After machining and washing, the products are consumed in the final assembly whenever it is needed. Since the pallet in the warehouse can accommodate only 480 parts per pallet, the batch size in the final assembly is 480. The assembly line is automatic expect for the first station, which needs human resource for feeding the valves into the assembly line and also for inserting few parts into the body initially before passing to the assembly station 2. After finishing the assembly, the valves are tested and laser marked automatically. After laser marking, the valves are sent to the packing station. The faulty valves in the testing are collected separately and are repaired near the assembly station manually. The valves which have good quality are packed by the packing operator and sent to the final warehouse through the automatic conveyors. The packed valves are collected at the receiving station in the warehouse, where they are scanned for feeding the information in the ERP system and then stored in the required place in the warehouse. This helps in easy retrieval of valves when the customer order is placed.

4.2 Current information flow

Currently all the processes in the company are operating as isolated islands. There are three planners who decide the amount of parts to be produced under each department. The production orders are sent to the corresponding departments every week. Limited amount of time is considered as a frozen horizon and the production orders are changed in the last minute before final production because of many reasons. The information is sent directly to the department heads and also to the team leads by emails and by informing them via phone calls. The planners check the inventory information via ERP systems. Even though the ERP systems are updated correctly there is still the prevalence of mismatch between the inventory values in the ERP system and the physical presence. The consequences include both the waiting times and also over production resulting in inventories in many places. The information flow is shown in the current state map (figure 4.3).

As mentioned before, there are three planners involved in scheduling the processes. One planner is responsible for the production scheduling of die casting, sand blasting and machining processes. The second planner is responsible for the production scheduling of sub assembly and the final assembly and the third planner is responsible for bar machining area. All the planners place the production orders to respective departments with the help of the forecast from the sales and operation plans from the top management. They also keep the track of the inventories in their individual departments separately. Currently, the Kanban cards for the production are controlled by the respective planners and there is a prevalence of mismatch between the production schedule and the quantity ordered from kanban. The production is carried out on the basis of the sales and operation plans and the planners release the kanban cards accordingly.

The traceability is one of the major issues in the flow. There is one single production order from the foundry till the final machining process. The production orders are updated in the ERP system only when it is finished. Since the process operations are based on the different production control planners, it gives the possibility for traceability issues, which is explained in the following sections.

5
Analysis

This section of the report explains the analysis of the current production of product SK along with the future state map.

5.1 Current state map

Efficient production flow can be achieved by improving the throughput time (Gabriel et. al. 1991). Excess inventory in the production is one major contributor for long lead times (Rother and Shook, 2009). The current state map shown in figure 4.3 clearly visualizes the amount of time spent on each process and the inventory in between the processes. The average production lead time or the throughput time is 9.5 days. The production flow starts from the die casting, ends in the final warehouse and after that the products are shipped to various customers based on their need.

Even though the production lead time is more than a week, the value added time for the product is only 140 seconds. The major part of the production lead time is from the inventories in various part of the production flow of SK. From the current state map, as shown in figure. 4.3, there are 5 major inventories in the production flow which includes a buffer between die casting and sand blasting (0.8 day), between sand blasting and both the machining processes (3.2 days), between the two operation step when the machining is done in Riello (1.3 days) , between the washing and final assembly (0.7 days) and finally finished product inventory (1 day). Table 5.1 Shows the details about the value added time and the time spent in the inventory.

Table 5.1: Values for the current state production

Total time	Value added time	number of buffer locations	Time spent in buffers
9.5 days	140 seconds	5	9.5 days

The maximum quantity is in between the sandblasting and the machining process. From this buffer, casted and sandblasted body parts are sent to both the Brother and the Riello machines based on the availability. Currently, machining the body of SK in the Riello takes longer time in the flow since it has two separate operations that is done in the same machine. The parts which have finished the first operation are kept in the inventory for approximately 1.3 days and later on it is sent for the second machining operation. Even though the cycle time for both the machining operations and the washing operations are very low, because of the waiting time of 1.3 days, it makes it lengthy. Whereas, since more than 70 product variants are machined in the Riello machine, availability for machining the product SK is also a main reason for the inventory of around 3.2 days before the machining process.

