DEGREE PROJECT

Integrating Value Stream Mapping and DMAIC Methodology

A Case Study at TitanX

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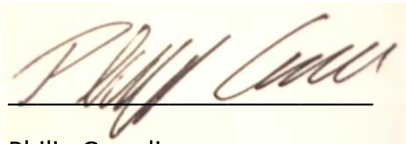

Philip Gremlin

Abstract

Value stream mapping (VSM) is a commonly used Lean tool which is appropriate when examining the current state of a process to identify improvement opportunities in the form of wastes. VSM can be helpful in identifying activities that do not create value for the customer which makes it possible to reduce the non-value adding activities and create a more efficient process.

The use of the Six Sigma methodology DMAIC has during the last decades increased substantially with the growing interest in Six Sigma. Despite the increased acceptance of the DMAIC methodology as a concept for improvement and the amount of research that has been undertaken on the implementation of VSM in various industries the literature on the integration between Lean tools such as VSM and the Six Sigma methodology DMAIC is scarce. Many authors argue that an important next step within the Lean Six Sigma research is to conduct practical studies verifying the effectiveness of the integration between DMAIC and Lean tools such as VSM.

Therefore the purpose of the thesis was to study and illustrate how value stream mapping (VSM) can be executed in a structured manner according to the DMAIC methodology. A secondary purpose of the thesis was to, through the use of the "VSM-DMAIC approach", present and implement improvements in a production process.

To fulfill the purpose literature was studied in order to find recommendations to how value stream mapping can be executed through the DMAIC methodology. The literature review resulted in six ways in which VSM could be integrated through DMAIC. In the case study one way to execute VSM through DMAIC methodology was studied since there was not enough time to examine all integrations. Therefore DMAIC methodology was used as the basis of the improvement project with VSM applied simultaneously in order to strengthen the DMAIC methodology.

To study and illustrate the "VSM-DMAIC approach" a case study was conducted at TitanX in Linköping where the thesis work was a part of a bigger project to eliminate losses in the manual assembly. Throughout the case study the use of DMAIC methodology along with Six Sigma tools were supplemented by value stream mapping.

The secondary purpose of the thesis work was to, through the use of the "VSM-DMAIC approach", present and implement improvements in a production process. The aim of the case study was to decrease blocking and starving with 10 % which is considered to be have been achieved since the proposed improvements results in reduced blocking and starving of approximately 30 % if implemented fully.

The conclusions were that the VSM worked well through the DMAIC methodology. The VSM gives a wider perspective while Six Sigma tools allow a deeper understanding of the problem and its contributing factors. Although only one way in which DMAIC methodology can be implemented with VSM was studied and illustrated through the case study it was concluded that using DMAIC methodology as the basis with VSM implemented simultaneously provided a more visual picture of the problem, highlighting the importance of the problem compared to other problems in the flow.

Sammanfattning

Värdeflödesanalys är ett vanligt verktyg inom Lean och är lämpligt när man undersöker det aktuella läget för en process och vill identifiera förbättringsmöjligheter i form av slöseri. Värdeflödesanalys kan genom identifieringen av icke värdeökande aktiviteter bidra till en reducering av aktiviteter som inte skapar värde för kunden vilket resulterar i en effektivare process.

Användningen av Six Sigma-metodologin DMAIC har under de senaste årtiondena ökat kraftigt i takt med det växande intresset för Six Sigma. Trots en ökad acceptans av DMAIC metodologin som ett verktyg för förbättring och mängden forskning som har bedrivits på genomförandet av värdeflödesanalys i olika branscher och situationer finns det fortfarande en brist på litteratur om integrationen mellan Lean verktyg som värdeflödesanalys och Six Sigma-metodologin DMAIC. Många författare hävdar att nästa steg inom Lean Six Sigma-forskning är att göra praktiska studier som kontrollerar effektiviteten av integration mellan DMAIC och Lean verktyg som värdeflödesanalys.

Syftet med examensarbetet var därför att studera och illustrera hur värdeflödesanalys kan utföras på ett strukturerat sätt enligt DMAIC metodologi. Ett sekundärt syfte med examensarbetet var att genom användningen av "VFA-DMAIC tillvägagångsätt", presentera och genomföra förbättringar i en tillverkningsprocess.

För att uppnå syftet studerades litteratur där sex sätt som värdeflödesanalys skulle kunna integreras genom DMAIC metodologin identifierades. I fallstudien kunde bara ett sätt att integrera värdeflödesanalys och DMAIC-metodik studeras då tiden för att undersöka alla sorters integration inte fanns. DMAIC metodologi användes därför som grund för förbättringsprojektet medan värdeflödesanalys applicerades samtidigt för att stärka DMAIC metodologin.

För att studera och belysa VFA-DMAIC tillvägagångssättet genomfördes en fallstudie på TitanX i Linköping där examensarbetet var en del av ett större projekt för att eliminera förlusterna i den manuella monteringen. Under hela fallstudien användes DMAIC metodologi tillsammans med Six Sigma-verktyg och värdeflödesanalys.

Det sekundära syftet med examensarbetet var att genom användningen av VFA-DMAIC tillvägagångsätt, presentera och genomföra förbättringar i en tillverkningsprocess. Målet med fallstudien var att minska blockering och svält i processen med 10 %. I denna studie bidrog de föreslagna lösningarna till en minskning av blockering och svält på cirka 30 %.

Slutsatserna från examensarbetet var att värdeflödesanalysen fungerade bra genom DMAIC metodologin. Värdeflödesanalysen gav ett bredare perspektiv av problemet medens Six Sigma verktyg tillät en djupare förståelse av problemet och dess orsakande faktorer. Även om endast ett sätt på vilket DMAIC metodik kan genomföras med värdeflödesanalys studerades och illustreras ytterligare genom fallstudien drogs slutsatsen att användning av DMAIC metodik som grund med värdeflödesanalys implementerat samtidigt gav en mer visuell bild av problemet. Kombinationen betonade vikten av problemet i förhållande till andra problem i flödet vilket gjorde det lättare att fatta beslut.

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Appendices

1. Introduction

This first chapter of the thesis explains the purpose of the thesis work and why the thesis work is needed. Initially the background to the subject is presented and the problem is described. The purpose of the problem is then presented and divided into aims that needs to be reached in order for the purpose to be fulfilled. The chapter ends with a presentation of the delimitations made and the reports logical disposition.

1.1 Background

Companies are facing an increasing pressure to improve their manufacturing operations in the form of increased productivity and customer service to stay competitive (Prasanna & Vinodh, 2013). According to the authors organizations seeking to reach future success do not only have to satisfy its current customers but also create opportunities to satisfy future customers. The future customer needs are probably different from the current customer needs, it is therefore necessary to constantly improve and adapt to maintain or hopefully gain market shares (Bergman & Klefsjö, 2007). As a result companies have according to Prasanna and Vinodh (2013) implemented different concepts for structured improvements.

The elimination of waste is a central part of Lean which reduces overall lead-time and gives the operators the time needed to control products and secure the flow from defects (Lapierre, 2000). The combination of operations and inspections in order to detect abnormalities early is called Jidoka. Jidoka has been used by Toyota for a long time and has been proven very successful (Lapierre, 2000). The reason for Jidokas' success is according to the author not only the possibility to detect abnormalities but also the possibility of stopping the production as soon as abnormalities are discovered. Stopping the process as soon as abnormalities are detected will lead to a prevention of the waste that would be created if defective products were produced (Lapierre, 2000).

Removing wastes in a process flow is not as simple as it might sound. Lean can for example be used to systematically eliminate waste but often the systematic elimination of waste fails to work as intended (Rother & Shook, 2003). According to Rother and Shook (2003) the reason why the systematic elimination fails is because many organizations do not map the entire value stream for the product families. Instead only a part of the value stream for each product gets mapped and improved. Improving just a part of the value stream means that the inventories and detours probably will increase in the next downstream step (Rother & Shook, 2003). Value stream mapping (from now on VSM) is therefore a good method to get an overview of the current state of both the material flow and the information flow (Montgomery, 2009; Rother & Shook, 2003). When attempting to improve a flow VSM is appropriate since it provides a structured approach towards a desired future state (Rother & Shook, 2003).

Lean is built upon philosophies which makes it difficult to interpret, the implementation of Lean is therefore often superficial (Arnheiter & Maleyeff, 2005). The use of Six Sigma methodology could therefore enhance the robustness of Lean and Lean tools by putting more focus on fact-based decision making and promoting a more scientific approach to quality (Arnheiter & Maleyeff, 2005).

According to Assarlind, Gremyr and Bäckman (2013) there are different benefits from using Lean and Six Sigma, most benefits can according to the authors be drawn from using a combination of Lean and Six Sigma since the concepts complement each other in many ways. The combination Lean Six Sigma is seen as a business improvement strategy which focuses on maximizing value through customer satisfaction, cost reduction, quality improvement and increased process speed (Arnheiter & Maleyeff, 2005; Berryman, 2002).

1.2 Problem Discussion and Purpose

VSM is a commonly used tool within Lean which is appropriate when examining the current state of a process in order to identify improvement opportunities in the form of waste (Dennis, 2007). VSM can be helpful in identifying activities that do not create value for the customer which makes it possible to reduce the non-value adding activities and create a more efficient process. VSM focuses primarily on improving the material flow as well as the information flow by visualizing wastes but can also be used in order to understand a process (Rother & Shook, 2003). VSM has been a part of Lean for a long time and has therefore been studied thoroughly and is considered an appropriate tool to identify improvements (Rother & Shook, 2003).

The use of the Six Sigma methodology DMAIC has for the last decades increased substantially with the growing interest in Six Sigma (Sörqvist & Höglund, 2007). DMAIC consists of five phases that constitutes the basis of improvement within Six Sigma. The phases are Define, Measure, Analyze, Improve and Control and can be said to represent the five most important success factors when it comes to making improvements (Sörqvist & Höglund, 2007). The most often used improvement methodology within Lean is according to Pepper & Spedding (2010) PDCA which consists of plan, do, check and act. The PDCA methodology is considered easier to understand by many but lack the systematic and fact based project management approach of the DMAIC methodology (Pepper & Spedding, 2010).

Despite the increased acceptance of the DMAIC methodology as a concept for improvement and the amount of research that has been undertaken on the implementation of VSM in various industries and situations there is still lacking literature on the integration between Lean tools such as VSM and the Six Sigma methodology DMAIC (Pepper & Spedding, 2010). Many authors argue that the next step within the Lean Six Sigma research is to conduct practical studies verifying the effectiveness of the integration between DMAIC and Lean tools such as VSM (for example Arnheiter & Maleyeff, 2005; Juan & Carretero, 2010). The reason for the lack of research and studies performed in this area is according to Smith (2003) because of the lack of commitment from management to combine Lean and Six Sigma.

The fact that the value stream map is a useful tool when identifying improvement opportunities and creating value for the customer is supported by many (for example: Rother & Shook, 2003; Arnheiter & Maleyeff, 2005; Juan & Carretero, 2010). However the lack of literature when it comes to implementing VSM with the Six Sigma methodology DMAIC shows a need for further studies in order to avoid problems that can occur when integrating the two concepts. Therefore the purpose of this thesis work was to:

Study and illustrate how value stream mapping (VSM) can be executed in a structured manner according to the DMAIC methodology. A secondary purpose of the thesis work was to, through the use of the "VSM-DMAIC approach", present and implement improvements in a production process.

In order to fulfill the purpose it was broken down into aims. The presented aims worked as gates where decisions on how to continue with the thesis work were taken. A fulfillment of all aims results in the purpose being achieved, see Figure 1.

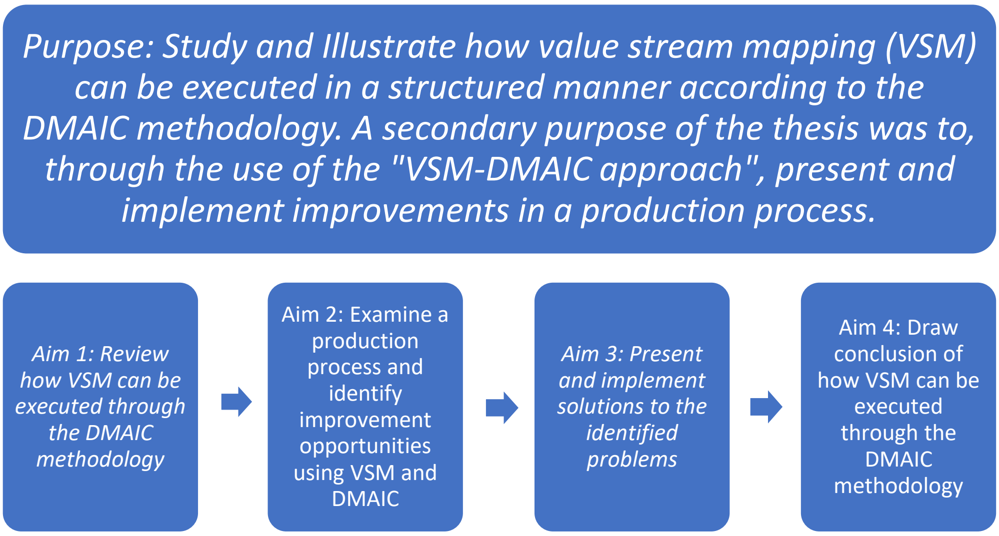

Figure 1: The purpose of the study and the aims needed to achieve the purpose.

The aims were approached in a particular order from left to right since the first aim needed to be fulfilled in order for there to be basis for the next one.

Aim 1: Review how VSM can be executed through the DMAIC methodology

The first aim was set up in order to create an understanding of how a value stream mapping can be executed, what the constituent parts are and in which phases of the DMAIC methodology they can be executed. Literature therefore needed to be reviewed in order to investigate the appropriate ways to implement VSM through DMAIC methodology.

Aim 2: Examine a production process and identify improvement opportunities using VSM and DMAIC

The second aim was connected to the Define, Measure and Analyze phases of the DMAIC methodology. The purpose of examining a production process and identifying improvement opportunities was to gain an understanding of the advantages and disadvantages of using VSM through the DMAIC methodology to identify causes to a problem.

Aim 3: Present and implement solutions to the identified problems

The third aim was connected to the Improve and Control phases of the DMAIC cycle where improvements were presented and implemented and where guidelines to control the suggested improvements were set up to secure a lasting change. The purpose of implementing solutions to the identified problem was to understand the advantages and disadvantages of using VSM through the DMAIC methodology.

Aim 4: Draw conclusion of how VSM can be executed through the DMAIC methodology

The fourth aim is presented in the conclusion where the integration of VSM through DMAIC methodology is analyzed and reviewed.

1.3 Company Description

In order to reach the aims and achieve the purpose of the thesis work a case study company was needed. In order to examine the integration of VSM and DMAIC TitanX was perceived as an appropriate company since their process needed improvements. TitanX is a company of 800 employees producing engine coolers for the commercial vehicle industry. TitanX operates globally with facilities in China, Brazil, Mexico, USA and Sweden with headquarters in Gothenburg and annual sales of 1,6 billion SEK (TitanX, 2016). During the study the factory in Linköping has been in focus since they are experiencing problems in their production.

The Linköping factory focuses solely on oil coolers and produces three different oil coolers; engine oil coolers, retarder oil coolers and transmission oil coolers. The coolers have according to TitanX been developed in cooperation with market leading commercial vehicle customers like Scania and Volvo providing high performance in the customers' desired size.

The coolers are made of stainless steel plates and can be either single flow integrated or twin flow integrated with the cooling and oil circuit integrated, examples of oil coolers are shown in Figure 2. Engine coolers have been designed by TitanX for decades, therefore their expertise in the area and the products' functionality are unquestionable (TitanX, 2016).

Figure 2: Example of the different products produced by TitanX in Linköping
Source: TitanX, 2016

1.4 Delimitations

To reach the aims and achieve the purpose of the study some limitations were needed in order for there to be enough time to reach valid results. First of all the study focused solely on the internal processes at TitanX in Linköping and its production and value flow. This means that no other sites or external stakeholders were taken into account when conducting this study.

Aim two and three have during the study been limited to focusing on the assembly and pre-assembly processes at TitanX. The assembly and pre-assembly processes were chosen because of the expressed need by the company to increase efficiency and quality in these processes.

1.5 The Logical Disposition

In order to fulfill the purpose of the study all presented aims need to be reached. Presented below is a framework of how the thesis work was structured in order to reach the aims and thereby the purpose, see Figure 3.

Chapter 2 describes the different methodological choices made and the approach chosen to conduct the study. In Chapter 3 a literature review is presented which has also been the foundation of the first aim which is "Review how VSM can be executed through the DMAIC methodology". Chapter 4 contains the Define phase which is the start of the DMAIC methodology. In the Define phase the examined problem is presented and the importance of the project is discussed. Chapter 5 presents the Measure phase and the gathered data used in the project. Chapter 4 and 5 also ensure that the second aim is reached which is to: *"Examine a production process and identify improvement opportunities".*

Chapter 6 contains the analysis of data gathered in the Measure phase. In Chapter 7 the improvements are presented and some are implemented. The Analyze and Improve phases secure Aim 3 being reached, *"Present and implement solutions to the identified problems".* Chapter 8 is the final step of DMAIC methodology where the improved process is standardized and the process monitoring is designed. Chapter 9 contain the findings from the study which will be discussed in Chapter 10.

Together with the control phase the Conclusion and Discussion will make sure Aim 4 is reached, thereby fulfilling the purpose of the study.

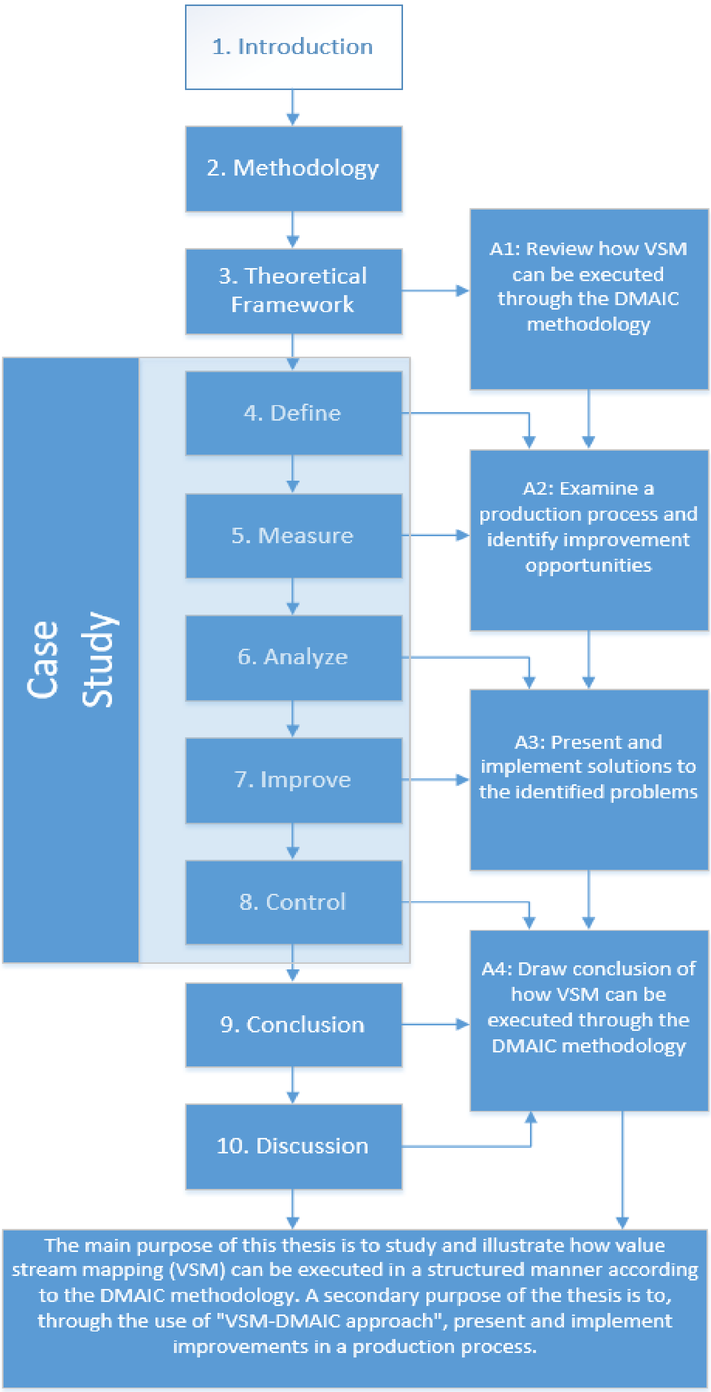

Figure 3: Description of the thesis' logical disposition

2. Methodology

Presented in the following chapter are the methodological choices made and the approach chosen in order to conduct the study and fulfill the purpose of the thesis. Initially the research purpose, research approach and research strategy are presented and discussed. The data collection, and data analysis are then presented followed by the approach of the study and a discussion of research quality.