On the other hand, the Brother machines are in the testing stage for the updated double chuck mechanism, to hold and machine two products at a time. This is another reason for the inventory of 3.2 days after the sand blasting process. The industrial engineers at the company explained that after the implementation of the new improvement, the brother machine will be able handle all the products of AF and it will remain as a dedicated machine for the AF product family. One main advantage of the Brother machine is that all the machining operations are done in a single step. This helps in eliminating the waiting time, as compared to the Riello.

After the machining and washing, the machined body parts lie in the the inventory for approximately 0.7 days and this is because of the production planning made for the final assembly.

5.2 Future state map

As mentioned earlier in the problem definition, currently the on time delivery for the product SK varies from 65% to 93% with the average of 84% for the past year. The main aim while formulating the future state map was achieving on time delivery rate of 96% by reducing production lead time and by optimizing the inventories in the flow. This part of the report answers the questions mentioned in the methodology (Section 3.7). This part of the report also examines the other factors relating to feasibility issues before the future state is being proposed. The demand for the product family AF which passes through the same production flow is 260260 for this year. The available production time is 100 hours per week as most of the processes are running 3 shifts per day, the takt time is 70 seconds per product. However, the yearly demand for the product SK is around 87500 and the average daily demand for the product SK is 350 per day as the total number of working days for a year in the company is 250.

As mentioned in the current production (section 4), since the company's delivery strategy is make to stock, the products are stored in the final warehouse and then supplied to the customers in various parts of the Nordic countries, Germany and Poland. Even though the average daily demand for the product SK is 350, the standard deviation of demand per day is 84. So, during high seasons, the company has a demand of approximately 436 products per day and on the other hand in the low seasons the demand for the product falls to 266 products per day. So in order to supply during high seasons, the company is following the make to stock, customer order decoupling strategy. Wouters (1991), states that the reduction in the lead time will have positive impact on the delivery lead time. So reducing the lead time is very much essential for achieving higher on time delivery rates.

According to (Rother and Shook, 2009), inventories should be placed in the production flow for the following reasons : a place where the need for the upstream process to operate in the batch mode, difference in cycle time between the processes in the value stream and the uncertainties in the lead time. Based on the steps explained in section 3.7, in the future state value stream map of product SK, the inventory is placed in two places. This is mainly because of the batch production processes and also uncertainties in the lead time. New buffer placements are shown in the future state map in figure 5.1.