2.1 Research Purpose

A study's purpose can be classified into three main classes, it can be exploratory, descriptive or explanatory (Saunders, Lewis & Thornhill, 2009). An exploratory study is according to Saunders et al (2009) useful when the purpose is to create understanding for unexplored methods and problems. A descriptive study focuses on describing a problem through existing knowledge (Saunders et al., 2009). Explanatory studies are used to obtain further knowledge in an explored area by explaining connections between different variables (Saunders et al., 2009). Research can also use combinations of the different approaches to reach the specified purposes (Saunders et al., 2009).

The purpose of this thesis work was to study and illustrate how VSM can be executed in a structured manner according to the DMAIC methodology. A secondary purpose of the thesis work was to, through the use of the "VSM-DMAIC approach", present and implement improvements in a production process. The purpose of the study was not considered exploratory since the methods used have been thoroughly examined and implemented in former studies. The purpose of the study can be defined as both a descriptive and explanatory. The purpose is descriptive since it aims to describe how VSM can be executed according to the DMAIC methodology. The purpose is also explanatory since it aims to explain why problems occur in order for solutions to be produced.

2.2 Research Approach

A study can take different approaches; it can either take a deductive or an inductive approach. The deductive approach uses empirical evidence to support theories while an inductive approach uses empirical evidence to create new theories (Saunders et al., 2009). Because the purpose was defined beforehand and the methods and tools in this study have been well examined and tested the purpose of this study can be said to be deductive. The purpose is considered deductive since methods and tools from existing litterature are chosen and tested in reality in order to develop knowledge in the studied area which according to Saunders et al. (2009) is the definition of a deductive approach. The hypothesis of the study therefore became: *"The integration between VSM and DMAIC can create value for companies by providing a structured way of identifying, presenting and implementing improvements in a production process".*

According to Saunders et al. (2009) there are two different types of data that can be collected and analyzed; these are qualitative data and quantitative data. Depending on the purpose of the study the use of qualitative data, quantitative data or a multiple method approach can be chosen to achieve the purpose (Saunders et al., 2009). This study used a multiple method approach and therefore both qualitative and quantitative data were collected.

2.3 Research Strategy

Saunders et al. (2009) define the research strategy as a plan on how a study is to be conducted. To reach the aims of the study and achieve the purpose there need to be a well-defined strategy. Depending on the formulation of the purpose, available resources and existing knowledge different strategies can be adopted (Saunders et al., 2009). The different strategies a study can adopt are experiment, survey, case study, action study, grounded theory, ethnography and archival study (Saunders et al., 2009). When choosing a strategy three different aspects should be considered; type of purpose, if control of behavioral events are needed and if focus should be on current events (Yin, 2009). In this study a case study strategy was used since the study was carried out in an uncontrolled environment with a desire to gain rich understanding of the process. The unit of analysis were TitanX, more specifically the production process including the operators assembling coolers in the assembly line and the machines pressing plates. A cases study approach is according to Yin (2009) suitable to reach purposes based on "how" and "why". Since the purpose was to study and illustrate how VSM can be executed in a structured manner according to the DMAIC methodology a case study approach was the most appropriate choice.

2.4 Approach of the Study

This study follows the Six Sigma approach for improvements where the DMAIC methodology has been used for it to be possible to draw conclusions on the presented purpose of the study, see Figure 4.

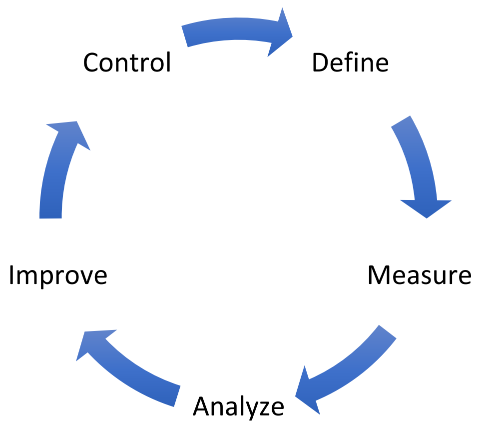

Figure 4: The project process in the form of DMAIC

The study also follows the steps presented by Rother and Shook (2003) for conducting a VSM. The steps presented by Rother and Shook (2003) are; defining a product family, mapping a current state map, mapping a future state map and set up a work plan for implementing improvements in order to reach the future state. These VSM steps were intertwined with the DMAIC cycle during the thesis work, see Figure 5.

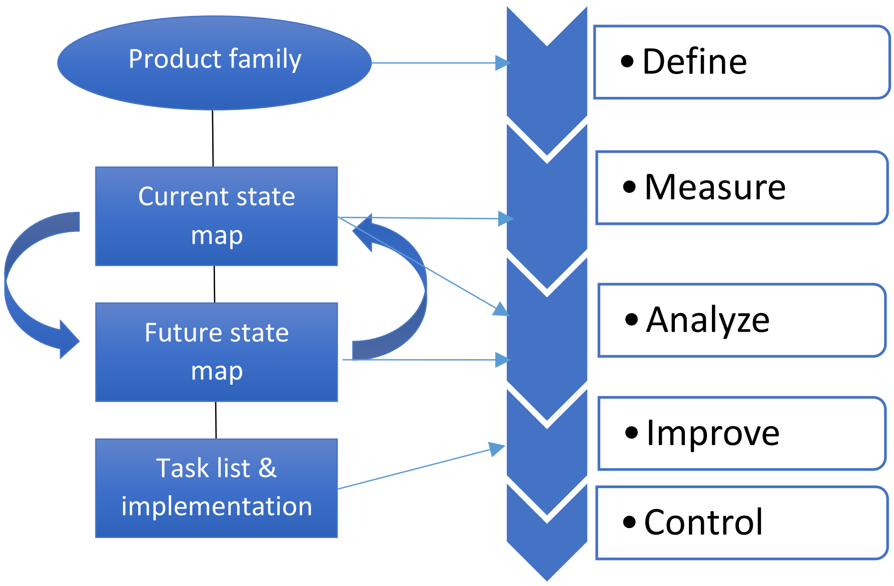

Figure 5: Rother & Shook's (2003) structure for making a Value Stream Map and the relationship with the DMAIC cycle

In the Define phase an appropriate product family was chosen based on suitability to the project. In order for a product family to be suitable for the project it needed to experience problems caused by blocking and starving and be a fairly high volume product so that appropriate measurements could be performed. In the Measure phase data were gathered through observations and interviews which were then compiled to create a current-state map of the process. In the Analyze phase the current state map was analyzed to create an understanding of which activities and costs could be connected to the defined problem, what the problem areas were and what could be improved. The future state map was also created in the Analyze phase based on the improvement opportunities identified in the current state map. In the improve phase the different improvement opportunities were examined further and a task list created with short-term and long-term improvements that should be implemented. In the Control phase all implementations were monitored to make sure the project resulted in a positive lasting outcome with reduced waste and a higher understanding of how Lean tools can be implemented with the Six Sigma methodology.

2.5 Data Collection

According to Saunders et al. (2009) there are two types of data that can be collected, primary and secondary data. Primary data is data collected by the researcher in the present. The collection of primary data is important but often neglected in studies are the possibilities to reanalyze data that have already been collected, for example secondary data (Saunders et al., 2009). During this study both primary and secondary data were used. By using a combination of primary and secondary data more resources could be put to analyzing and interpreting the data since all the data did not need to be collected in contrast to using only primary data. The secondary data could also be used as a comparative and contextual data if necessary, thereby triangulating the findings.

In this study different types of secondary data were used. The secondary data used were data collected during the last year provided by TitanX as well as existing data in the production system. The secondary data provided by TitanX were data collected with the purpose of finding losses in the production. The data therefore contained information about cycle times, process times and overall equipment effectiveness (OEE). The reason why the data from the production system was not solely used was because the data was not reliable enough. Using several sources of data also improves the credibility of data so that a more realistic picture of the process can be obtained.

Apart from data gathered by the company relevant literature was used. The search for relevant literature was conducted through searches in the databases Google Scholar, SCOPUS, Wiley Online Library, Emerald and Google Books. In these databases examples of the keywords used were: *Value stream, Value chain analysis, Value stream mapping, DMAIC, Six Sigma, Lean, Lean Production, 8 wastes, Blocking and Starving.* These keywords have been used separately as well as in pair in order to find as relevant material as possible.

Primary data were gathered when needed secondary data were not available, non-existing or when the secondary data were not reliable for some reason. TitanX have had problems with the credibility of data in their production system, therefore primary data were needed. The primary data were gathered through observations and interviews. The reason for gathering primary data through observations and interviews was the flexibility of the data collection when it comes to execution. Both observations and interviews can be conducted in a way where little constraint is put to the personnel, therefore production was not blocked which was a request from the studied company.

2.5.1 Observations

According to Gill and Johnson (2010) there are four different roles which the observer can adopt; these are complete participant, complete observer, observer as participant and participant as observer, see Figure 6.

According to the authors observing as a complete participant means that the observer is involved in the process, learning by doing what the ones being observed normally do. Observing as complete participant means that the person being observed is aware of the observers' presence and the purpose

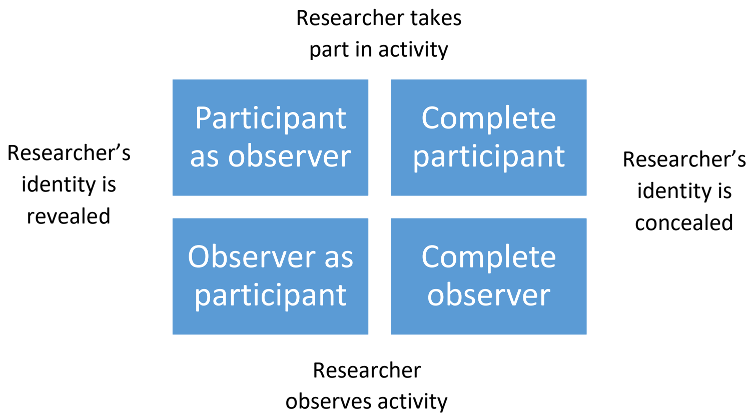

Figure 6: The different kind of observations, loosely drawn from Saunders et al. (2009)

with the observation (Gill & Johnson, 2010). When conducting observations through the observer as participant approach the observers' purpose and presence is known by the ones being observed, however there is no participation in the actual process (Gill & Johnson, 2010). When choosing a participant as observer approach the observer is part of the process, however the observed does not know they are being observed and the purpose is hidden (Gill & Johnson, 2010). A complete observer is an observer that observes from a distance with a hidden purpose to the people being observed (Gill & Johnson, 2010).

In this study two different observation roles were applied, an observer as participant role and a participant as observer role. The participant as observer role was applied in the beginning of the study since it made it possible to connect and communicate with the operators to obtain an understanding of the process and its flow. The data collected through the participant as observer role were gathered through experiencing the process, it was mainly applied to create the current value stream map. After trust had been created with the operators and the process had been mostly understood an observer as participant role was applied to minimize affect from the researcher during the measurements. The data gathered through the observer as participant approach were data explaining which activities the operators perform and the time spent performing the activities. During the thesis work observations were performed at the pre-assembly station and the assembly station. Three observations were carried out for each examined station, resulting in 6 observations, each lasting for three to six hours. The obtained data from the observations were then compiled in an excel file were the data could be presented in appropriate charts.

2.5.2 Interviews

According to Saunders et al. (2009) there are three different types of interviews; structured interviews, semi-structured interviews and unstructured interviews. Structured interviews are interviews where the questions are predetermined and the interviewer carefully follows the structure of the prepared interview (Saunders et al., 2009). A Semi-structured interview is an interview where questions have been prepared but the way the questions are asked and in what order may vary (Saunaaders et al., 2009). By using semi-structured interviews it is according to Saunders et al. (2009) possible to vary the interview questions and structure, it is thereby possible to adjust the interview to the situation. Using a semi-structured interviewing technique makes it easier to adapt the interview for the interviewee which can be appropriate when interviewing different roles in an organization (Saunders et al., 2009). Unstructured interviews are non-standardized interviews and are often referred to as qualitative research interviews (Saunders et al., 2009).

In this study semi-structured and unstructured interviews were conducted in order to obtain data. The semi-structured interviews were used to understand the process, the roles, responsibilities and flow of information. Unstructured interviews were used to understand why operators performed certain tasks. The reasons for choosing these techniques were the variance of roles and duties in the process which made it difficult to use a standard form. Personnel in the process were often put under time pressure, using unstructured and semi-structured interviewing techniques made it possible to adapt the interviews after the situation the interviewee was in. Since many interviews were conducted the interviews were not transcribed since it would be too time consuming.

2.6 Data Analysis

Even if data have been collected it does not mean that it is useful, the data analysis is defined in order to make data understandable where it can be used to support decisions (Saunders et al., 2009). In many cases analysis of data is not standardized; the result from the analysis can therefore vary (Saunders et al., 2009). In order to perform a good analysis it is therefore important to have a plan of how the data analysis should be performed (Saunders et al., 2009).

During this study both existing secondary data and primary data were collected in order to reach the aims. Before the data could be used a validation whether the data could be trusted or not had to be made. In the cases where data were sticking out without an obvious reason data had to be validated. The validation was made through control measures. If data were perceived as questionable new measurements were performed in order for it to be possible to make decisions whether the data were valid or if it should be rejected. After the validation data needed to be presented in a way where it could be understood. In order to make the data understandable pie charts and Pareto charts were created. After data had been presented in an appropriate way it could be interpreted through the use of the pie- and pareto charts to find the main losses and reasons for the process not performing as expected. The interpreted data could then be explained in a way which contributed to the aims, see Figure 7.

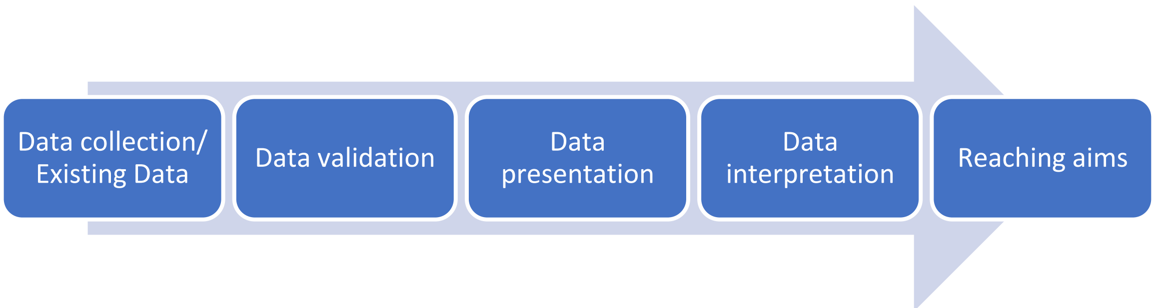

Figure 7: The data analysis process

2.7 Research Quality

An issue when conducting a study is often its credibility which can be difficult to prove (Saunders et al., 2009). According to Saunders et al. (2009) there is no possibility to know whether the produced conclusion or solution actually will work, however it is possible to reduce the risk of bad solutions. The authors argue that by paying attention to validity and reliability the risk can be greatly reduced.

2.7.1 Validity

The validity of the study assesses whether the study findings are trustworthy, if data have been collected in an appropriate way and if the conclusions have been grounded from the collected data (Saunders et al., 2009).

In this study methodological triangulation has been used to secure validity of the data gathered through observations and interviews. By using more than one source of data the validity can be improved since the different methods complement each other (Saunders et al., 2009).

According to Saunders et al. (2009) testing can affect a study's validity. Testing is when the result of data is affected because people know they are being observed, in this study affect of testing was a possibility since the presence of the observer was known. Measurements such as cycle time and work in progress are closely connected to the operators; therefore there was a possibility that the measuring affected the result. Testing is something that according to Saunders et al. (2009) can be hard to completely avoid, but was during the study handled through explaining the importance of "true" measurements to the operators. What was explained was that in order to improve the value flow, giving the operators more time to create quality products it was important that they operate as usual.

Companies constantly develop, the developments can therefore affect the process in ways which means that data is no longer valid (Saunders et al., 2009). This is called maturation and can be dealt with in different ways (Saunders et al., 2009). To avoid maturation in this study an appropriate amount of time was distributed for measuring data. Apart from the above mentioned methods of securing data all measurements were control measured so that a trustworthy picture could be obtained.

A concern with the design of a case study was whether the study results were generalizable. It can be difficult to prove that the study's results are applicable to other study settings when it is conducted in only one organization (Saunders et al., 2009). In order to prove generalizability a literature review was conducted where generalizability could be motivated.

2.7.2 Reliability

Reliability refers to whether the study findings will be consistent with the current data collection techniques and analysis procedures (Saunders et al., 2009). According to Saunders et al. (2009) reliability can be assessed by three questions:

1. *Will the measures yield the same result on other occasions?*
2. *Will similar observations be reached by others?*
3. *Is there transparency in how sense was made from the raw data?*

Reliability can be secured in several ways, in this study it has been secured by following standardized and well tested ways of finding and making improvements. In the study the DMAIC methodology and the general execution of a VSM has been used, both are well tested and standardized ways of making improvements. Through the use of semi-structured interviews the reliability of data has been secured which according to Saunders et al. (2009) is a good way to use triangulation to increase reliability. In order to increase reliability of observations a large amount of data were gathered and analyzed through the use of appropriate tools such as pie charts and Pareto charts. The reliability of the interviews were secured through the use of appropriate respondents that were well versed in the interview subject. The respondents were given enough time to answer the questions in a good way, however not too much time was given in order to obtain truthful answers.

During the thesis work short interviews were also conducted continuously in order to verify that collected data were correct. If the thesis work had been conducted for a longer time further interviews would have needed to be conducted to ensure reliability of the information. The data from the observations were also control measured during implementation in order to make sure no big changes would affect the result. Data that was control measured were for example cycle times, different losses, standard work in progress.

Through the above mentioned methods of securing reliability along with the data analysis, see chapter 2.6 Data Analysis, it is believed that the measures would yield the same result on other occasions, result in similar observations by others and a transparency in how sense was made from the raw data.

3. Theoretical Framework

The following chapter introduces the theoretical framework used in order to fulfill the purpose of the study. Presented in the chapter are the different concepts used to define the problem, measure and analyze the data, implement improvements and control the changes in order to draw conclusions.

3.1 Improvement Concepts

When trying to improve an organization, process or activity improvement concepts can be very useful. There are today a large amount of different improvement concepts that can be appropriate to use in different circumstances (Bhuiyan & Baghel, 2005). Most of the concepts can be traced back to the initiatives undertaken by several companies in the 1800s where managers started to encourage employee driven improvements, rewarding employees that brought about positive change (Bhuiyan & Baghel, 2005; Van der Wiele, Dale & Williams, 2000). In the beginning of the 1900s a lot of attention was given to scientific management which used scientific methods based on tightly controlled time-trials to achieve proper work standards (Bhuiyan & Baghel, 2005). Improvement concepts in the past have focused on improving work making it as efficient as possible. Modern day improvement concepts however does not only focus on work improvement, they are associated with organized and comprehensive methodologies (Bhuiyan & Baghel, 2005).

Although there are many different concepts used in organizations today only a few concepts have been widely implemented (Van der Wiele et al., 2000). Van der Wiele et al. (2000) explains the similarities and differences between five commonly used improvement approaches; Total Quality Management (TQM), Lean, Six Sigma, Total Productive Maintenance (TPM) and Business Process Reengineering (BPR). The authors argue that there in many cases are a lot of similarities between the different concepts, mostly when it comes to principles, techniques and tools. However when it comes to how the improvement process is handled it differs a lot (Van der Wiele et al., 2000). According to the authors the two concepts BPR and Six Sigma focus on achieving fast results with an emphasis on savings. TQM, Lean and TPM describe a desired end state and therefore have a more long-term focus (Van der Wiele et al., 2000). Walters (2005) argue that TQM, Lean and TPM give a more holistic picture of what needs to be done while Six Sigma often focuses on a process step. Therefore different concept can be appropriate to use in different situations (Walters, 2005).

3.2 Six Sigma

The Six Sigma methodology was developed by Motorola in the late 80s and is one of the latest quality movements (Pande, Neumann & Cavanagh, 2000). It was later greatly refined during its application at GE in the late 90s where it was very successful, within 10 years it had spread to other industries (Pande et al., 2000). Six Sigma is today one of the most well-known improvement methodologies used in a large variety of businesses (Krishna, Dangayach, Motwani & Akbulut, 2008). At first the Six Sigma methodology was an approach to improve product and service quality by eliminating quality issues before they occur (Krishna et al., 2008). By eliminating quality issues before they occur companies can save valuable resources and improve the process performance (Krishna et al., 2008). To avoid quality issues before they occur Six Sigma refers to the capability of a process to deliver products within specific limits, for the process to be a Six Sigma process it cannot have more than 3,4 defects per million opportunities (Bergman & Klefsjö, 2007). Over time Six Sigma has evolved into being more than a way of eliminating quality issues, it has evolved into a business process change initiative with a combination of statistical control tools and total quality management with emphasis on customer satisfaction (Arnheiter & Maleyeff, 2005; Rajamanoharan & Collier, 2006).

Six Sigma relies on experimental design in order to improve product and service quality, however many find it difficult to determine which factors to include in the experiments, especially when it comes to services (Kovach, 2007).

In the Six Sigma methodology improvements are conducted through DMAIC which is a structured approach for making improvements (Andersson, Eriksson & Torstensson, 2006; Pande et al., 2000). The DMAIC methodology is consistent with PDCA-cycle but is structured in a different way in order to avoid the main reasons for project failure (Pande et al., 2000).

3.2.1 DMAIC

As previously mentioned DMAIC is a methodology for making improvements; it was initially developed as a quality improvement tool but later evolved into an approach to reach perfection in both manufacturing and service industries (Andersson et al., 2006; Pande et al., 2000). Sörqvist (2011) describe DMAIC as a problem solving approach which is suitable to use when the solution to a problem is unclear and a systematic analysis is needed in order to make improvements. However DMAIC is according to Sörqvist (2011) not the best approach for all improvement activities since DMAIC can be time consuming for less extensive problems that could be solved faster using other approaches. DMAIC is therefore appropriate to use when the problem is more extensive since it contain a clear focus toward five areas; Understand and reduce variation, Improvements based on the customers' needs and expectations, understanding and developing processes, identifying and eliminating chronic problems and specified target toward measurable results (Sörqvist, 2011). These focus areas are imbedded in the DMAIC methodology's five different phases; Define, Measure, Analyze, Improve and Control. According to Montgomery (2013) the DMAIC methodology can also be seen as a uniform process creating conditions for solving complicated problems in a highly sequential manner with tollgates between each phase where stop or go decisions can be made and where changes can be discussed.

Define

In the Define phase of the DMAIC methodology the process that needs improvement is defined along with critical customer requirements also known as critical to quality factors (CTQ) (Andersson et al., 2006; Pande et al., 2000). By determining the CTQs in a process it is according to the authors easier to create a common view of the situation and identify which process to focus on and what tools such as process maps and flow charts can be used to understand the process. Understanding the process and its problems makes it possible to set objectives in the term of performance level and savings which creates a common understanding of the importance of a project (Arumugam, Antony & Douglas, (2012).

Measure

According to Sörqvist and Höglund (2007) successful improvements are based on facts. In order to base improvements on facts the authors claim that the studied problem need data that have been systematically collected and analyzed. In the Measure phase of the methodology the product or process characteristics should be selected and the process should be mapped (Sörqvist & Höglund, 2007). Necessary measurements should be made and the result of the process documented (Sörqvist & Höglund, 2007). According to Arumugam et al. (2012) the Measure phase directs the activities through tools and techniques such as capability studies, cause and effect diagrams and data collection. These tools are used in order to identify and understand the possible variables affecting the CTQs. According to Sörqvist and Höglund (2007) secondary data can be applied in this phase if available and valid, however primary data should be collected in the cases where the secondary data is not reliable.

Analyze
In the Analyze phase data is analyzed with the use of tools like hypothesis testing, Failure Mode Effect Analysis and Multivare methods (Arumugam et al., 2012). The described tools are appropriate to analyze the gathered data objectively and find route causes affecting the CTQs (Arumugam et al., 2012).

Improve
The Improve phase involves activities such as design of experiments (DOE) and brainstorming in order to select and implement solutions to the identified root causes to the problem (Arumugam et al., 2012). The activities should be designed to achieve the desired result (Arumugam et al., 2012). In order to choose the right improvements a matrix diagram can be used where solutions can be evaluated in terms of cost, risk and possible outcome (Sörqvist & Höglund, 2007). Another appropriate tool to use in the improve phase is the Failure Mode Effect Analysis (FMEA) which can be used to highlight possible weaknesses with the suggested solutions (Sörqvist & Höglund, 2007).

Control
The Control phase is the final stage in the DMAIC methodology, in this phase process conditions need to be properly documented and monitored in order to control that the improvements are functioning as planned and that the gains of the suggested improvements are obtained (Arumugam et al., 2012). If new problems appear in this stage a new cycle is started and continuous improvements are applied in order to reach a perfect process or product (Arumugam et al., 2012).

3.3 Lean

Lean is a combined name for several different operational development strategies (Womack & Jones, 1996). The elimination of waste which Lean is often associated with started with Henry Ford in the early 1900s when he established mass production in the Ford factories (Womack & Jones, 1996). Henry Ford's system was then adopted by Japanese companies that later improved the concept turning it to a methodology for identifying and eliminating waste also known as Lean manufacturing or the Toyota production system (Womack & Jones, 1996). The improvement involved activities such as quality circles within the production process itself, the goal was to maintain a continuous flow of products in order to adjust to changes in demand (Womack & Jones, 1996). This sort of flow is known as just-in-time (JIT) production and is the basis of Lean production (Womack & Jones, 1996). The authors mean that the purpose of Lean is to streamline flow by reducing the time to produce a product, with less human effort, less inventory and less space in order to produce top quality products in the most efficient way. Lean can therefore be defined as a dynamic process of change, aiming at achieving continuous improvements with the use of principles and best practices (Womack & Jones, 1996). In many circumstances the implementation of Lean has been superficial; focus has been put into 5s and JIT without an understanding of Lean as an entire system. What is important with Lean is balancing the role of people, their values and continuous improvements with a technical system focused on high value-added flow (Liker, 2009; Ricondo & Viles, 2005). The authors argue that for Lean to work properly it is therefore important to focus on all the elements together as a system. Therefore the Lean concept has over time evolved and extended its meaning from a method of reducing waste into a whole enterprise model (Ricondo & Viles, 2005).

According to Akbulut-Bailey, Motwani and Smedley (2012) there are five fundamental steps in applying a Lean concept; value identification, VSM, creating a flow, pull production and perfection. According to the authors the value identification focuses on identifying what customers perceive as value in products or services. In the VSM the concept of value is clarified and the products or services value streams are identified with the focus on eliminating non-value adding activities (Akbulut-Bailey et al., 2012). When creating a flow it is important to make sure that the products and services flow continuously without interruptions such as blocking or starving (Akbulut-Bailey et al., 2012).

3.3.1 Eliminate Waste

Waste elimination is according to Hicks (2007) a fundamental aspect of Lean and is often used to introduce Lean thinking to manufacturing environments. The identification and elimination of waste first have to be understood before Lean tools can be applied (Hicks, 2007). Within manufacturing there exist eight types of wastes; these are according to Womack and Jones (1996):

- Overproduction – Occur when operations continue when they should have ceased which results in more products being produced than requested increasing the In-plant inventory levels.
- Waiting – Occurs when there are periods of inactivity in a downstream process because the upstream process is not performing as intended.
- Transport – This waste occurs when materials are being moved unnecessary from one operation to another, generally transport should be minimized as it ads no value to the product and the movement can implicit damage to the materials.
- Extra processing – Includes extra operations such as rework, reprocessing, handling, overproduction or excess inventory.
- Inventory – All inventories that are not required to fulfill customer orders are considered wastes. This includes inventory of raw materials, WIP and finished gods. Holding too much inventory can lead to extra cost in the form of additional handling, space, frozen assets and processing.
- Motion – All extra movement made by employees and equipment to accommodate inefficient layout, defects, reprocessing, overproduction or excess inventory.
- Defects – All finished gods that does not conform to the specifications.
- Underutilization of people – Not taking advantage of employees' ideas and creative input.

3.3.2 Value Stream Mapping (VSM)

Value stream mapping is a flow chart analysis tool and is a commonly applied tool within Lean (Montgomery, 2013). Montgomery (2013) and Rother & Shook (2003) describes flow charts as appropriate tools to identify value adding and non-value adding activities within a process. Value adding activities are the activities and elements performed during production that add value to the output of the production (Rother & Shook, 2003). What adds value to the output product is directly dependent on what the customer needs are and what activities the customer is prepared to pay for (Nicholas, 2010). Non-value adding activities are all the activities or elements that does not add value to the end product which the customer is not willing to pay for (Nicholas, 2010). The non-value adding activities can also be divided into necessary and non-necessary where necessary activities are all the activities that need to be performed in order for the product to be processed in a later stage of the process (Nicholas, 2010). Pande and Holpp (2002) explains the use of flow charts further as an appropriate tool to use when seeking a deeper understanding of a process and its different flows. Bergman and Klefsjö (2003) adds that flow charts are useful to define the relationship between different processes and activities and can provide a common language and a reference point for process improvement. However VSM is not only a flow chart but also the process of examining the value flow in order to find improvement opportunities (Nash & Poling, 2008). A value stream map can according to Nash and Poling (2008) be divided into different flows:

- Process or product flow

- Communication or information flow
- Timelines and travel distance

The process or product flow is also known as the traditional flowchart and depicts the flow of the product being produced (Nash & Poling, 2008). According to the authors the flow should be drawn from left to right, never doubling or angling back on itself. If there are subtasks or parallel tasks that are being performed these should be drawn underneath the main flow (Rother & Shook, 2003). If the product flow is mapped this way it should according to the authors be possible to see what the mayor tasks conducted are and where optional paths occur. This will make it clearer where there are problem areas and therefore where improvement opportunities exist (Nash & Poling, 2008).

The communication or information flow section of the map makes it possible to see the communication that exists within a process (Nash & Poling, 2008). The communication flow unlike the product flow does not follow a standardized flow; it can go in any direction and most often consist of non-value added activities that the customer is not willing to pay for (Nash & Poling, 2008).

The timelines and travel distance is most often the most compelling information to the viewer (Nash & Poling, 2008). The timeline and travel distance is presented in the form of lines depicted in the bottom of the flow chart (Nash & Poling, 2008). These lines purpose in the flow chart is to communicate information about production lead time and distance traveled (Nash & Poling, 2008).

The Structure / Flow of Work

As previously explained VSM is a process of examining value flows. VSM can according to Rother and Shook (2003) be performed through four phases; Identifying product families, map of current state, map of future state and work plan for implementation, see Figure 8.

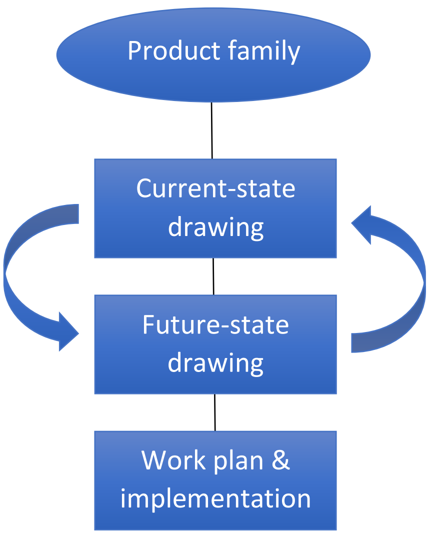

Figure 8: The structure of VSM according to Rother and Shook (2003)

The first phase in the VSM is defining the product family, in this step an appropriate product family needs to be chosen and defined (Rother & Shook, 2003). In most plants several different products are produced, mapping the flow for all products might therefore be time consuming and costly (Rother & Shook, 2003). Choosing a product family that can represent the whole flow is therefore appropriate in order to get a clear picture of the process and its flow. Although this step might sound easy it is possible to define product families from several starting points mapping the value backwards up the value stream (Rother & Shook, 2003). This means that product families can be understood differently where a product family early in the process can be seen only as a component further down the flow (Rother & Shook, 2003).

The current state map is the view of what the process looked like when it was created and is the base of all improvements (Rother & Shook, 2003). It is Important to understand that the current state map is a snapshot in time; therefore it does not change but represent the state at a certain point in time (Rother & Shook, 2003).

The future state map is a vision of how the value stream map will look in the future after the improvements have been implemented, it is the basis of the implementation plan which is the next step in the VSM (Rother & Shook, 2003). The future state map is created through the identification of wastes and improvement opportunities in the current state map which are then eliminated to create a future state map (Rother & Shook, 2003). The difference between the current state map and the future state map is also used in order to identify root causes of waste that exist within the flow (Rahani & Al-Ashraf, 2012). The implementation plan is the last step in the VSM and is used to create solid implementations that will make the most of the available resources and reach the project objectives (Rahani & Al-Ashraf, 2012).

3.4 Lean Six Sigma

Carreira and Trudell (2006) define Lean Six Sigma as the combination of the best features of Lean and Six Sigma in the pursuit of sustainable improvement. Lean and Six Sigma are both methodologies for continuous improvements and have different set of tools and techniques, however they should not be seen this way but rather as business improvement strategies that uses proven techniques and methods (Antony & Banuelas, 2002; Kumar et al., 2008).

Since Lean focuses on speed and efficiency while Six Sigma focuses on accuracy they are in many ways complementary when combined (Arnheiter & Maleyeff, 2005; Berryman, 2002). Lean Six Sigma can therefore be seen as a business improvement strategy which focuses on maximizing value through customer satisfaction, cost reduction, quality improvement and increased process speed (Arnheiter & Maleyeff, 2005; Berryman, 2002). The view that Lean can work well together with Six Sigma is shared by several authors (Pepper & Spedding, 2010; Dahlgaard & Dahlgaard-Park, 2006; Arnheiter & Maleyeff, 2005; Berryman, 2002). However in what way they should be combined varies, Pepper and Spedding (2010) means that Lean can contribute a strategy and structure to drive improvements while Six Sigma tools can be used to drive the improvements to its full potential. Arnheiter and Maleyeff (2005) and Berryman (2002) however means that Lean tools should be implemented along with Six Sigma tools in various stages of the Six Sigma methodology. Even if the view of how Lean Six Sigma should be implemented differs a common gain of the integration can be seen that by using both sets of tools the effectiveness of the Six Sigma approach can often be improved because wastes and non-value adding activities can be identified and eliminated (Arnheiter & Maleyeff, 2005; Berryman, 2002; Pepper & Spedding, 2010).

Although Lean Six Sigma could refer to either integrating Lean and Six Sigma into one concept or using the two concepts separately in different ways, it seems as the benefits of the combination of the concepts are clear (Arnheiter & Maleyeff, 2005). The Lean concept by itself is quite ambiguous, the use of Six Sigma could enhance the robustness of Lean by putting more focus into making decisions based on data and promoting a more scientific approach to quality (Arnheiter & Maleyeff, 2005). At the same time Six Sigma by itself risk providing poor service to customers in the form of long lead times, therefore a combination of the two concepts is beneficial in all cases (Arnheiter & Maleyeff, 2005). According to Juan and Carretero (2010) the best way to perform a qualitative project with good implemented results is to carry out the project according to the DMAIC methodology with proper Lean

Six Sigma tools such as VSM in accordance with the problems faced. The authors also argue that the next step within the Lean Six Sigma research is to conduct practical studies verifying the effectiveness of the integration between DMAIC and Lean tools such as VSM.

3.5 Selected Improvement concepts

From the previously explained concepts Lean, Six Sigma and Lean Six Sigma it is clear that there are positive and negative factors in the different concepts and that benefit can be drawn from using the combination Lean Six Sigma. There is according to Assarlind et al. (2013) no clear-cut standard to how Lean Six Sigma should be implemented; it is however important to have a conscious and easily understandable approach based on Lean Six Sigma when improving processes. According to Juan and Carretero (2010) there is 6 main ways in which Lean and Six Sigma can be combined where Six Sigma can be used as a part of Lean, Lean as a part of Six Sigma, Lean and Six Sigma separately to solve different problems, Lean and Six Sigma separately to solve one problem, Lean and Six Sigma in a sequence and Lean simultaneously to Six Sigma.

Implementing Six Sigma as a part of Lean means that Lean is the main encompassing methodology while Six Sigma is used as a tool to for example improve kaizen events detected in the VSM (Juan & Carretero, 2010). Lean as a part of Six Sigma on the other hand means that the Six Sigma DMAIC is the encompassing methodology while Lean tools are integrated within these steps (Juan & Carretero, 2010). In the third model type Lean and Six Sigma is used separately at the same time to tackle different problems within the project (Juan & Carretero, 2010). In the fourth method both methodologies are applied to the same problems separately in order to get a more holistic picture (Juan & Carretero, 2010). The fifth method is closely connected to the previous method and means that Lean and Six Sigma is implemented to a problem one after another (Juan & Carretero, 2010). The final approach discussed by Juan and Carretero (2010) is the one also recommended by the authors where Lean and Six Sigma is applied to the same problem simultaneously. In the study VSM plays a central role in order to give an understanding of the studied process and its activities. VSM is also a good reference point for further improvements (Rother & Shook, 2003). Juan and Carretero (2010) explains that different tools can be appropriate to use in different phases depending on if a project is run through the Lean methodology PDCA, Six Sigma's DMAIC or Lean Six Sigma DMAIC. However the use of tools is dependent on the project where different emphasis can be put on different phases of the project (Juan & Carretero, 2010). VSM is generally known as a Lean tool however it can be used in Six Sigma and Lean Six Sigma projects as well (Juan & Carretero, 2010).

In this study a DMAIC methodology was used which according to Sörqvist and Höglund (2007) is a theoretically more suitable approach than the Lean methodology PDCA. Sörqvist and Höglund (2007) explains that the reason why DMAIC is considered a better approach is its structured way of improvement with emphasis on result and fast implementation. The implementation of Lean Six Sigma should however be through a holistic DMAIC structure where the define phase creates an understanding of customer value and the process (Sörqvist & Höglund, 2007). The current state map of the VSM is according to Juan and Carretero (2010) supposed to be in the phases Measure and Analyze where data is collected to understand the baseline performance. When creating the current state map improvement ideas start to arise which causes the analysis to start. This means that the integration of Lean and Six Sigma forces the Measure and Analyze phase to be closer to each other. In the improve phase the process is adjusted to improve the production flow and create a pulling production (Juan & Carretero, 2010) In the control phase the process is controlled in order to reach perfection, see Figure 9.

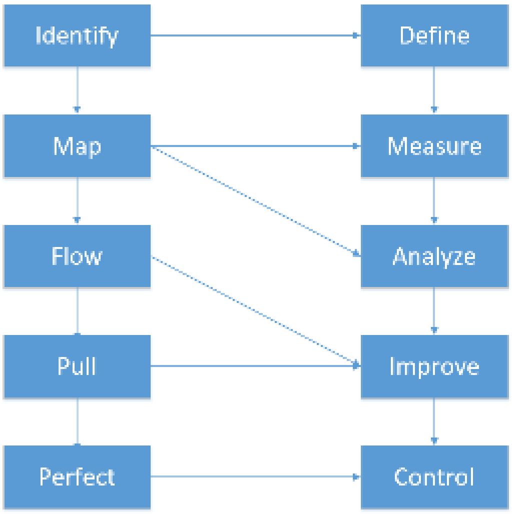

Figure 9: The integration of Lean and Six Sigma

Juan and Carretero (2010) also describe the tools that can be used in the different phases for a Six Sigma projects where Lean is a part of Six Sigma. The phases along with appropriate tools are presented below, see Table 1.

Table 1: Description of tools used in the different phases of a Six Sigma project where Lean is a part of Six Sigma based on the article by Juan & Carretero (2010)

Six Sigma project phase	Applicable Lean Six Sigma tools
Define	• Introduce financial analysis: identify waste; and quantify waste financially • Use SIPOC to understand the VOC and prepare for VSM • Introduce process baseline performance including VSM metrics; inventory; lead time; cycle time; value-added versus non-value-added activities; and downtime • Identify the LSS suitable tools and approach to the selected project: determine if the focus is on product flow or variability
Measure	• Measure the baseline performance of the current process • Use the Lean metrics to measure the baseline • Map the current state value stream • Identify waste and quantify it financially • Use a Kaizen event approach and identify any quick improvement actions
Analyze	• Implement the quick hits as they do not require further analysis • Analyze the current state VSM. For example: analyze unnecessary steps and ways to minimize waste within and between steps; analyze flow of products and information; analyze lead time, cycle times and rework; and analyze downtime and changeover time. • Create a Lean future state VSM to implement in the next phase
Improve	• Optimize and standardize the process; eliminate unnecessary steps or at least minimize waste within it; develop standard operating procedures and best practices; build an improvement implementation action plan • Use a Kaizen event to implement improvements. For example: improve time and motion; improve cell design, consider human factors and work balance; implement single piece flow (reduce batching); standardize processes; use Kanban; use 5S approach; use TPM and quick changeover approach; use mistake-proofing techniques; and use visual workplace approach
Control	• Design a control plan using the mistake-proofing approach; design and implement corrective actions; design an audit plan; and design visual work place controls • Train process owner on using the control plan and monitor continuously

3.6 Overall Equipment Effectiveness (OEE)

According to Dal, Tugwell and Greatbanks (2000) Overall equipment effectiveness is a combination of operation, maintenance, management of manufacturing equipment and resources. The authors also argue that accurate performance data are essential in order to achieve long-term success. If the extent of equipment failures and their reasons are understood it is according to Dal et al. (2000) easier to solve major problems.