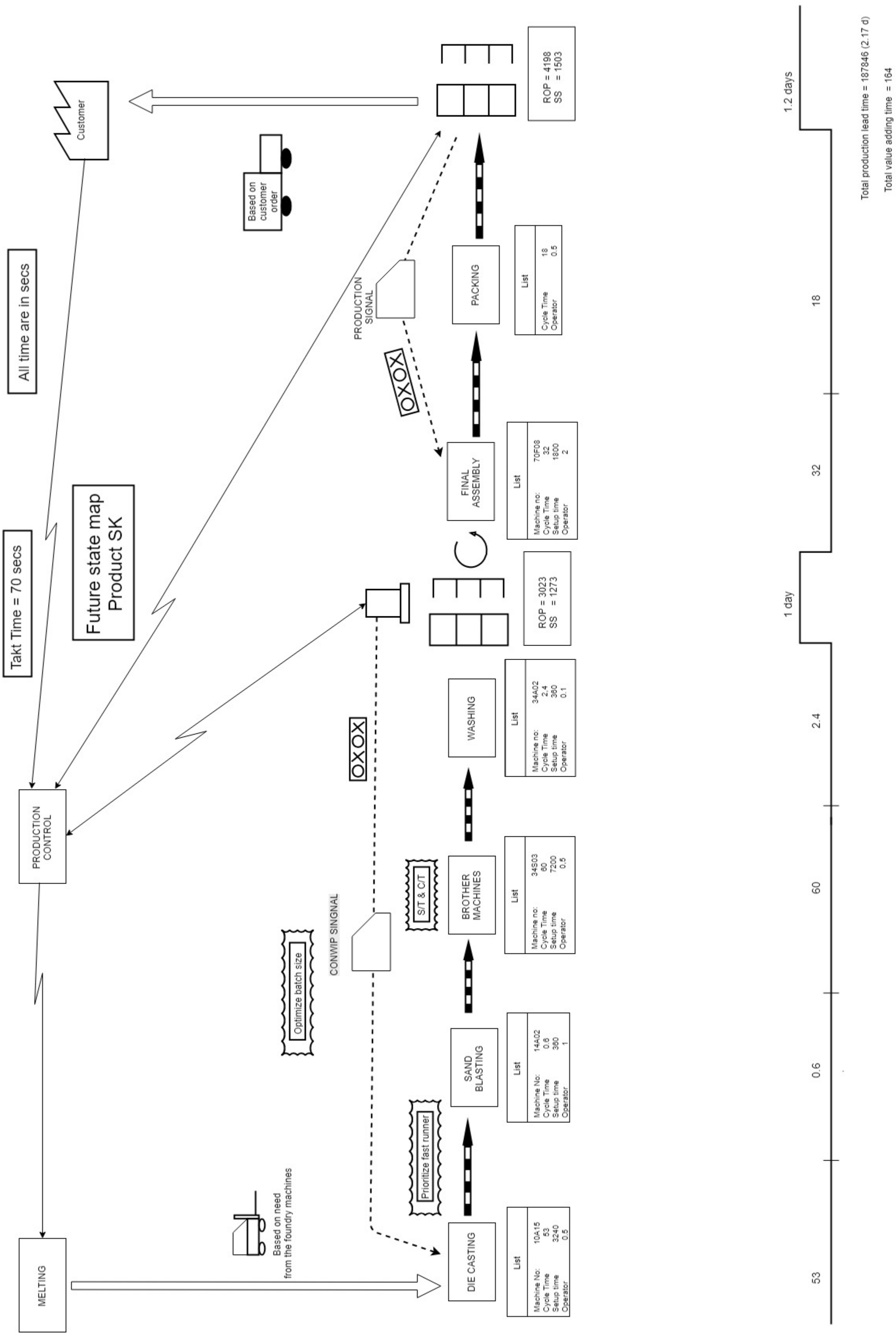

Figure 5.1: Future state map

Coyle, et. al., 2003, argue that for the company with both demand and lead time variations, reorder point system with fixed quantity and variable time is the best suited material replenishment system over other types like Kanban. Constantin (2016), states that having optimized safety stock and inventory levels is essential for achieving higher delivery rates with low tied up capital. Therefore, having unnecessary inventory will lead to poor delivery performance. On the other hand, many companies have higher safety stocks for achieving higher service levels to the customers. However, optimization of safety stocks helps in achieving high service levels and having low tied up capital as well (Constantin, 2016). So in the future state map, safety stock is placed in both the buffers in the flow. This safety stock is to provide higher service levels for the delivery.

Safety stock at the specified service levels can be calculated efficiently with the help of the standard deviation (Constantin, 2016). According to Constantin (2016), since both the lead time and the demand have uncertainties, formula used for calculating the safety stock is

$$Safety\ stock = Z * \sqrt{(\frac{LT}{T} * \sigma_D^2) + (\sigma_{LT} * D_{avg})^2}$$

Where,
Z is the service factor
LT is the maximum lead time
D avg is average demand
σ_D is the standard deviation of demand
σ_{LT} is the standard deviation of lead time
T is the total time taken for calculation (1 day)

Constantin (2016), states that the optimum service level for the fast runners should be 96-98%. Here for calculating the safety stock, in both the places, the service level, as required by the management is 96%. The safety stock in the buffer before final assembly is 1273 products and in the final warehouse is 1502 products. Table 5.3 shows the numbers used for calculating the above mentioned safety stock values.

Table 5.2: Values used for calculating safety stock

Terms in formula	**Supermarket before final assembly**	**Warehouse**
LT - maximum lead time till that point	5 days	7.7 days
D avg - average demand	350 / day	350 / day
σ_D- standard deviation of demand	350 / day	84 products / day
σ_{LT} - standard deviation of lead time	2.0	2.4
T - total time for calculation	1 day	1 day

Reorder point (R.O.P) is the sum of the safety stock and the lead time demand, whereas the lead time demand is the product of the demand per unit time and the average lead time (Jonsson and Mattsson, 2009).