At TitanX overall equipment effectiveness (OEE) is a measurement dependent on three factors; availability, performance and quality. The OEE is calculated from the planned time where the planned time is equal to 100 % OEE. Depending on the availability to operate, performance of the machine or operators and the product quality a measurement of OEE is calculated where availability* performance* quality equals the OEE, see Figure 10.

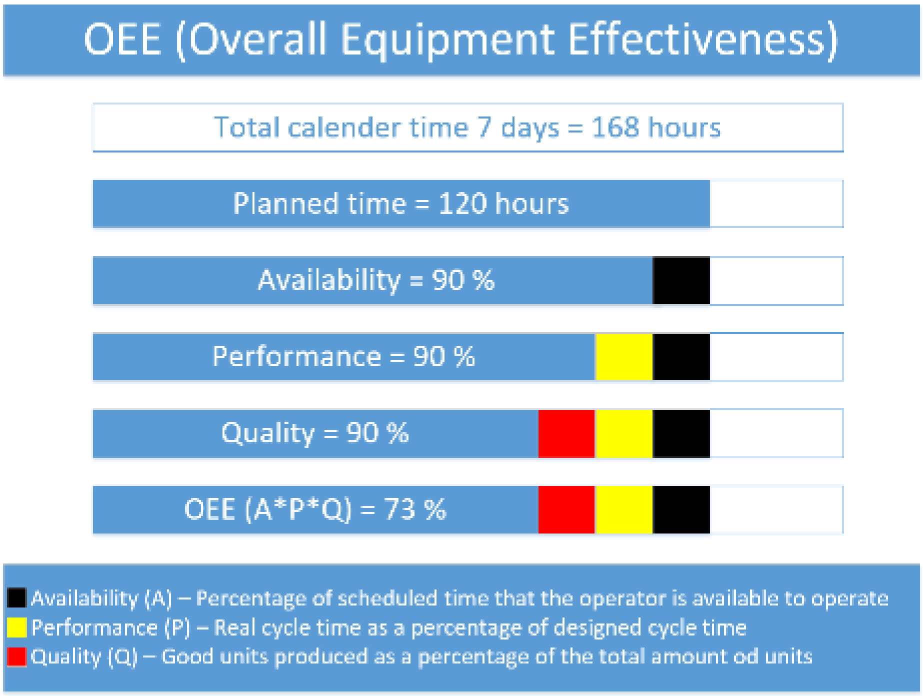

Figure 10: Overall equipment effectiveness and its included parts according to TitanX

3.7 In-plant Transportation

There are many ways in which transportation can be carried out in a plant, through the use of forklifts, manual movement or by conveyor belts. In order to adapt to the needs of Lean production principles many manufacturers in the automotive industry have begun to use new material supply concepts such as the In-plant milk run system, also known as Mizusumashi (ElMaraghy, 2012).

The milk run system means that in-plant transport is being manually operated in a cyclic transport system where material is being delivered and empties disposed at the different work stations, see Figure 11.

According to ElMaraghy (2012) the usual steps for an In-plant milk run are:

- Loading materials on means of transport at a warehouse or stock
- Transporting materials to the work station
- Unloading materials at the workstation

- Transporting empties to warehouse or stock
- Unloading empties

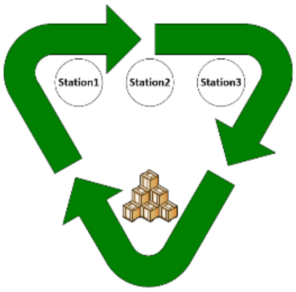

Figure 11: Example on how the in-plant milk run can be executed, drawn loosely based on (ElMaraghy, 2012).

The delivery of material and disposal of empties should according to ElMaraghy (2012) be based on consumption through fixed route and time schedule. The design of the milk run is dependent on a number of different general conditions; material source, handling unit, replenishment principle, route, assignment of vehicle to route, milk-run control principle, integration of loading process and integration of empty bins in process (Klenk, Galka & Günthner, 2012).

The use of In-plant milk run systems are constantly increasing, the reason for this increasing interest is the In-plant milk run systems possibility to supply numerous different materials to the production line (Klenk et al., 2012). If used correctly the In-plant milk run system can provide a fast, frequent and reliable In-plant supply process (Klenk et al., 2012). However choosing how to supply material using an In-plant milk run is a complicated process with many different options, see Table 2. Therefore creating an appropriate supply run is not often simple (Klenk et al., 2012).

Table 2: Classification criteria for different milk run concepts, drawn loosely based on (Klenk, Galka & Günthner, 2012)

	Criterion	Values
General conditions	Material source	Automated storage system
		Manual storage system
		Production supermarket
		Buffer area
	Handling unit	Small load carrier
		Large load carrier
		Special carrier
		Mixed carriers
	Replenishment principle	Kanban
		Reorder level
		Sequenced orders
		Demand-oriented
Organizational structure	Route	Fixed route
		Dynamically planned route
		Flexible route
	Assignment of vehicle to route	Fixed assignment
		Flexible assignment
	Milk-run control principle	Takt/fixed schedule
		Workload oriented
		Permanent
		On demand
	Integration of loading process	As part of tour
		Separate loading, buffering of loaded trailers
	Integration of empty bins process	1:1-exchange
		Pick up on demand
		No integration

Shown below are the results from a case study by Klenk et al. (2012), see table 3 where 21 companies supply systems were examined. Every point represent what conditions a company have when it comes to the supply of material. The conclusions drawn was that the use of In-plant milk run systems can vary a lot, however commonly milk-runs are operated on fixed routes with fixed assignment of vehicles on routes. Most small bin processes operate on a fixed schedule whilst large bin processes run permanently with the gathering of empty bins integrated into the milk-run.

According to Klenk et al. (2012) following the common way of conducting a milk run is most often the best alternative, however depending on the circumstances other alternatives can be more suitable. Therefore it is important to develop a system that suits the operation and the need of materials (Klenk et al., 2012).

Table 3: Morphology of typical milk run concepts, drawn losely based on an empirical study by (Elmaraghy, 2012)

General conditions	Material source	Automated storage system	Manual storage system	Production supermarket	Buffer area
	Handling unit	Small load carrier	Large load carrier	Special carrier	Mixed carriers
	Replenishment principle	Kanban	Reorder level	Sequenced orders	Demand-oriented
Organizational structure	Route	Fixed route	Dynamically planned route	Flexible route	
	Assignment of vehicle to route	Fixed assignment	Flexible assignment		
	Milk-run control principle	Takt/fixed schedule	Workload oriented	Permanent	On demand
	Integration of loading process	As part of tour	Separate loading, buffering of loaded trailers		
	Integration of empty bins process	1:1-exchange	Pick up on demand	No integration	

4. Case Study Define

This chapter is the start of the DMAIC methodology containing the Define phase where the problem, process or product to improve is defined and the importance of the project is discussed. In the chapter the case study project is described along with its purpose from different perspectives. The problem is also described followed by a SIPOC of the studied process. Finally the examined product families are described followed by the business improvement opportunities.

4.1 Project Description and Purpose

The following project was part of a bigger project to eliminate losses in the manual assembly at TitanX. In the assembly process blocking and starving was according to the company considered the main block for OEE, therefore reducing blocking and starving was considered crucial for the production. Blocking and starving affects the performance of the process where starved time is the total time a process is stopped due to upstream problems and blocked time is when the process is stopped because of downstream problems (Rother & Shook, 2003).

The purpose of the thesis work was to study and illustrate how value stream mapping can be executed in a structured manner according to the DMAIC methodology. A secondary purpose with the thesis work was to through the use of the "VSM-DMAIC approach", present and implement improvements in a production process. In this study the Six Sigma methodology was implemented in the way discussed by Juan and Carretero (2010) where the Six Sigma methodology DMAIC was considered most appropriate to use as the basis of the improvement project with Lean tools as complementary tools in order to strengthen the Six Sigma approach and its tools.

The purpose of the project from the company's perspective was to decrease losses due to blocking and starving in the production by implementing solutions suggested by the researcher. A Reduction of losses caused by blocking and starving was needed in order for the company to reduce cost of missed sales, poor quality because of a stressful environment and personnel working overtime.

4.2 Problem Description

In order to reach customer requirements materials for the assembly are needed for the operators to start building; if materials are not available the process is starving. In order for operators to produce products there need to be capacity in the next process step. If the capacity is not enough stock will build up and the process will eventually be blocked. The assembly station should never be at a stand-still during scheduled production for the production to go as planned. The linefeeder is responsible for supplying material to the pre-assembly and assembly areas in order to avoid operators running out of material. The replenishment process was according to the company not running very smoothly and the operator often ran out of material or had to get materials themselves.

TitanX also felt they had problems with the blocking and starving of material entering the assembly. The lack of materials made it difficult to produce to customer orders which lead to production of defective products because of the increased pressure to produce when materials were available. When materials must wait for the next coming process it is difficult to follow up and find the causes of defects since many of the parts were produced a long time ago. The causes of the defects can then have been forgotten or lost. Therefore the defined problem to examine is: *The manual assembly process is not performing as expected due to blocking and starving.*

4.3 SIPOC

To obtain an understanding of the process a SIPOC was created containing information about the suppliers, the process, input and output of the process followed by the main customers, see Figure 12.

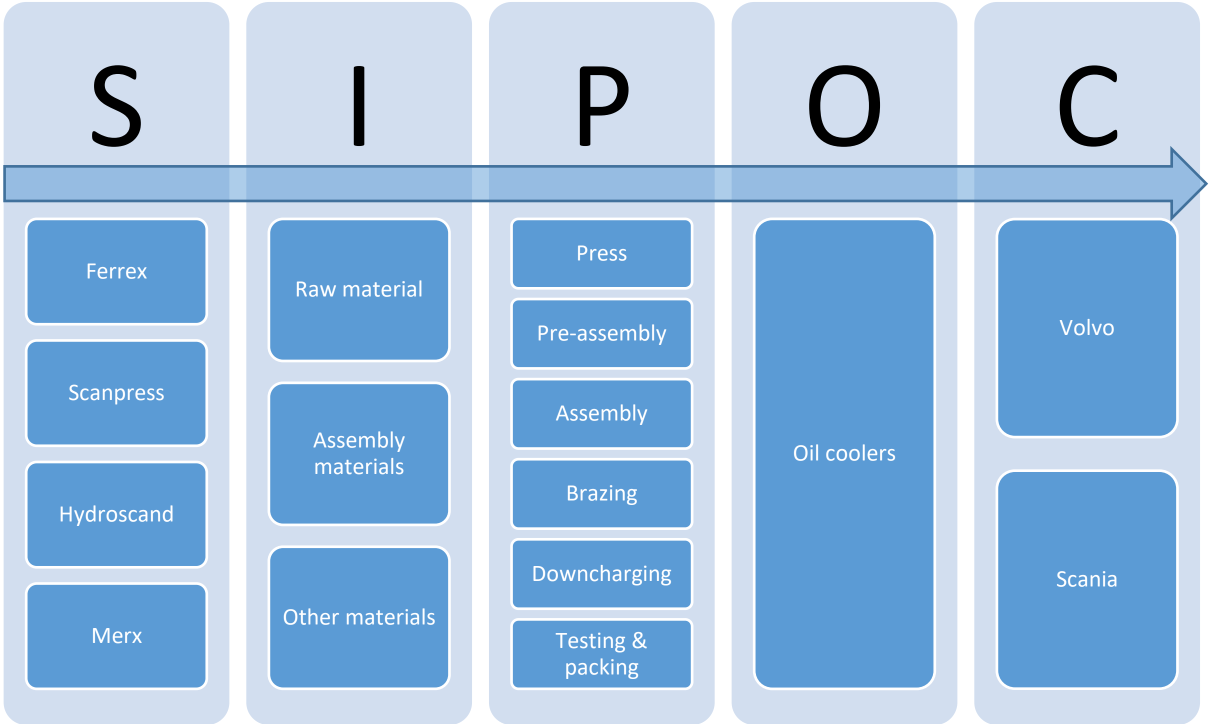

Figure 12: SIPOC analysis of the studied process

4.3.1 Supplier

The suppliers of the process are both external and internal. Internally there are previous processes that produce materials needed in subsequent processes. Externally there are both suppliers of raw materials needed in the presses as well as suppliers of specific parts needed in the pre-assembly and assembly process.

4.3.2 Input – Process - Output

The production consists of mainly six operations; press, where raw materials are pressed into plates and turbulators. Pre-assembly where produced and purchased materials are welded, punched or riveted into components before they reach assembly. In the assembly process the coolers are assembled manually from internally produced parts together with purchased materials before they are sent to the furnace where they are brazed to finished coolers. In down-charging the coolers are picked from there grids into trolleys. In testing the trolleys are rolled into an area where coolers are tested for leakage and other defects. After tested the finished coolers are packed into boxes ready for delivery.

4.3.3 Customer

The customers of the process are companies in the heavy vehicle industry who need the produced coolers in order to produce their own products. The demand is registered electronically by the customer to TitanX customer service.

4.4 Defined Product Family

In order to get a deeper understanding and a common view of a process value stream maps can be used (Montgomery, 2013). When selecting a start point from which to move upstream, mapping the process it is often best to follow a single product family. A product family can consist of several products which also consists of several components (Rother & Shook, 2003). Mapping the value stream of every component for every product would therefore be very time consuming, costly and result in an overwhelming amount of data (Rother & Shook, 2003). In order to choose an appropriate product family to investigate the different product families had to be defined. From observations and interviews two different product families were identified. Products flowing through the pre-assembly and products where material flows directly from stock to assembly.

TitanX has a lot of different products, to get a clear picture of what the process looks like three products were examined, this is because "*the first objective of extended mapping is to achieve a breakthrough in shared consciousness of waste and to identify systematic opportunities for eliminating the waste*" (Rother & Shook, 2003). It is very likely that the identified wastes for the chosen component going upstream are the same for other products in the same product family (Rother & Shook, 2003).

The products chosen to examine during the project were Matdosan XL, MD 13 and HDE 13. The chosen products are high volume products with components going through the pre-assembly phase. The pre-assembly process is of extra interest since the company has experienced most issues with blocking and starving in the pre-assembly production step. The three products chosen to examine have a high or fairly high production rate and are therefore of most importance to the company. There is also plenty of usable data on the products gathered by the company as well as opportunities to visually check the coolers being produced. Being able to follow production makes it easier to map the value stream and identify wastes.

4.5 Business Improvements Opportunities

The monetary benefit of the performed case study is quite difficult to define however by decreasing blocking and starving in the assembly stations efficiency can be increased and lead time for the products can be reduced. Stock can be decreased before the pre-assembly and assembly processes and starving can be decreased after the assembly process where machines stand empty in the wait for mounted coolers. Apart from the explained improvements above a more efficient pre-assembly and assembly process will lead to the possibility to produce more products if needed or reduce number of operators. From the production system it was clear that from august 2014 to September 2015 a total of 4304 hours were lost in assembly when other activities than mounting were performed, see Figure 13.

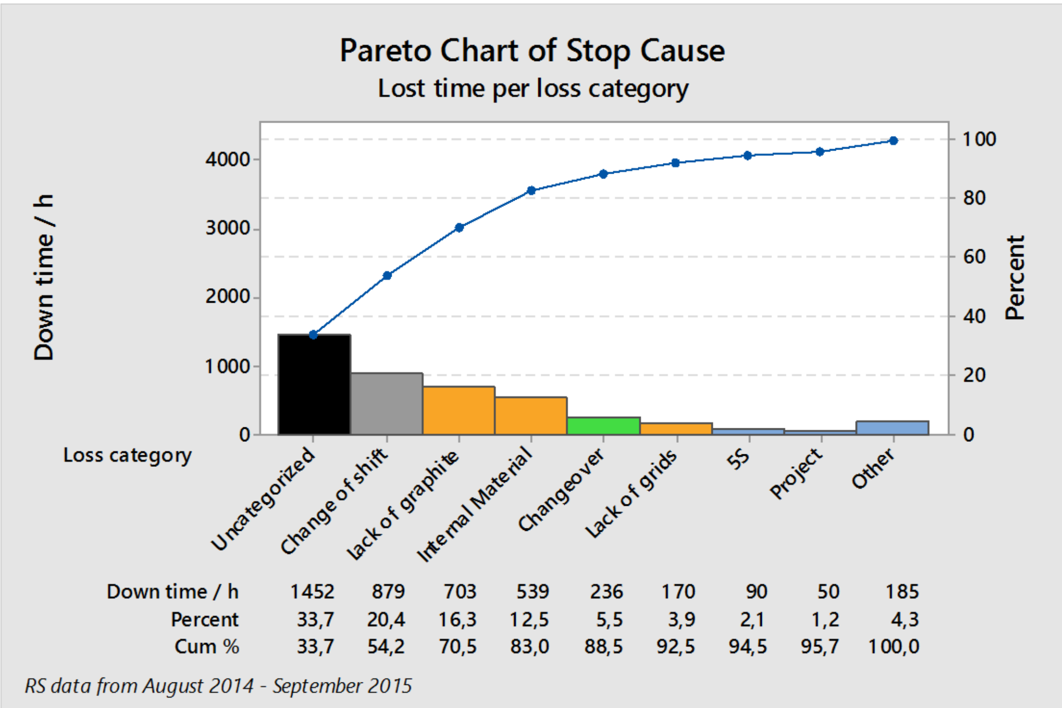

Figure 13: Pareto chart of stop causes according to baseline data

A total of 1412 hours of down time was because of starving and blocking which are colored orange in the Pareto chart. Apart from these hours of down time some starving and blocking was believed to be hidden in uncategorized down time.

In order to estimate the cost of the down time three frequently produced coolers sales value and production value were examined to estimate the cost of missed sales. The cost of missed sales were examined through cost per hour of down time, see Table 4.

Table 4: An estimate of cost per hour lost in production

Cost per hour in lost production			
Cooler	**Matdosan XL**	**MD 13**	**HDE 13**
Sales value			
Prod. Value		**Classified information**	
Cycletime (CT) in seconds			
Lost parts			
Total cost / hour	**4746 kr**	**4136 kr**	**7225 kr**

The average cost per hour a cooler is not produced was 5369 kr with the assumption that all produced products are sold. Assuming all coolers are sold this would result in a cost of missed sales of approximately 7 million SEK each year. An option to calculate the indirect cost through lost revenue is to calculate the direct cost for personnel that are not being utilized. The cost for one operator is approximately 300 kr/hour which would result in a cost of 390 900 SEK each year.

The aim of the project was to reduce losses in the assembly phase to an as high extent as possible. However in order to call the project a success a decrease of 10 % needed to be achieved. A decrease of blocking and starving with 10 % might not sound much but the examined problem is a complex problem that has existed for years. In order to suggest and implement solutions in the given time frame delimitations needed to be made resulting in the presented aim. A reduction of blocking and starving with the goal of 10 % would result a reduction of indirect costs of 697 477 kr each year or a reduced cost of unutilized personnel by 39 090 kr.

5. Case Study Measure

In this chapter information connected to the defined problem was collected. Presented in the chapter are current state maps followed by a problem breakdown and a data collection plan. Finally the base line performance and losses of the process are presented.

5.1 Current State Map

To achieve the research purpose, current state maps were produced. The maps were created in order to ensure that blocking and starving was a prominent problem in the process that needed attention. The maps were also created to simplify the identification of causes to the problem and ways in which the problem could be reduced.

From the chosen product families current state maps were produced. The current state maps were created for the complete flow within the plant; three different products were examined through the flow in order for a secure and valid picture of the value stream to be obtained. The value stream maps were created by the researcher following the production for a week to ensure that all steps were included and properly understood. When needed interviews were conducted so that a true picture of the current state could be obtained. The process data were then finalized through the use of baseline data from recent data collections. The results of the value stream mapping are presented below, see Figure 14. The different value stream maps were very similar, the value stream maps for MD 13 and HDE 13 are therefore presented in the appendix, see Appendix B.

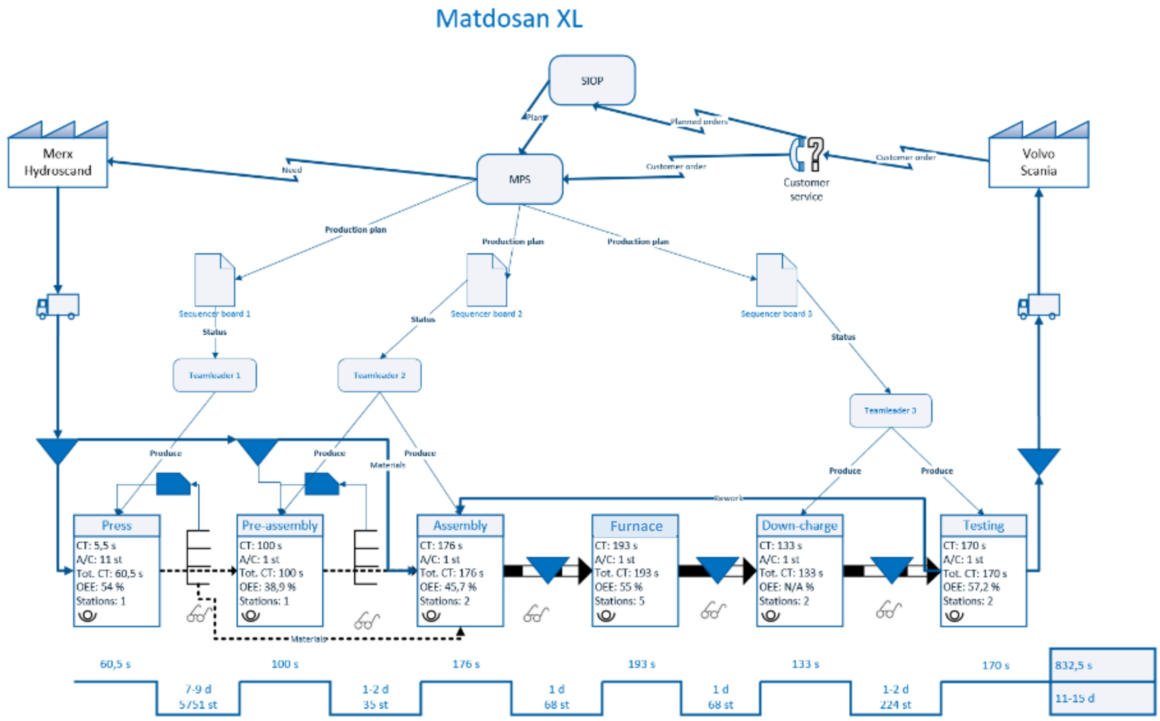

Figure 14: Value stream map for Matdosan XL

The process consisted of mainly six process-steps press, pre-assembly, assembly, furnace, down-charging and testing. Between each operations there were different sorts of inventories, between press and assembly supermarkets were used together with a Kanban system. In assembly materials were not only picket from the supermarket, but also from two regular inventories containing graphite and purchasing materials. All inventories were manually monitored and checked regularly since the production system could not be completely trusted. After the assembly a pull system was hard to obtain since the assembly process seemed to be a bottleneck in the process and batch sizes in the furnaces were not constant. Presented in the value stream maps are also values such as cycle time, needed parts per cooler, cycle time to produce the amount needed for one cooler and OEE. Examples of suppliers are Merx and Hydroscand who received needs from the MPS. The Siop was the basis for the Master production schedule (MPS) together with the direct customer orders and changes in demand from customers such as Volvo or Scania. The long-term demand was put into the Siop which is a sales inventory and operations plan. This plan was updated monthly and was a rough plan for 13 months ahead. The MPS was a plan of all the production in the plant and was therefore the basis for the sequencer boards which explained what needed to be done in the different work areas where a Team leader was responsible for making sure the planned amount of coolers were produced.

The throughput time for the product was 11- 15 days while process time was 832,5 seconds resulting in a value added ratio of 0,074 %. A value added ratio of 0,074 % was not considered to be good enough; the main reason for the low ratio was the long inventory times in the beginning of the process.

5.1.1 Process Balance

In order to obtain a better picture of whether the process was unbalanced and where the process was unbalanced the cycle time for the different operations were examined, these are also the values presented in the value stream maps, see Figure 15. In the case where the production system could be trusted it was used to get a picture of process time, however this was only the case for press and testing. For the other processes manually gathered data from the last months were used where time to produce a whole batch had been examined. The measured cycle time was the complete cycle time and therefore included stoppages in production for different reasons. Therefore it was possible to improve efficiency without putting emphasis on operators needing to produce faster.

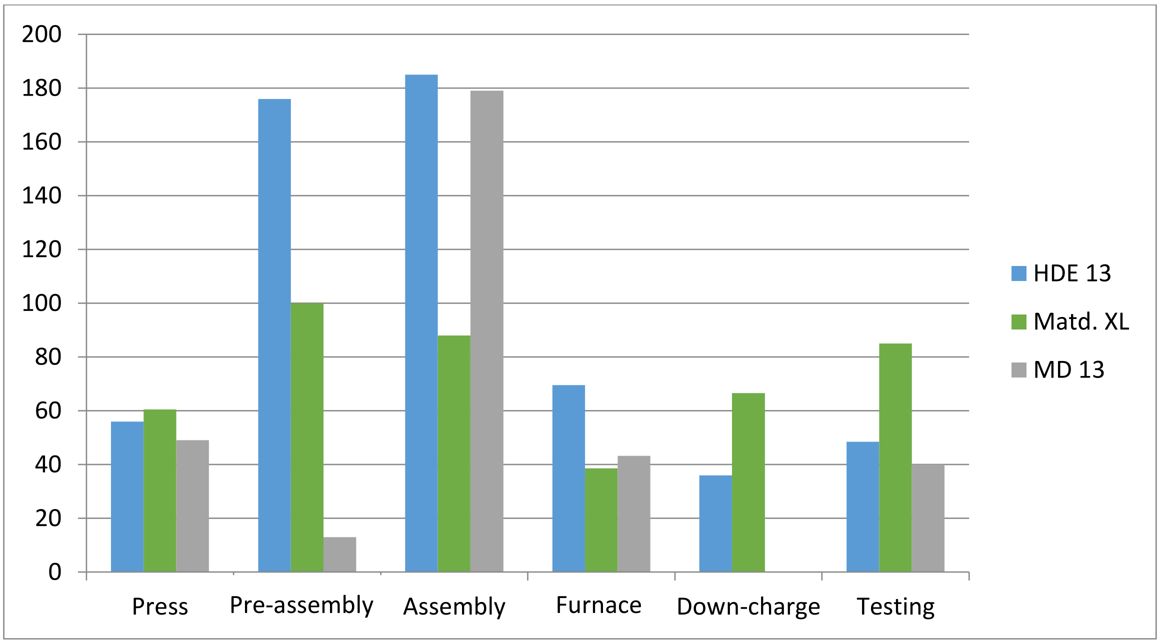

Figure 15: Cycle time per cooler in the different process steps

From the process analysis it was clear that some processes take more time than others. In the examined flow pre-assembly and assembly are the main issues that need to be improved since the long lead times results in the presses being blocked and the subsequent processes starving. Since blocking and starving was the most visible problem in the value stream maps it was chosen to continue with.

The Assembly process and pre-assembly process were closely connected to each other since they were operated by the same work team, which means that the same people assembling also had to operate the pre-assembly stations. Assembly personnel often had to move to pre-assembly because there were pre-assembly parts missing which assembly needed. Therefore cycle time in assembly could be improved by decreased cycle time in pre-assembly. In order to decrease cycle time in pre-assembly and assembly blocking and starving needed to be reduced.

5.1.2 Assembly Current State Map

In order to get a better picture of the process flow in the assembly areas a more thorough value stream map was created, see Figure 16. The reason for the creation of a focused value stream map was the complexity of the flow in the area and because the process was perceived as problematic.

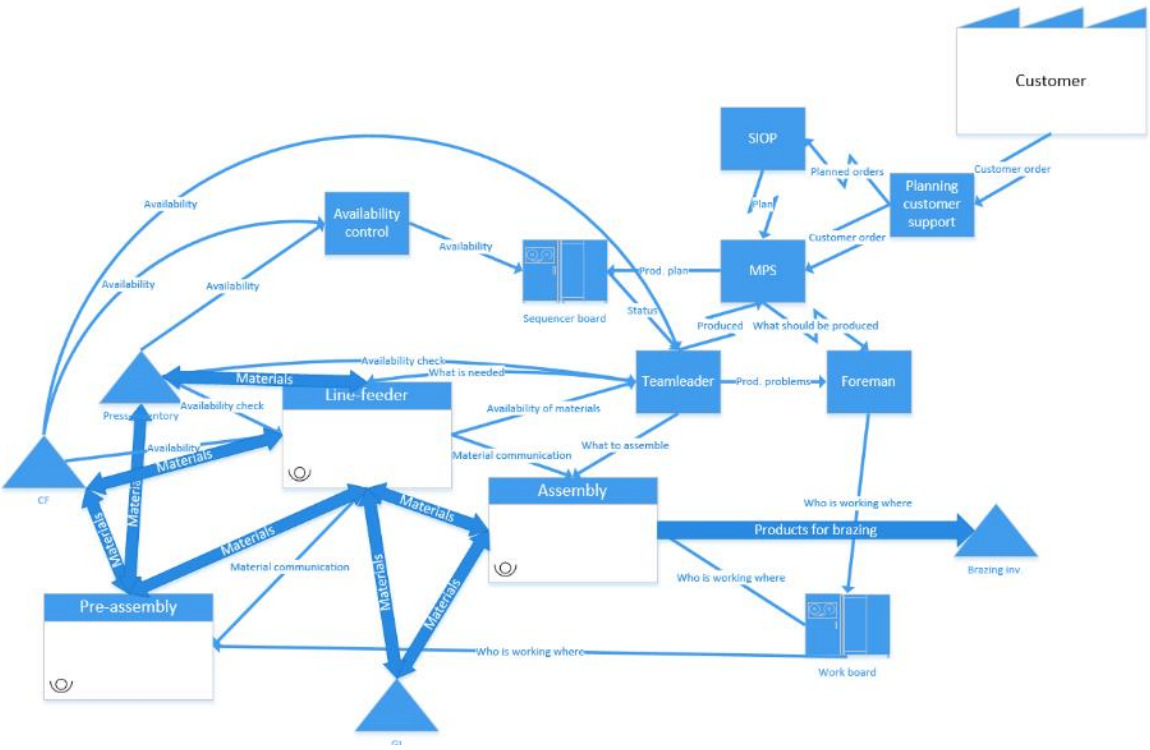

Figure 16: Focus value stream map of the assembly processes

What can be seen in the focus area was that the linefeeder plays an important role since he was the hub of most material movement and communications. It was therefore crucial that the linefeeder performed work as intended. However the linefeeding task was perceived as quite complicated since a lot of different materials from different stocks were needed in different stations resulting in the linefeeder not knowing what materials assembly and pre-assembly needed and when they were needed.

The problems that can be seen from the focus map was the need for inventory checks each day since the system could not be trusted. The inventory checks were also performed by several people amongst them the linefeeder resulting in even more wasted time.

The linefeeder also provided materials for some stations but not to other stations and some materials but not others. Which materials were provided to which stations depended on who was linefeeding. The fact that not all materials were replenished created need for operators to fetch the needed materials themselves.

While several people controlled inventory of some materials no one checked availability of graphite in the graphite inventory. The graphite needed in the assembly process was not a value-adding component but was needed in order for the coolers to go through the furnace. The fact that availability of graphite was unknown was creating many problems for the assembly stations where production was blocked because graphite was missing for some products.

5.2 Problem Breakdown

To get an understanding of the problem caused by blocking and starving an ishikawa-chart was created with a 6M foundation where the experienced problem was divided into manpower, machine, method, material, measurements and management. The chart was created through brainstorming within the project group and resulted in the following causes, see Figure 17.

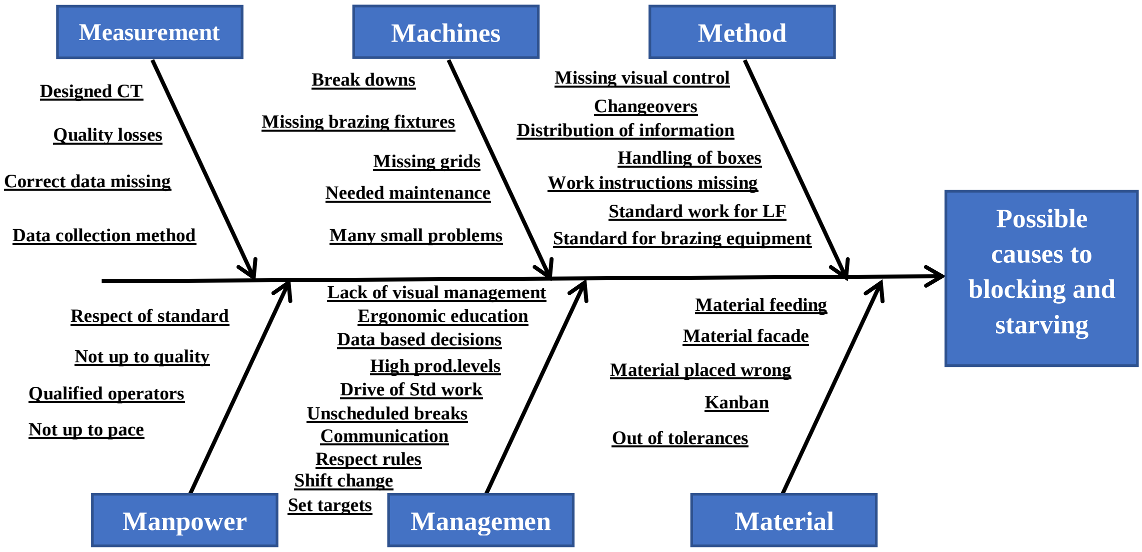

Figure 17: Ishikawa-chart of the possible causes to blocking and starving

From the ishikawa-chart it was clear that the blocking and starving was a quite complicated problem with many possible influencing factors and possible causes. A focus area for improvement was therefore appropriate in order to reach the aims.

5.3 Data Collection Plan

To reach a deeper understanding of the problems experienced by the company the current process needed to be measured and an understanding of the problem needed to be obtained. In order to obtain the needed information without missing or invalid data a data collection plan was created. Data collection plans are often used within Six Sigma to assure that the data collection process and measurement systems are stable and reliable (Kwak & Anbari, 2004). The authors argue that using a data collection plan ensures that the data can be used to support the analysis. The general steps in a data collection plan are: Define the goals and objective of the data collection, agree on the methods for collecting data, ensure data collection repeatability, reproducibility, accuracy and stability, collect the data and ensure data is reasonable.

The project was meant to reduce stoppage because of blocking and starving in the manual assembly processes at TitanX, in order to do so specific data were needed. In order to understand why stoppages in assembly occurs, data were needed that could explain how much time was spent on other activities and what those activities were. The data needed to provide insight of not only how much time was spent performing other activities but also how much time was spent performing certain activities. Knowing what was occurring was crucial in order to reduce the stoppages. The collected data were then analyzed through Pareto charts in order to create an idea of what should be the focus area to improve.

In order to get an overview of how the process performs the pre-assembly and assembly processes needed to be measured. After a discussion with the project supervisor it was clear that three measurements on each station were enough to receive a valid picture of the process. The process also needed to perform somewhat normal during the measurements in order for a valid overview of the processes performance to be achieved. It was also decided that these measurements should be at least three hours at a time in order for changeovers and other activities to be detected. The data collected were present data because of two reasons; it gave the best picture of the process at the time since reasons for stoppages were often not categorized by operators. The data were gathered by observing one station at a time and documenting how much time was spent doing other activities than assembling. The measurements were performed by timing the operators as soon as they left the station, when the operator returned the reason for the operator leaving the station was noted.

In order to ensure that the data collection was accurate a practice test was conducted at pre- assembly and assembly in order to reach an understanding of how the measurements could be conducted and what possible activities existed. During the practice test questions such as: what should be measured, how should it be measured and what is needed to do the measurements were answered.

The data collection was then performed according to plan where three measurements were conducted in each sub process. All measurements were conducted for three hours or longer. The data were then put in to an excel file where it was compiled and checked if reasonable.

5.4 Baseline Data of the Current Process

Presented below are the results from the conducted data collection where measurements were conducted on the linefeeding, pre-assembly and assembly processes. Although baseline data were available in the beginning of the study, the existing data were not 100 % reliable with a lot of information missing. Therefore there was a need to collect new data containing information of what was happening when stoppages occurred and how much time stoppages took.

5.4.1 Performed Activities at Pre-assembly

The measurements conducted in the pre-assembly area made it clear that approximately 55 % of the available time was spent assembling while 18 % was spent performing activities caused by blocking and starving and 27 % of the time was spent performing other activities not caused by blocking and starving, see Figure 18.

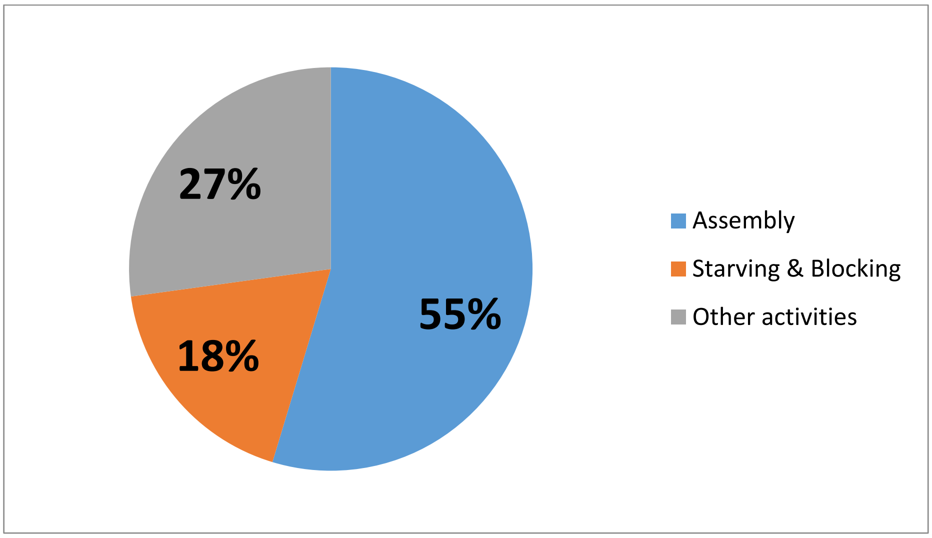

Figure 18: Performed activities in pre-assembly

To get a clearer picture of what the blocking and starving and other activities were and what caused the losses the activities were divided into different losses. The three main losses in pre-assembly were material pick-up and drop-off which stands for 23,3 % of the total loss in pre-assembly while polishing materials stood for 19,4 % and changeover stood for 17,1 %. The losses that are circled are the losses caused by blocking and starving, see figure 19.

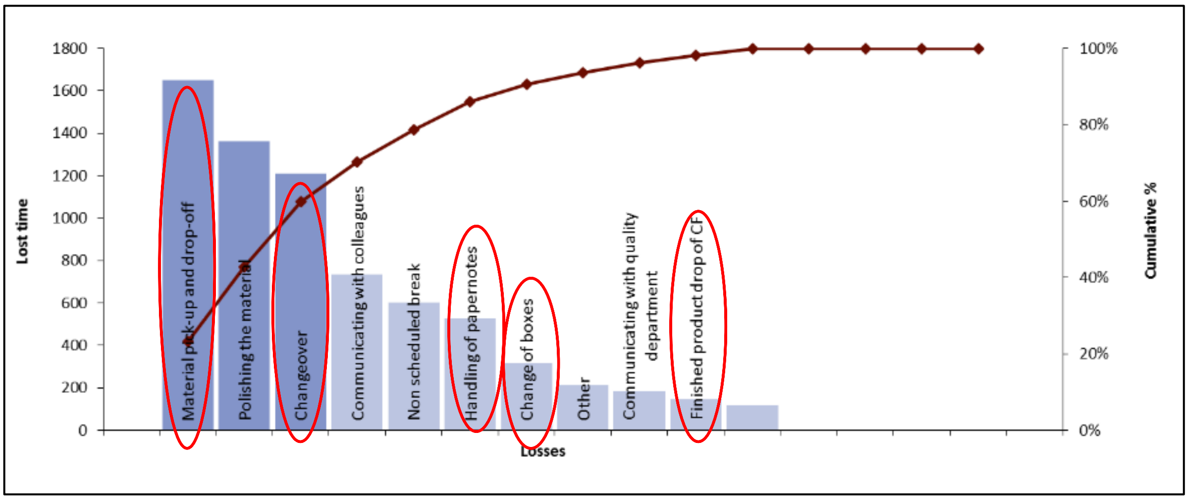

Figure 19: Losses in pre-assembly

Material pick up and drop of was directly connected to the linefeeding since it was the linefeeders task to supply materials to the stations. Changeovers were also connected to the linefeeding since they should be prepared beforehand by the linefeeder who should try to reduce the time to perform changeovers. Handling of paper notes, change of boxes and finished product drop-off were activities performed by the operators since no one was in charge of handling these tasks.