R.O.P = Safety stock + (D*L) Where,
D is the demand per unit time
L is the lead time

The reorder points for warehouse is 4198 and the reorder point before final assembly is 3023. Table 5.3 shows the reorder point values in the two buffers.

Table 5.3: Safety stock and reorder point values

	Lead time in demand	**Safety stock**	**Reorder point**
Warehouse	2695	1503	4198
Before final assembly	1750	1273	3023

Rother and Shook (2009), argue that placement of pacemaker determines the level of capacity changes in the upstream processes and, also, after the pacemaker, all the downstream processes, should be continuous. Therefore, in the future state map, the pacemaker is placed before the final assembly. The pacemaker controls the upstream processes starting from the die casting process. Once the inventory at the pacemaker falls below the reorder point, it sends a signal to die casting process. After die casting, the products are pushed in the subsequent downstream processes i.e. through sand blasting, machining, washing and finally to the inventory at the pacemaker. Constant work in process (CONWIP) ensures the constant workload in the process in between and also it allows the production flow for a better production mix the CONWIP loop (Jonsson and Mattsson, 2009). Since the AF product family has to be produced in the same machines, having CONWIP with reorder point system will hold good for IMI. In the same way if the inventory in the final warehouse runs below the reorder point, the products are ordered from the final assembly. Final assembly pulls the required amount of parts from the supermarket before the final assembly. This is shown in the future state map in the figure 5.1. The proposed total production lead time in the future state map is around 2.17 days and with a total safety stock of 2776 products. With this safety stock and with the average daily demand of 350 products, the company can sustain up to 7.5 days with only the final assembly alone. Table 5.4 shows the values of the proposed future state map.

Table 5.4: Values for proposed future state map

Total time	**Value added time**	**Number of buffer locations**	**Time spent in buffer**
2.17 days	164 secs	2	2.17 days

However, the total production lead time is based on the safety stock and value added time. The products which are present in the super markets except the safety stock is not taken into consideration as it varies with time in the production. Even after considering that, both the buffers contains parts upto the reorder point level (total 7221 products), the throughput time is around 5.8 days which is lower than the current production lead time of 9.5 days.

The total value adding time is 164 seconds, this slight increase is because of the usage of brother machines for the above mentioned reasons. However industrial engineers at the company are continuously working for reducing the cycle time and set-up time further.

6
Recommendations for the company

This section contains the recommendations for the company to achieve the proposed future state. The first subsection explains about the process level improvements needed for the implementation of the proposed future state. The following subsection describes about the system level improvement suggestions.

6.1 Improvements for implementation of the proposed future state

For the implementation of the proposed future state and also for further tuning of the production flow of product SK, it calls for several process level improvements. After the analysis of the current state the authors came up with the suggestions for the future improvements. The improvements include:

1. Introduction of pacemaker and CONWIP loops along with fixed quantity irregular interval reorder point systems in the production flow of product SK, as mentioned in section 5.1. The quantity is fixed and the time is variable in the sense that, if the quantity in the buffer falls below reorder point, only then the production orders are initiated according to the demand. Hence, it is not initiated on a timely basis but at irregular intervals. This introduction of pacemaker and CONWIP along with reorder point system loops helps in ensuring the control over the material flow and also reduces the chance of inventories getting stacked in the flow, except the planned super markets.

2. In the production flow of SK, all the machines in the production flow are dedicated to handle the product family AF except the sand blasting machine which handles the products from various product families. Currently this causes the casted products from the die casting area to wait in the queue, before sand blasting machine, which is operated on a first come first serve basis. This causes the waiting time of 0.8 days in the production flow. The company should work on prioritizing their faster runners over the other products passing through the sand blasting machine. Simple way is to have two parallel waiting lanes before the sand blasting machine, that is one for fast runners (high priority line) and the other line for normal products (low priority line)

that are passing through the sand blasting machine. By doing this the waiting time of 0.8 days can be reduced to great extents.

3. In the production flow of product SK, the Brother machine is having the maximum setup time and cycle time compared to the other processes in the flow. In the production flow of SK, sand blasting and packing are considered as a subsidiary processes for the die casting, machining and final assembly processes. In this case die casting, machining and final assembly are the main processes in the flow. Out of the three main processes brother machine is having the highest cycle time and set up times. In long run there chances of accumulation of products before the brother machines. However, the future state map (figure 5.1) shows only the processing lead time, the non value adding times and support times such as transportation time between the processes are not considered in this thesis. The transportation times between the sandblasting and the machining processes is comparatively high, since the distance between the departments is far and the products have to be transported by the internal logistics personnel. This must be considered during the cycle time analysis process, since this might become a reason for the accumulation of sand blasted parts before machining process.