5.4.2 Performed Activities at Assembly

In the assembly process not as much time was spent on other activities. For the twin flow integrated coolers (TFI) 21 % of the time was spent performing other activities than assembling, 12 % was caused by blocking and starving. For the single flow integrated cooler (SFI) 21 % of production time was spent on other activities. For the SFI 10 % of time was spent on activities caused by blocking and starving, see Figure 20.

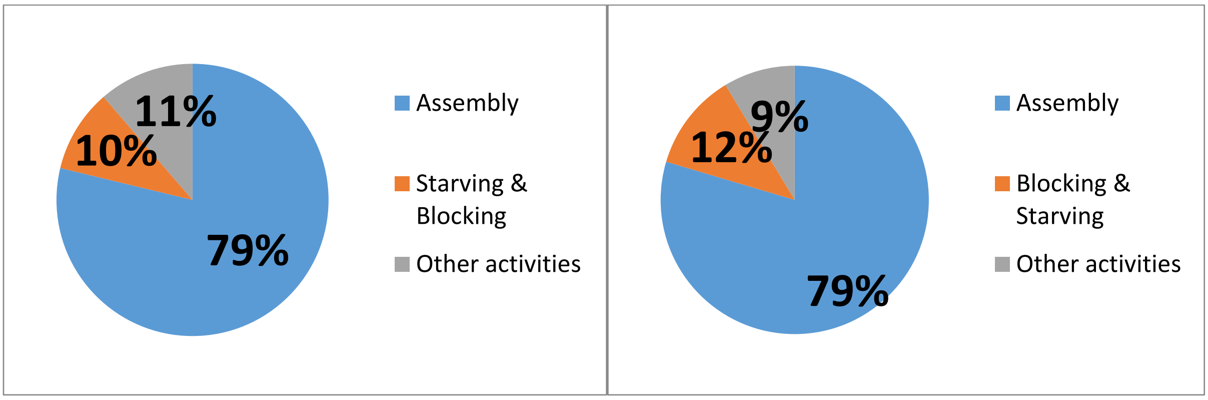

Figure 20: Performance of TFI assembly to the left and SFI assembly to the right

The loss Pareto for the TFI-stations shows that the main losses were non-scheduled breaks, changeover and missing materials, see Figure 21. Missing materials was directly connected to starving as well as communication with linefeeder since the communication often appeared when materials were running low. Changeovers taking a long time were also connected to blocking and starving since the stations were blocked by old materials and starved of new materials during changeover.

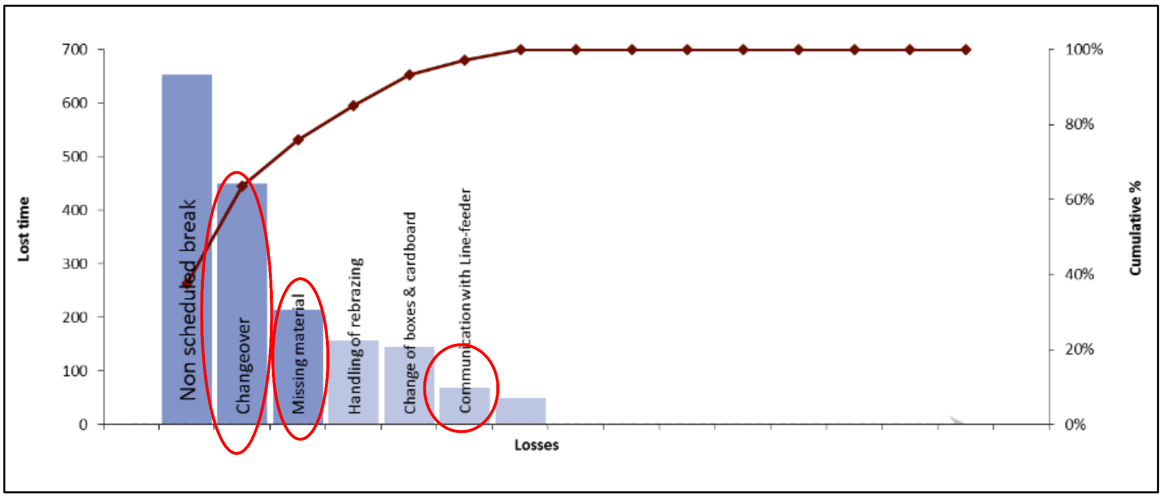

Figure 21: Losses in TFI-assembly

For the SFI-stations changeover, non-scheduled breaks and change of boxes were considered the biggest problems where change of boxes was closely connected to blocking and starving. Change of boxes were performed by the operators when there was no room at the station resulting in blocking, see Figure 22.

In the Pareto charts for the assembly stations the linefeeder also plays an important role. It is believed that in the TFI assembly losses; Changeover, Missing materials, Change of boxes and Communication with linefeeder were activities connected to the linefeeding. In SFI assembly losses; Changeovers and Change of boxes were activities connected to the linefeeding. What could be seen from the gathered data were that a lot of the time spent doing other activities, especially the ones connected to blocking and starving in pre-assembly and assembly were activities that should or could be handled by the linefeeder but were not specified in the linefeeder standard.

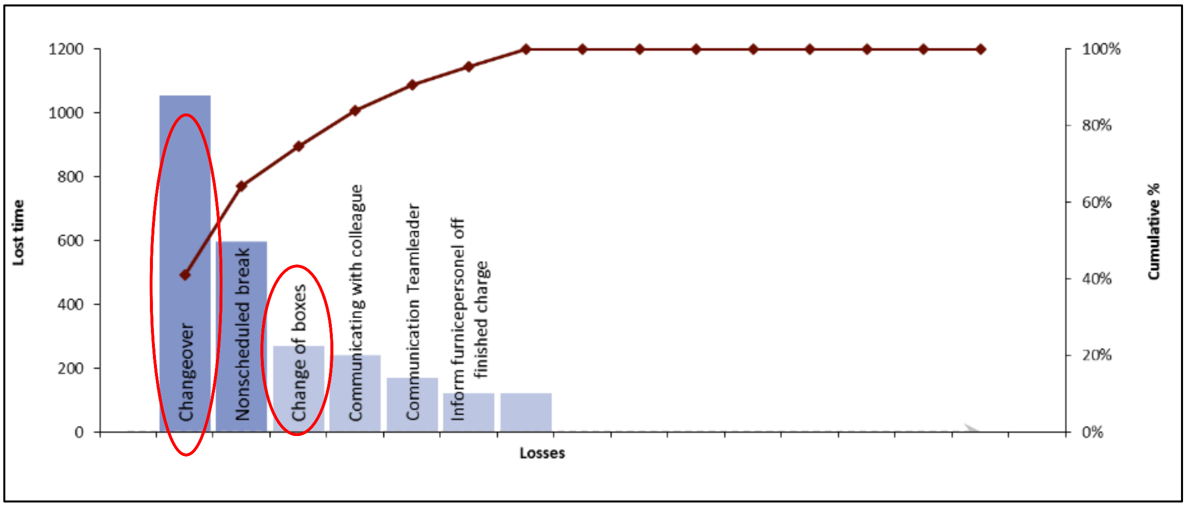

Figure 22: Losses in SFI-assembly.

5.4.3 Performed Activities by Linefeeders

Since the linefeeder play an important role in avoiding starving and blocking appearing because of missing materials, changeovers that have not been prepared and boxes blocking the production linefeeder activities were examined to see where the issue could lay. What could be seen was that only 42 % of the activities performed by the linefeeder were linefeeding activities while for 58 % of the time other activities were performed, see Figure 23.

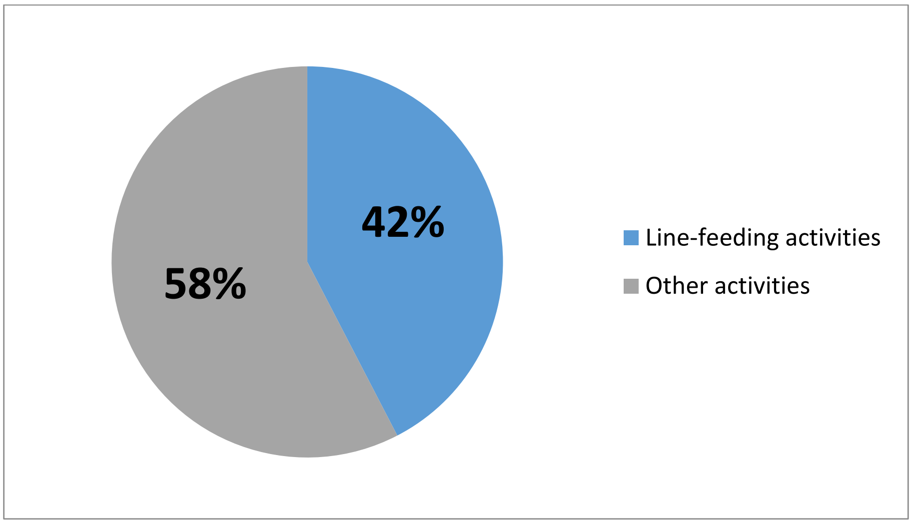

Figure 23: Activities performed by the linefeeder

To get an understanding of what these other activities performed by the linefeeder were a Pareto-chart was created, see Figure 24. From the Pareto-chart it was clear that transportation was the main cause of lost time followed by visual checks, non-scheduled breaks and wait.

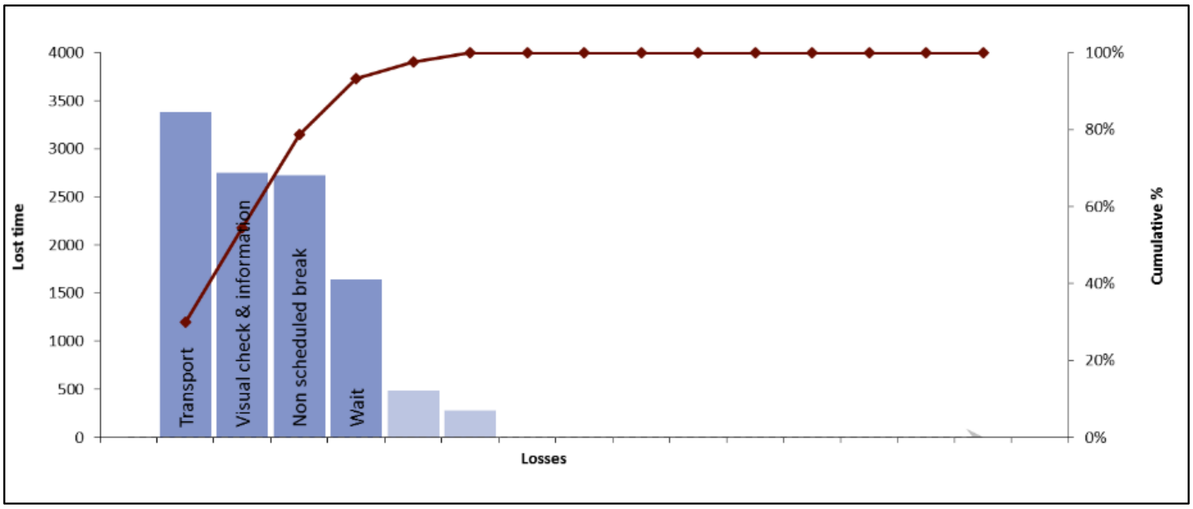

Figure 24: Other activities performed by the linefeeder

The fact that the linefeeders takes a lot of breaks and wait a lot meant there was time available if the work was planned in a good way, a statement which foreman for the assembly area and former linefeeder supported.

5.5 Linefeeder Movement

In order to understand exactly what the linefeeding looked like and why the linefeeding was not working as intended a spaghetti chart was created. In most cases it can be hard to realize how much time that could have been used for production that is actually used for moving around (Webber & Wallace (2006). Most often all the materials, tools and information needed to complete an assignment is not located at a single place, therefore retrieving the materials, tools and information becomes a time consuming part of the assignment which in most cases can be avoided (Webber & Wallace (2006). The Spaghetti chart is a tool appropriate to use when trying to identify the amount of travel in a process and examining the actual flow (Webber & Wallace (2006).

Since the linefeeder was practically always moving it was difficult to map the work being performed and what was being done. One way to examine movement is the use of spaghetti-charts. Creating a Spaghetti chart is according to Webber and Wallace (2006) very simple; it is done by simply following the operator and mapping the movements on an overhead map of the process. It is important to map the actual movements, not only drawing straight lines in order to understand how time consuming movements are (Webber & Wallace (2006). By following the linefeeder for three hours and mapping down all the movement on a plant layout a spaghetti-chart was created, see Figure 25.

The Spaghetti-chart shows how the linefeeder moved during the day and with what purpose. There are three different colors symbolizing three different kinds of movement. The blue line symbolizes movement with boxes. The movement with boxes can be divided into two categories, movement of materials and movements of empty boxes. The red line symbolizes movement with the purpose of checking inventory, either in stock or at the different processes. The black line symbolizes all other movements.

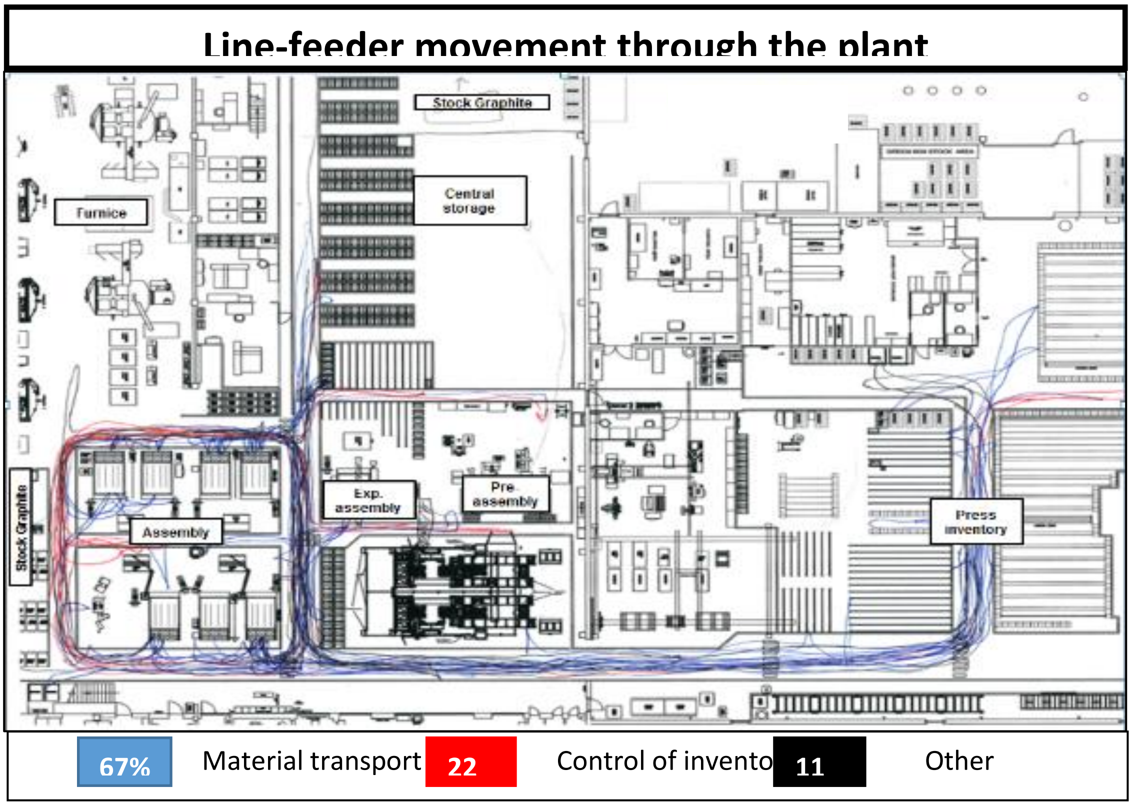

Figure 25: Spaghetti chart of the line-feeder movement

5.6 Material Movement

To gain an understanding of how the materials were moved from their storage locations to the stations that need the materials a map of materials movement was created, see Figure 26. The map was created through an observation of all material movement conducted by the linefeeder. The linefeeder was observed for one and a half hours. During the measurements five different coolers were being produced.

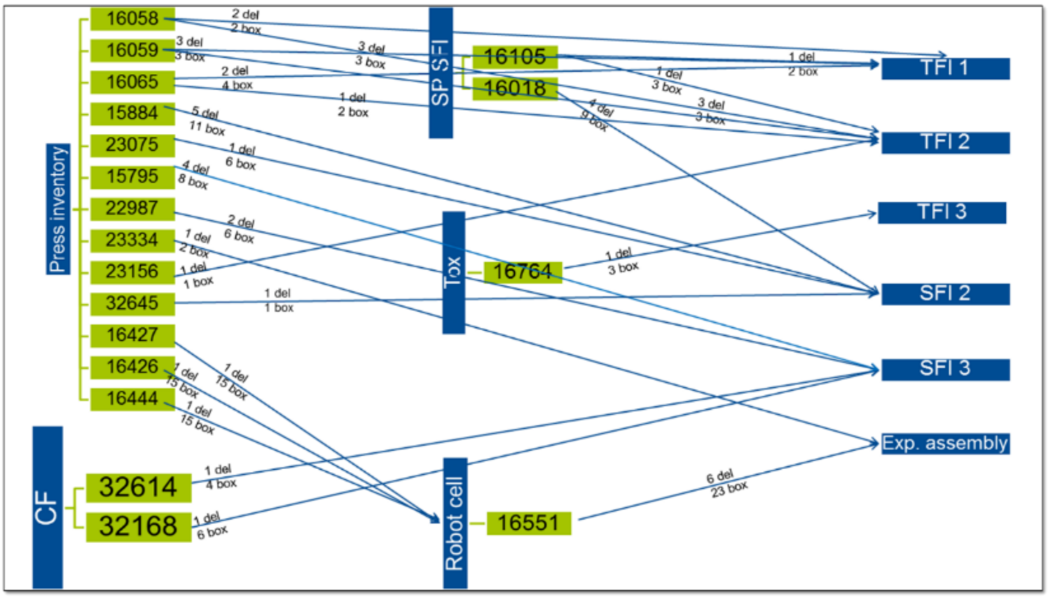

Figure 26: Material movement in the process

Farthest to the left are the different inventories; Press inventory and CF containing materials. The materials were then brought to the stations where they were needed. Some materials needed to go through pre-assembly before reaching assembly while other materials went directly to assembly. There are also different amounts of materials needed for each station at different occasions resulting in a very complicated replenishment process.

5.7 The Linefeeder Task

In order to present and implement solutions to the problem the linefeeding task needed to be examined further in order to see why the job was considered complicated. To get an understanding of the linefeeding the general conditions and structure of the task were examined along with linefeeder movement and material movement.

The spaghetti diagram compiled in the measure phase explained how the linefeeding looked. There was no continuous flow; materials were replenished randomly when there was space available in the racks and the linefeeder notices it. How often the stations were replenished varied a lot and no clear route was taken when replenishment was needed. The linefeeder often chose the shortest way when supplying materials. Most linefeeders did not fill up TFI-assembly and SFI-assembly at the same time. It was not often that the whole route was used, which lead to lack of material in some stations when a lot had to be supplied to another station, see figure 25.

The linefeeding task was completely up to the individual performing it and could therefore be perceived as confusing. The way that the linefeeding task was performed meant long travel since only one station was filled at a time.

What was clear in the spaghetti diagram was the difficulty to determine what to do next, which station to supply materials to and what material to supply resulting in a lot of visual controls which was shown by the amount of red lines of the spaghetti-chart, see Figure 25. What was also shown is the fact that expander assembly and pre-assembly were seldom checked resulting in lack of materials.