4. Leveling of load is one option to keep the low inventory level in the supermarkets. The leveling of the loads can be done by placing the production orders based on the demand and also based on the present conditions in the inventory for the products of the AF product family. This helps in preventing piling up of inventories in the flow for particular product variants when they are not in demand.

5. All the other products in the production flow of AF product family, except product variant SK have to pass through the visual inspection before storing it in the supermarket, near the final assembly. Even though this is not included in the thesis scope, we would like to point out that, the visual inspection of these other products, might cause delay in the production lead time of product SK. This might affect the CONWIP loop when the production schedule of product SK comes after the production schedule of other products in the product family AF. This also causes transportation waste since the products from washing is transferred to the visual inspection area first and then it is transported back to the supermarket near final assembly. One way to avoid separate visual inspection is to have the visual inspection near final assembly. This might help in maintaining the lead time for all the product variants of the product family AF and also it helps in eliminating the transportation wastes.

6. For increasing the flexibility in the production and for having the best suited production mix, the production batch size should be optimized. Currently, for product SK the batch size is 4500 till final assembly and for final assembly it is 480, since one pallet can accommodate only 480 product SK's. Batch sizes for production should be optimized to have levelled production in order to reflect

quickly to customer demand and also to reduce the unnecessary staking up of inventories for the products which are not in demand.

6.2 System level improvements

During the interviews and during the collection of quantitative data, the authors came know that the ERP system at the company is devoid of many modern functionalities. For example, the traceability of products between processes is very difficult as the production order numbers are same from the foundry till the machining process. Due to this, the ERP system shows as if the entire process, between foundry and final assembly, is just one operation. One of the main issues arising due to this is that of the veracity of the information regarding quality. The information about quality, for example scrap values, are fed in the system after the machining process. It then becomes difficult to identify, where exactly in the flow has the defect occurred. Another issue is that the defective products are initially included in the inventory counts and entered in the ERP system. But later on, after defects are identified, the inventory has to be revised again. This results in loss of time and resources in managing the situation and furthermore the production schedule has to be changed to make up for the scrap generated.

One of the solutions is to have information regarding the products entered in the ERP system, after every process is completed in the flow. The current ERP system is not able to handle this level of product information details and therefore, the upgrading the ERP system, considering the future state requirements, can be implemented. Another solution is to split up the production orders for every process in the production flow. This will help in improving the traceability and keeping track of real time information.

Currently, the information flow is such that it is operating in isolated island as explained in section 4. As shown in the future state map, the information flow is now limited to the first and the last process with the pacemaker at the buffer before the final assembly. The pacemaker is the point at which the information flow regarding production is controlled (Rother and Shook, 2009). The production control now has to check the inventory levels at only this buffer. When the inventory levels go below the reorder point, a CONWIP card is initiated and sent to the first process i.e. the foundry. As explained earlier in section 2, CONWIP card does not specify exactly which products to produce. Therefore, the specification list should be sent by the production control to the foundry regarding the specific product to produce depending on the customer demand. It is, therefore, the responsibility of the production control to check, or have a mechanism to check, the reorder point levels as well.

Similarly, when the inventory levels in the final buffer goes below the reorder point, the production control has to send replenishment orders to the final assembly. The final assembly now will be using products from the inventory at the pacemaker and when that inventory goes below reorder point, the procedure, as explained previously, has to be followed. Furthermore, the production control has to be responsible for both the inventory levels and customer demands. Based on this, they have to maintain the level of each product variety in product family AF, as explained earlier. For example, in one day 1042 SK products can be produced, but the demand might be only 350. Therefore, to avoid all the wastes, it is necessary to take into consideration the customer demand. This also helps in freeing up the resources for the other products in the product family AF. The optimal level of each product variety should be maintained and thereby having a levelled inventory.

6.3 General recommendations

Apart from the above mentioned recommendations, there are some general tools which can be implemented to further improve the efficiency of the flow.