The map of material movements explained why it looks the way it looks, see Figure 26. The conclusion drawn from the map is the complexity of the task where it was very hard to understand when stations needed to be refilled and how often. Materials in the different stations had different replenishment needs and the amount of material in the boxes varied between materials resulting in the linefeeder basically guessing when a station needed to be refilled.

To achieve an explanation of why the linefeeding task is perceived as complicated in this specific case a comparison to how it is done in other companies according to a study conducted by Klenk, Galka and Günthner (2012) was made. The way linefeeding was conducted at TitanX compared to how most companies with small load carriers handle supply of materials differed in some ways and was similar in some ways. The points in which the linefeeding differed at TitanX might have been the reason for the job being considered complicated, see Table 5.

Table 5: Comparison between linefeeding at most companies and TitanX where the black dots symbolize the linefeeding at TitanX while the red dots symbolize the norm according to a study by Klenk, Galka and Günthner (2012).

General conditions	**Material source**	Automated storage system	Manual storage system	Production supermarket	Buffer area
	Handling unit	Small load carrier	Large load carrier	Special carrier	Mixed carriers
	Replenishment principle	Kanban	Reorder level	Sequenced orders	Demand-oriented
Organizational structure	**Route**	Fixed route	Dynamically planned route	Flexible route	
	Assignment of vehicle to route	Fixed assignment	Flexible assignment		
	Milk-run control principle	Tact/fixed schedule	Workload oriented	Permanent	On demand
	Integration of loading process	As part of tour	Separate loading, buffering of loaded trailers		
	Integration of empty bins process	1:1-exchange	Pick up on demand	No integration	

The linefeeding differed in four out of eight points compared to the norm. TitanX used both production supermarkets and manual storage systems compared to the norm of using just production supermarket. TitanX also used a flexible route when supplying materials with flexible assignment to the route which is carried out permanently where the norm was to use a fixed route with a fixed assignment after a fixed schedule.

5.8 Ergonomics

During the measuring phase of the study many ergonomic issues connected to the linefeeding were discovered. The linefeeding was experienced as hard work for most linefeeders, therefore not many wanted to be linefeeders. The fact that ergonomics was inadequate could also have been the reason for the linefeeder taking many unscheduled breaks and waiting a lot. Therefore improving ergonomics was considered a needed area to examine in order to improve the supply of materials and the will for linefeeders to perform since it shows that the company cares about them.

6. Case Study Analysis

Presented in the following chapter is the analysis of the data collected in the Measure phase. The chapter contain an analysis of unnecessary steps and ways to minimize waste through the value stream maps. The data from the Measure phase in the form of the value stream maps and the process performance data are also analyzed for root causes resulting in an updated problem description and a desired future state map.

6.1 Current State Map Analysis

Presented below is the current state map analysis performed in order to identify wastes and unnecessary steps in the process, see Figure 27. The first part is an analysis of the wastes in the complete flow while the second part is an analysis of the flow in the assembly area.

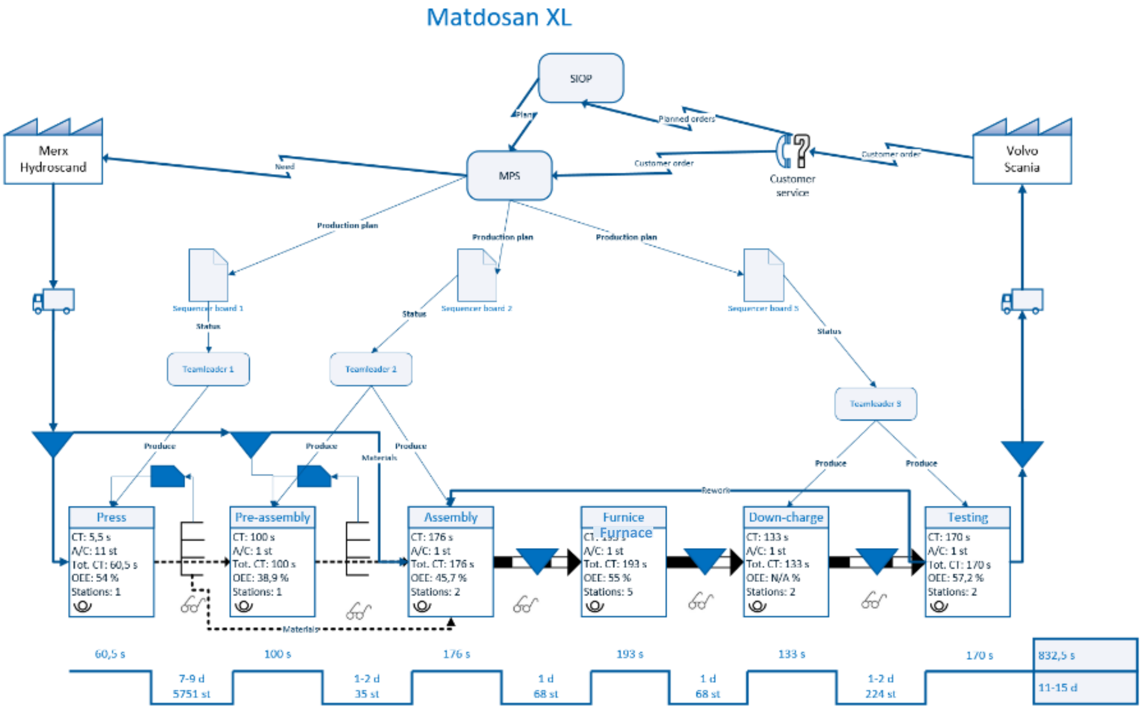

Figure 27: Analysis of wastes in the current state map

6.1.1 Wastes Seen from the Complete Flow

From analyzing the complete flow it was clear that overproduction occurs in part processes resulting in large inventories of materials that are not used; this was the case especially in the press shop where stock was large lasting for several days, however after assembly stock was quite small often lasting less than a day. Overproduction of materials was directly connected to blocking and starving since the overproduction of parts filled up inventory and therefore blocked production. The time spent overproducing could also have been used to create materials that were missing leading to starving. As a consequence of overproduction inventory was too high in the press shop and was therefore a main cause to the long lead time experienced in the process. It was not unusual for pressed plates to be in the press shop for more than 10 days, some low production articles could lay in inventory for years. After assembly the inventories were often low, not lasting more than one day.

Waiting occurred in most station after assembly as a consequence to the long process time in assembly. In the assembly process wait occurred for the operators when materials were not available and for the linefeeder when there was little to do.

The transportations between processes and inventories were not that many in most cases, the plant layout was logical resulting in quite little transportation. In the assembly areas however, stations were being refilled before the material was needed resulting in more transportations than necessary when sudden changeovers occurred. Often more materials than needed were replenished resulting in the need to transport materials back to the inventories.

6.1.2 Wastes Seen from the Assembly Area

From the current map focused on the assembly areas there were a few additional wastes that could be identified since it contained a more detail description of the different roles and their connections, see Figure 28.

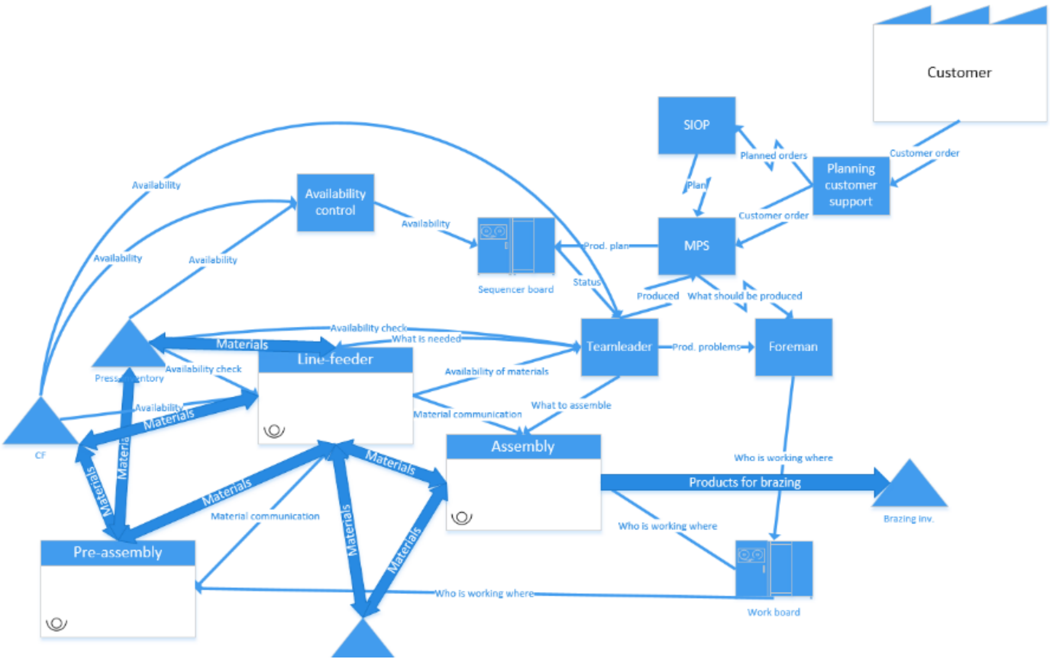

Figure 28: Analysis of waste in the focused current state map

Transportation was considered a problem in the assembly area because materials often needed to be brought back to inventory and extra trips were needed because materials were missing. From the focused current state map it was quite clear that in some cases operators fetched materials themselves while in some cases the linefeeder provided the needed materials. Most often transportation of materials back to their inventory spots were needed since it was not clear how much should be brought to the station in order to produce the planned amount. Transportation of non-value adding materials needed in the assembly processes such as graphite and batch notes were executed by the operators since no one had received the responsibility to replenish these materials. The non-value adding materials missing resulted in operators leaving the stations to fetch materials because the stations were starving.

Extra processing was present in the process in the form of inventory checks made by several people during the day. Three different roles were in charge of checking availability of materials. In the mornings the control was performed by the logistics department however circumstances changed during the day resulting in controls being performed by the linefeeder and team leader as well. Change of plans and sudden changeover was also a problem resulting in extra processing. The changed plans were often because of unreliable machines or unreliable suppliers delivering parts out of tolerance or at the wrong time.

Excess motion existed in the assembly phases in the form of linefeeder movement. The linefeeder often moved with the intention of controlling inventories since it was too complicated with a lot of materials needed from different inventories. Waiting occurred for the linefeeder as a result of the insecurities in the task.

6.1.3 Main Sources of Blocking and Starving According to VSM

The main sources of blocking and starving identified through the value stream analysis was that several people did the same tasks, no one was responsible for completing certain tasks and non-value adding materials such as graphite, grids and paper notes for pre-assembly were not controlled if available.

Several people performing the same task occurred in the process, an example was that more than one person checked inventories because the roles were not defined properly. The fact that roles were not defined properly resulted in extra work for the linefeeder and team leader who was responsible for making sure production flows as intended and that no stations were being blocked or were starving.

Another source of blocking and starving was the fact that no one was responsible for completing certain tasks, supplying materials to pre-assembly was a grey area where some linefeeders supplied materials if they had the time while others ignored the task completely, this resulted in lack of materials and starving stations.

6.2 Problem According to Process Performance Data

According to the process performance data there were several reasons for blocking and starving. The main reasons for lost production due to blocking and starving were changeover, missing materials and change of boxes.

Changeover took a lot of time from production; this was because the changeover had not been prepared appropriately by the linefeeder. For a changeover to be smooth the material needed to be prepared beforehand, preferably in the adjacent station so that the operator easily could switch to a prepared station when a batch was finished. Missing material was an issue frequently occurring resulting in operators fetching the material themselves. Operators fetching materials occurred for most materials but most often the non-value adding materials such as graphite, grids and paper notes for pre-assembly. Operators needing to handle boxes because they are blocking the station was commonly occurring in the assembly station while in the pre-assembly production was blocked by finished parts. The removal of boxes and finished parts therefore needed to be improved so that operators did not have to remove them resulting in production losses.

6.4 Root Cause Analysis

With the information from the collected process performance data and the value stream maps a root cause analysis was conducted in order to find causes for the process not performing as intended. There were according to the VSM and gathered data mainly six sources to the assembly process experiencing problems due to blocking and starving; Several people do the same tasks, Changeover takes a lot of time from production, Not all needed material is delivered, All stations are not replenished, Time is spent checking inventory and Personnel take many unscheduled breaks. From the sources of the problem five whys where asked within the project group where the root causes; Lacking linefeeding instructions, Missing instructions for tasks, Lacking visual aid for linefeeder and Missing education in benefits of ergonomics were discovered, see Figure 29.

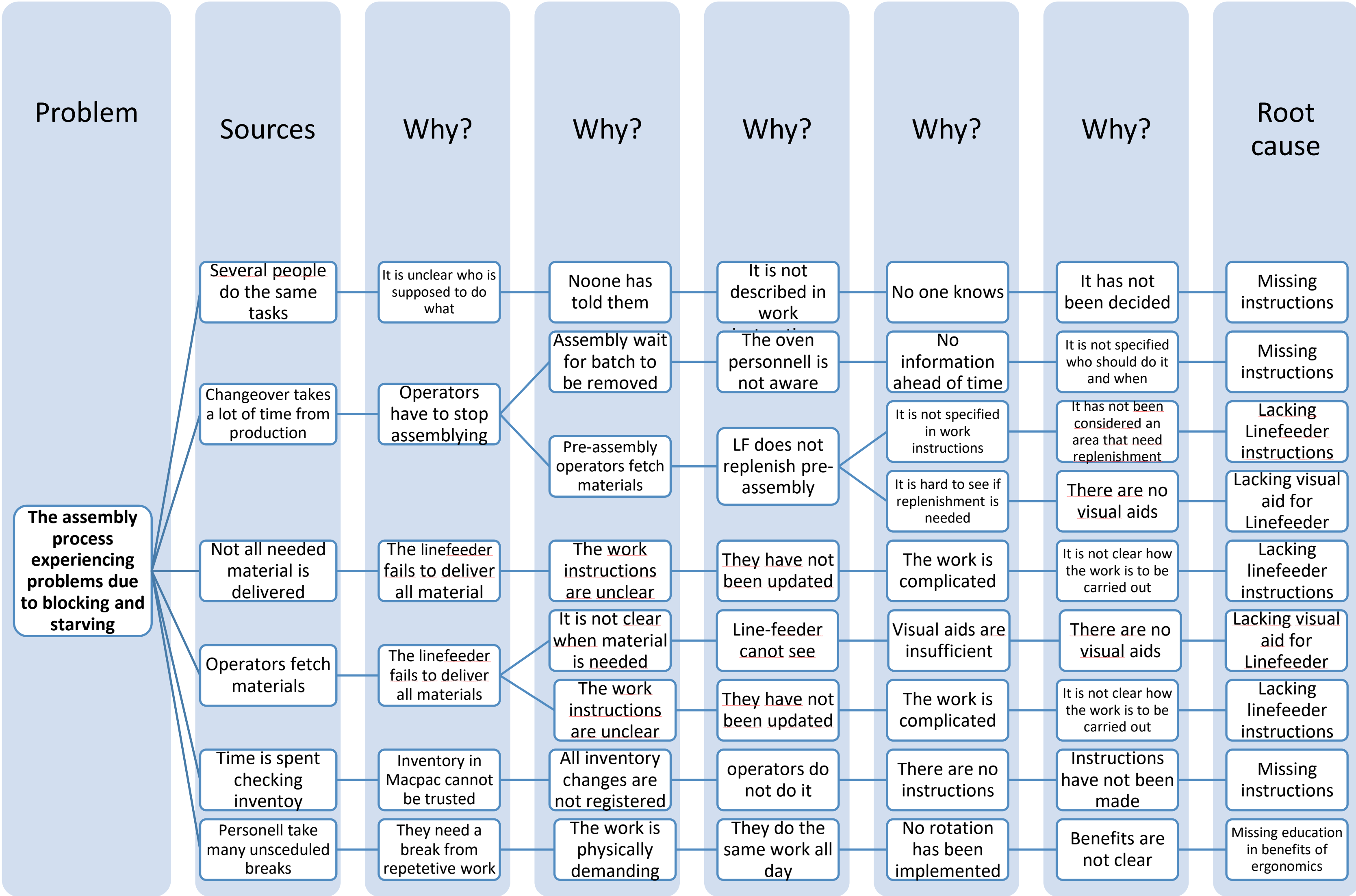

Figure 29: Root cause analysis for the perceived problem

In order to tackle the root causes in an appropriate way two of the root causes were focused on for there to be enough time to develop suggestions for improvements to implement and control. The chosen root causes to continue with are colored orange in the figure below. The causes colored orange were the ones that seemed manageble to improve in the time intervall of the thesis work, see Figure 30. The chosen root causes were both connected to linefeeding and it was therefore logical to try to improve both of them.

Root cause 1 Lacking Linefeeder instructions

- Many sorces of the experienced problem was because of the complexity in the Line-feeding task and the fact that instructions on what had to be done and how activities should be done were missing.

Root cause 2 Missing instructions for tasks

- For many tasks there were no instructions on how tasks should be carried out and by whom, this needs to be made clear in order to avoid blocking and starving and double work.

Root cause 3 Lacking visual aid for Linefeeder

- In many circumstances it was difficult for the line-feeder to see if material needs to be refilled, what material needs to be refilled and how often.

Root cause 4 Missing education in benefits of rotation

- Missing education in rotation and the benefits of implementing rotation has lead to more unscheduled breaks since operators need to take breaks more often.

Figure 30: Root causes of blocking and starving

The identified root causes above were also present in the ishikawa-chart produced in the Measure phase. The root causes chosen to focus on were Missing visual control and Standard work for linefeeder marked with a red circle, the root causes not chosen to focus on was marked with blue circles, see Figure 31.

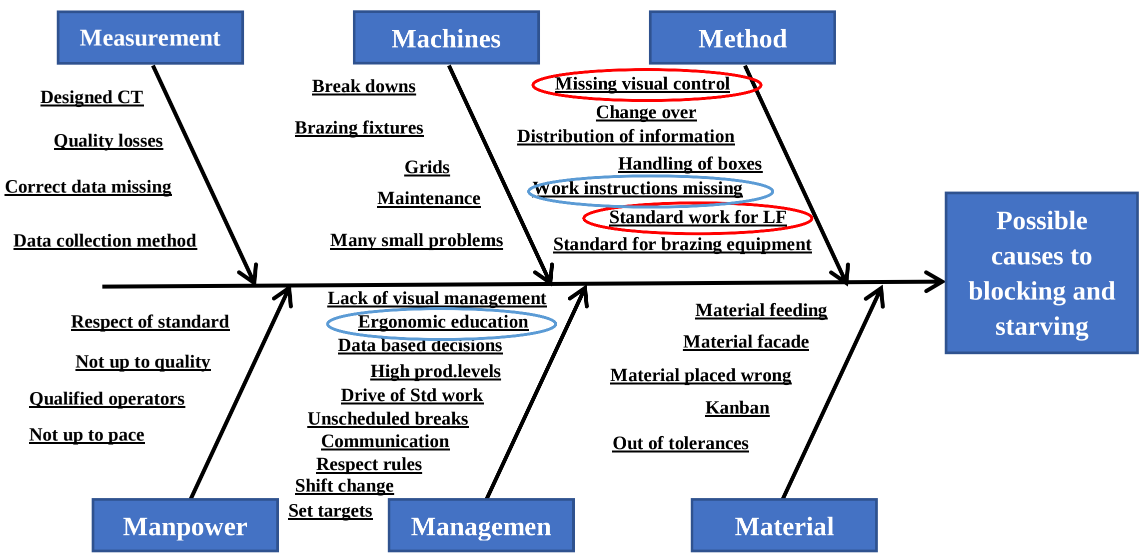

Figure 31: Ishikawa-chart with marked areas of improvement

6.5 Updated Problem Description

In order to find solutions to the chosen root causes an updated problem description was created. In order to be able to finish the case study on time focus was put into the two root causes connected to linefeeding; Lacking linefeeding instructions and Lacking visual control for linefeeders. The root causes were chosen because they were closely connected to each other and covered most of the sources of the problem with blocking and starving. From the updated focus area the problem description was updated to: *The line-feeding task is too complicated because of lacking linefeeder instructions and lacking visual control.*

6.6 Future State Map

By focusing on the root causes and improving the process the following value stream map was the wanted outcome in the assembly phases, see Figure 32.