Currently, there are standardized work procedures, but it can be further improved in the sense that it can be made more visual. For example, the work procedures are available at the workstations, but an improvement would be to have a visual representation of the task to be performed at that particular station. Furthermore, any new work procedures, should be communicated directly to the workers or to the one concerned, as it might be the case where the instructions are updated and visually represented but it might be overlooked by the worker.

To cultivate a culture of continuous improvements (kaizens), everyone should be encouraged to give ideas regarding their own space of work, at least in the initial stages. Currently, this process is going on, such as, the feedback from workers are taken into consideration. But at the same time it is not documented and this results in the improvements ideas not being potentially implemented elsewhere in the processes.

7
Discussion and conclusions

This chapter of the thesis report explains briefly about the research statements and the how the future suggestions relate to the purpose of the thesis. This part also showcases the achieved results and the final conclusions of this thesis project.

The purpose was to find improvement potentials for decreasing the production lead time and optimizing the inventories for the enhancement of OTD. The initial step, in this, was to identify the issues in the production flow which affected the lead times and this was approached by using value stream as a tool. Value stream mapping is a widely used tool for visualizing the production flow in relation to the customer demand. Since, in this method, the mapping is done for the entire processes involved, it is much easier to visualize the value added time, bottlenecks and constraints in the production flow. The product SK was chosen for this purpose and the reasons for the same have been explained in the earlier sections.

Considering the various parts involved in the product SK, the longest lead time was observed in the 'Body' part of the the product SK. Following this body part, value stream mapping was done which included all the processes related to it. It was observed that the products from all the individual processes were pushed into the inventory and the time spent by the products in the inventory was also too high. This was one of the causes for increased lead time and thereby not able to deliver on time. Also, it was noticed in the information flow that the each department had their own planners who sent production plans. The information is not integrated and are working as isolated functions, which is nothing but a push flow.

The next part of the purpose was to have control over the production flow and the approach was to first stabilize the processes and then have control and visibility across the production flow. This was done by establishing the reorder points and safety stocks. The main reason for this was variability in lead times and demand in the production flow and the that the manufacturing strategy was make to stock. The reorder point was chosen before the final assembly as it served as a decoupling point between push and pull processes. The push process being from foundry to washing and the pull process being from the final assembly to the warehouse. For the safety stock calculations, which is part of the reorder point, the lead time deviations, demand deviations and service level factors were considered while proposing the solution.

Initially the feasibility of kanban was checked, but as there is a lot of demand variation, and therefore, it cannot be implemented. The CONWIP system, which is similar to the generic kanban system, was proposed as it secures a constant work in process between the first and last process, with mix model variations. The CONWIP loop is proposed to be placed from the reorder point, back to the foundry, as this was a push process and using this method a pull mechanism can be introduced. It is therefore a combination of push and pull. Based on the proposed future state the expected lead time is 2.17 days. Also, with the proposed safety stock, it is expected to sustain up to 7.25 days without production of SK products as explained in the analysis.

The shortcomings of this thesis is that there is consideration for only the body part of SK and that only one KPI (OTD - on time delivery), was analyzed. Furthermore, the effects of other products in the AF product family on SK product group, in relation to the production flow, was not analyzed as it was out of the thesis scope. Furthermore, the sequence of production in the CONWIP loop was not calculated as this was not part of the thesis scope as well. The main idea here is to also have a balanced quantity, based on the customer demand, of all the varieties of the product so that there is no pile up in the final inventory. These two factors should be taken into consideration, along with the potential new ones, while implementing the proposed future state map.

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A

Appendix 1

A.1 Interview questionnaire for planner

General

1. Brief description about your job profile
2. What are your views on the current production flow of Product SK and product family AF?
3. What are the current departmental goals?
4. What are the long term, intermediate and short term plans?
5. Brief description about the coordination required in supply and movement of material and labour.

Scheduling

1. Brief description about the production scheduling process.
2. What are the decision making process for production scheduling?
3. What are the current challenges in it, according to you? what way is it creating bottlenecks in production, if any?
4. Production planning is partly based on forecasts. Since it is not accurate , how is it managed?
5. How are the batch size decided? For example, in the foundry, machining, etc
6. How is the coordination between the different processes/ departments (ex. between foundry, machining, etc) managed, in relation to batch size?
7. How are the reorder points fixed?

Logistics

1. Brief description about the logistic/distribution process
2. What are the current challenges in it, according to you?
3. In what way is it creating bottlenecks in production, if any?

Production control

1. Brief description on the production control methods, currently in place?
2. How can it be improved?
3. Any views on the current manufacturing operations flexibility, if any?
4. According to you, what are the initial steps required for creating a pull flow, at IMI?
5. There is one production order for foundry, chuck and CNC. It becomes difficult to know where in the process are we. Any solutions/ideas to this?
6. Quality checks are after machining. Defects are occurring at an early stage but detected only after machining, which means the entire process before machining is waste. Can there me more quality checks?

Inventory and utilization

1. How is the inventory level maintained/ optimized?
2. Is there any economic order quantity set, to minimize all inventory costs?
3. How economic and balanced utilization of machines are achieved?

A.2 Interview questionnaire for Supply chain planner

General

1. Brief description about you and your job profile
2. What is your position and job responsibilities? - Job profile
3. What are your views on the current production flow of product SK and product family AF?
4. What are the current departmental goals?
5. What are the long term, intermediate and short term plans?
6. Brief description about the coordination required in supply and movement of material and labour.

Supply chain

1. Brief description about the supply chain process
2. What are the decision making process involved in it?
3. What are the current challenges in it, according to you?
4. In what way is it creating bottlenecks in production, if any?
5. What is the supply lead time for key components of product SK and product family AF?
6. Is there any level of uncertainty involved in the entire supply process?
7. According to you, is there a pull flow or a push flow?
8. Where in the supply chain can there be a differentiation between a pull and push flow?
9. How can the flow be improved?
10. What are the initial steps that are the most important to achieve this?
11. IMI is aiming for lean implementation, how will it affect the supply chain processes?

Inventory and utilization

1. How is the inventory level maintained/ optimized?
2. Is there any economic order quantity set, to minimize all inventory costs?
3. How economic and balanced utilization of machines are achieved?
4. Production planning is partly based on forecasts. Since it is not accurate, how is it managed?
5. How is the batch size decided? For example, in the foundry, machining, etc
6. How is the coordination between the different processes/ departments (ex. between foundry, machining, etc) managed, in relation to batch size?
7. How are the reorder points fixed?

A.3 Interview questionnaire for Industrial Engineers

Inventory and utilization

1. Say us few words about the company
2. Say about your designation and your job profile
3. Say about the products that are manufactured in IMI?

Inventory and utilization

1. What are your views on the production flow of product SK in Ljung?
2. Say about your views on the production flow of compact modulator
3. What are the constraints that you feel in the production of product family AF ?What are the current challenges in it, according to you?
4. According to your point of view, which is the main constraint / bottleneck in the flow?
5. How do you prioritize the bottlenecks in the flow?
6. How do you feel about the present production batch size?
7. How the batch sizes are fixed for the processes? Is it based on the forecast?
8. How the reorder points are fixed for the processes?
9. How do you feel about the production lead times for AF product family ?
10. What do you feel about the current inventory and super markets at various places in the production flow?

Future Improvements

1. Do you have any suggestion for improvement in the production flow of product family AF?
2. How do you feel about having the pull and continuous flow for the product family AF?
3. What are the hindrances that you think that could come on the way while doing adopting the pull and continuous flow?

A.4 Interview questionnaire for quality manager

General and current process

1. Brief description about you and your job profile?
2. What are your views on the current production flow of product SK and product family AF?
3. What are the current departmental goals?
4. What are the long term, intermediate and short term plans?

General and current process

1. Brief description about the quality process
2. How do you feel about the current quality problems of product SK and product family AF?
3. How many times the quality is been verified in the total production flow of AF?
4. Quality checks are after machining. Defects are occurring at an early stage but detected only after machining, which means the entire process before machining is waste. Can there me more quality checks?
5. What are the current challenges in it, according to you?
6. In what way is it creating bottlenecks in production, if any?
7. Say about the future action plans for the quality improvement (short and long term goals)?

B
APPENDIX B

B.1 Symbols used in Value Stream Mapping