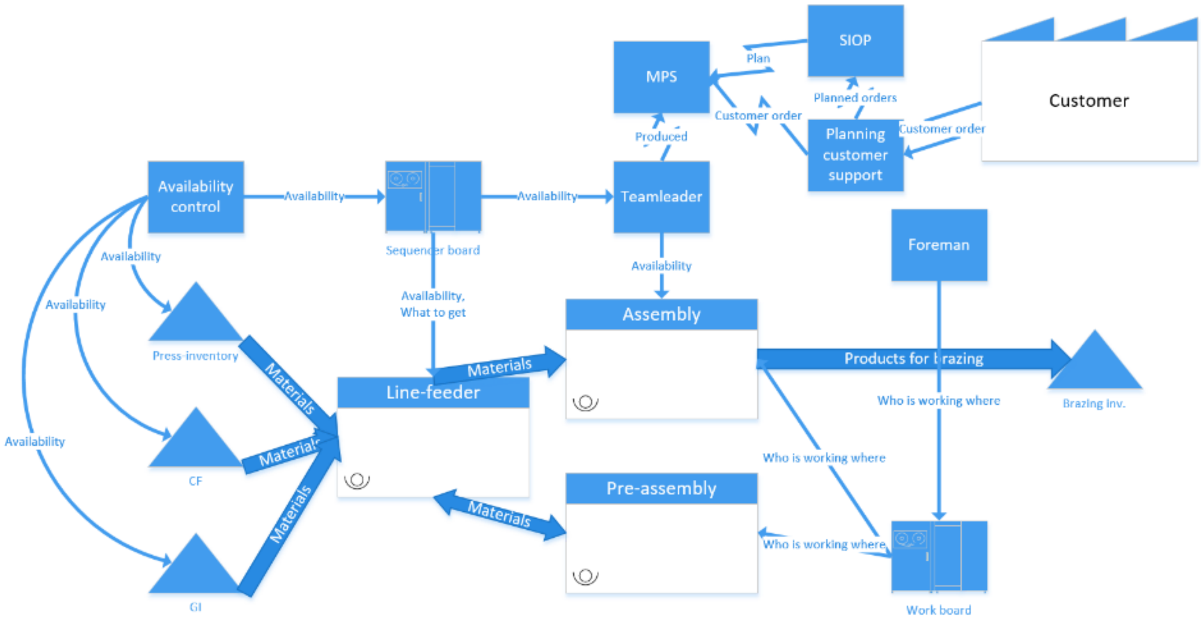

Figure 32: Future state map in the assembly processes

The differences between the current state map and the future state map is that there is no transportations back to inventories, no transports made by assembly and pre-assembly personnel, one person is responsible for checking availability of all materials including graphite and the communication flows mainly through the sequencer board.

Production was planned according to cycle time since production according to takt was not reachable since more products than possible needed to be produced. By reducing time spent on blocking and starving in the assembly process more coolers can be produced in a shorter amount of time which leads to a higher possibility to use takt time in the future, this should be something to strive for in order to avoid waste in the form of overproduction.

The future state map presented above is not necessarily the optimal process in the assembly area, however it is a picture of an improved state which TitanX can strive to reach along with other improvements.

7. Case Study Improve

In the improve phase of the report a task list is presented with improvements needed in order to reach the desired future state. The improvements are presented and have been implemented so that they easily can be controlled in the Control phase.

7.1 Task list

Presented below are the short-term and long-term improvements needed in order to solve or at least partially solve the updated problem described in the Analyze-phase and reach the desired future state.

7.1.1 Information Flow Improvements

For the information flow to work as intended the linefeeder needed something visually showing what was left to replenish in order for the operator to produce the needed amount of coolers. A visual system was therefore appropriate in order to make sure that all needed material had been replenished at the right time and that no materials needed to be returned to its inventory spot. The replenishment could not be carried out to early when material was not needed and not to late when the line was starving since it would result in blocking and starving.

A standard was needed for the work performed by the linefeeder so that roles and responsibilities were clear for all. The replenishment of materials to pre-assemble and graphite to assembly varied a lot between different linefeeders; therefore there was a need to make responsibilities clear. Another example of the importance of making responsibilities clear were the inventory checks which were performed by several people resulting in wasted time.

The sequencer board needed to be continuously updated when conditions changed. In the mornings when the inventory check had been performed the availability of material was known, however during the day conditions changed resulting in several persons performing additional inventory checks.

A lot of the experienced problems in the information flow could be solved through the use of the company's business systems. The used systems were not reliable, there was a need to make the systems more reliable so that manual inventory controls were not needed. Making the systems more reliable was however a more long-term improvement since there were many factors that needed to be improved for personnel to be able to trust them.

7.1.2 Physical Flow Improvements

In the physical flow there was a need to plan the supply of materials so that no material had to be moved without creating value. A more planned replenishment could be reached in several ways, usual ways are through fixed routes and planned schedule.

The linefeeding process needed to be less complicated for the linefeeder and there needed to be one way to perform the linefeeding. During the study all linefeeders supplied materials in different ways resulting in blocking and starving along with a role that was very difficult to teach new employees. The linefeeding task could be made easier to understand through a standardized way of working, planned replenishment schedule and fixed routes.

7.2 Chosen Improvements

The improvement opportunities chosen to work with during the study were the ones that was of most interest to the company and had the best probability to be implemented in the time frame of the thesis work. This means that no long term improvements were chosen to continue with because the time to implement long term improvements was not available. Two improvement opportunities of suitable proportions were created from the task list. The improvement opportunities are presented below:

Create standardized work for the linefeeding process including clear responsibilities, routes for the linefeeding process and a planned schedule for the linefeeding process.

The second improvement opportunity chosen to focus on was to make the supply of material easier for the linefeeder through visual tools. Creating a more visual environment for the linefeeder included showing the amount of coolers left to produce, what materials were needed when and what to produce next. The linefeeder also needed something visible showing how much material was needed in order to produce the planned amount of coolers.

The presented improvements opportunities needed to be solved in other ways than just instructions although instructions on how to use the visual tools might be needed. These improvements were believed to solve the updated problem description, thereby reducing blocking and starving in the process.

7.3 Linefeeder Improvements

Before creating a standard the linefeeders role and responsibilities needed to be defined. From conducted interviews it was clear that the linefeeders main task was to ensure that all materials needed to assemble were present during production. To define what tasks this could include a brainstorming was conducted within the project group. Eight different tasks that the linefeeder could/should do were suggested, see Table 6. The tasks were then checked and approved by the supervisor.

Table 6: The brainstormed tasks the linefeeder should/ could be in charge of. The tasks colored green need to be continuously executed while the blue tasks need to be executed once a shift or less. The tasks colored yellow need to be executed when time is available for the linefeeder

Tasks
Follow the routes to replenish materials
Prepare and execute changeovers
Provide assembly with graphite
Control inventory
Make sure notes in pre-assembly are filled up
Control material center
Sorting and cleaning
Repacking materials

Making sure materials are available for the operators does not only include materials needed in the cooler, but also materials needed in the process not adding value to the product. This means that the linefeeder should also be in charge of supplying graphite and making sure notes are available in pre-assembly.

In the list the first four points are colored green, this is because they are tasks that need to be executed continuously while the blue colored tasks need to be performed twice a week and once a shift. The tasks colored yellow are tasks that should only be performed when excess time is available.

The linefeeder needed to make sure materials were filled up in the assembly stations, however the linefeeder also prepared some changeovers and controlled some inventories. This new task list for the linefeeder might seem ambitious with quite a lot of additions to the current task, it can be questioned whether all activities can be performed by one linefeeder each shift. The list presented above was a preliminary list that could be reduced if it was discovered that something takes too much time. As previously shown a lot of time for the linefeeder was spent waiting, taking unscheduled brakes and checking WIP, the plan was to also reduce the time spent on these activities. The time spent on controlling assembly inventory could be reduced by using routes and a schedule for the delivery of materials. The unscheduled breaks were believed to be connected to waiting since linefeeders took breaks when they felt like there was nothing to do. The time spent controlling WIP and taking breaks together with the time spent waiting was planned to be utilized for performing the extra activities presented above.

The plan with standardizing the work for the linefeeder was to create routes allowing the linefeeder to fill up stations less often creating time for other activities such as supplying graphite and preparing changeovers. The notes and graphite were not prepared beforehand and could not be part of a route, therefore time in between routes was needed to secure that everything the operators needed was supplied.

7.3.1 Task Description

Presented below is a description of the different tasks that could be performed by the linefeeder and how they should be performed.

Follow the routes for filling up the stations

In order to create routs that the linefeeder can follow an excel-file was created containing information about 45 different coolers produced in the assembly stations and 59 parts produced in the pre-assembly stations. The excel-file thereby contained most of the articles produced the last couple of years at TitanX Linköping. The file contained information such as components for each cooler and part, cycle time, needed amount of parts per hour, amount of articles in charge, box type, and amount in box. The information was collected from baseline data, manual checks in the different inventories and from the existing standards. From the excel-document the different routes the linefeeder should travel were designed.

From the file it was possible to see that a route should be carried out every 30 minutes where stations needing materials are replenished. The routes were dependent on replenishment rate, the stations that were not used did not need to be replenished. The way the replenishment was designed is presented in the linefeeding operator instruction sheet (OIS) located in appendix C.

The material at each assembly station should not last for more articles than what is planned to produce in order to reduce the risk of needing to transport back a lot of materials during changeovers. To make the replenishment of materials as simple as possible for the linefeeder materials were divided into four colors; blue, green, yellow and red route depending on how often they needed to be replenished.

The materials categorized as blue needed to be replenished once every half hour.

The materials categorized as green needed to be replenished once every hour.

The materials categorized as yellow needed to be replenished once every two hours.

The materials categorized as red needed to be replenished once every four hours.

These materials are carried out in the following routes where route A is a quick route with a small amount of materials and route D is a heavy route with a larger amount of materials. After four hours the route containing materials from all routes are delivered continued by the fast route A, see Figure 33.

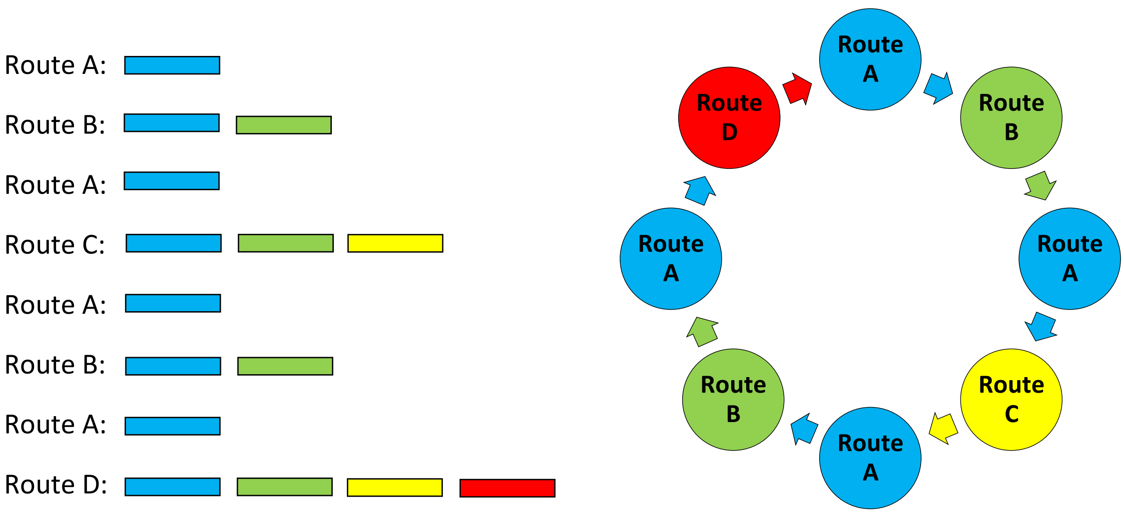

Figure 33: Route sequence

In order to know what materials to bring and when to bring it linefeeder orders-notes were created, see Figure 34. The notes contain information about what materials were needed for a specific article, how much was needed and what route the material was in. If a material was missing a route it meant that the material should fit at the station and that all of the material could be supplied during changeover. If a changeover was performed replenishment of the station still needed to be carried out according to schedule resulting in an almost full station being replenished. Replenishing an almost full station was needed in order to include the material in the routes, when the first route had been carried out the work could continue as usual.

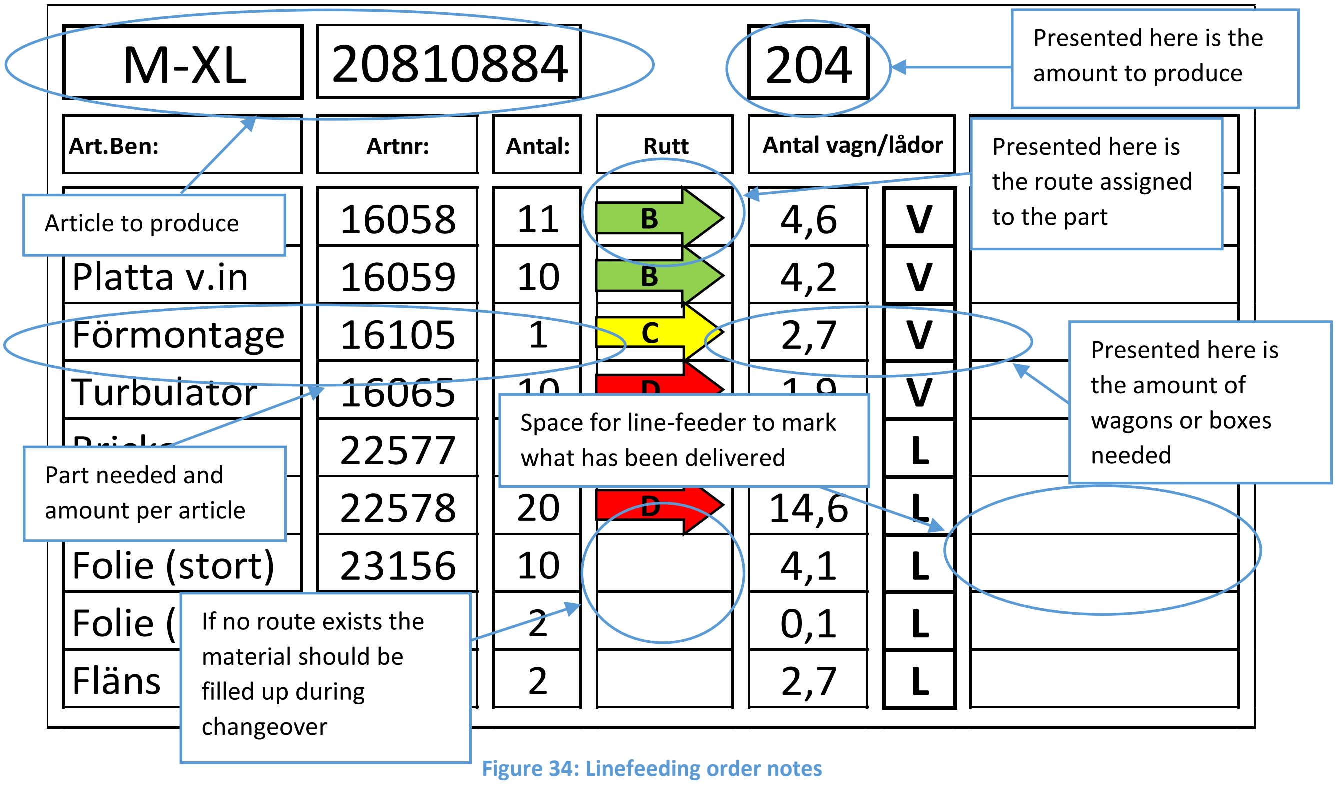

Figure 34: Linefeeding order notes

Prepare Changeover

All the material handling during a changeover should be handled by the linefeeder to an as large extent as possible. The changeover should be prepared before the batch has been completely assembled. The changeover should therefore be prepared at least 10 minutes before a batch is completed. The changeover should be performed at the assembly and pre-assembly stations following the described steps for changeovers in the Work element sheet (WES), see appendix C.

If the linefeeder is able to handle and prepare the changeovers completely a reduction of lost time by 5,6 % can be achieved in pre-assembly, 5,5 % in TFI assembly and 6,6 % in SFI assembly according to the collected data in the Measure phase.

Control Inventory

When controlling inventory there are four inventories that mainly need to be checked. Press inventory, the central storage and robot inventory contains all the actual materials needed to make parts and coolers in the pre-assembly and assembly process. The fourth inventory that need to be checked is graphite inventory which contains graphite needed in order for coolers to go through the furnace.

When a work element sheet (WES) was created for the control of inventory it was realized that the task took an hour for an experienced person to perform. Controlling inventory took more time than what was available between routes, therefore it was too much to handle for the linefeeder. If the time to control materials could be reduced it might be possible for the linefeeder to perform the task in the future.

Supply Graphite

When needed the linefeeder should supply the assembly station with needed graphite and grids in order to reduce time spent on these actions for the operators. The replenishment of graphite can be performed by the linefeeder between routes when no other material need to be replenished.

Refill Notes

The linefeeder should refill the notes at pre-assembly when there is time to do so. Refilling notes involves printing and cutting notes for the pre-assembly stations. These notes should be put in their designated plastic pocket by the stations which should be filled up twice a week.

In order to make sure notes did not run out a visual system was implemented based on the production forecast. In the system different pockets were marked with colors depending on how many notes were needed each week. The system contained the colors:

- Red = There should be 200 notes in the pocket.
- Yellow = There should be 100 notes in the pocket.
- Green = There should be 20 notes in the pocket.

The amount of notes were more than what was needed each week, there was therefore a safety stock in order for the notes to never run out. A description of how the refilling of notes should be executed is described in a work element sheet (WES), see Appendix C.

Sorting and Cleaning

Sorting and cleaning should be performed by the linefeeder when there is excess time to do so. The sorting and cleaning should be performed at the places where it is needed the most but generally at assembly, pre-assembly and in the different inventories. The sorting and cleaning should follow the 5s workplace method which is visual at the different stations.

Repack Material

Repacking of materials is not a task that generally should be performed by the linefeeder, however if time is available it should be performed after checking with responsible personnel for repacking.

7.3.2 Prioritized Tasks for the Linefeeder

After examining the possible tasks the linefeeder could perform it was clear that seven of them were suitable for the linefeeder to perform. Together with the supervisor it was decided that the only task that needed to be removed from the list was Control of inventory since it was a task that took too much time for the linefeeder.

Since there were many tasks to be performed by the linefeeder a priority list was created in order for the linefeeder to know what to prioritize, see Table 7. In the top of the priority list are the most crucial tasks to execute in order for the production to work as intended. Further down in the priority list are tasks not directly connected to the assembly processes that still needs to be performed by the linefeeder.

The reason for using priorities was the uncertainty in how much time different activities took. If there are many operators and there is a lot of planned production for the day, then the replenishment of material might take a long time. If there is little production planned then other activities can be performed in order to avoid waste.

Table 7: The chosen tasks to be performed by the linefeeder

Tasks
1. Follow the routes to replenish materials
2. Prepare and execute changeovers
3. Control material center
4. Make sure notes in pre-assembly are filled up
5. Provide assembly with graphite
6. Sorting and cleaning
7. Repacking materials

7.4 Standard WIP

The standard work in progress is the amount of material there should be in a process when an operation is being performed. The standard WIP should be as low as possible in order to discover defects as soon as possible however if it is to low material shortage can be an issue.

In the assembly stations there were many different products being produced at different occasions. In order to know what amount of materials were needed at the stations a list of the different products was produced where needed amount of materials per hour was displayed. The list was based on the production cycle time. It was decided together with the logistics department that there should not be less than one row of material left in a rack since operators assemble coolers in different pace.

Since the different stations were of different sizes and different amount could fit depending on which boxes the parts were in the standard work in progress differed. The standard work in progress was therefore dependent on which coolers were being produced and in which stations it were being produced. In the most common stations with the most common boxes the standard work in progress is five boxes (2,5 rows).

7.5 Other Improvements

In order for the linefeeder to know what to bring to the operators communication with the Team leader was crucial. In order to increase the possibility to communicate a phone was issued for the linefeeder. The Team leader already had a phone which allowed them to communicate with each other even if they were not close to each other. The phones could be used when something was wrong in order to solve problems quicker.

From a brainstorming on linefeeding communication it was decided that the existing sequencer board should be the main way of communication, however it was agreed upon that improvements were needed, see Figure 35. Problems in communication appeared because order cards on the sequencer board were not removed when a batch was finished which made the board more complicated to understand. The board needed to be updated by the Team leader who also decided what should be produced next. Another issue was the fact that the linefeeder did not know what products where being produced in what stations. In order to make it easier for the linefeeder to see what were being produced magnets were created with four different numbers so that it was possible to see if a certain product was being assembled in station 1, 2, 3 or 4.

Figure 35: Improvement of sequencer board

7.6 Pilot Test

To achieve an understanding of how the different routes cover the replenishment need of the stations a trial was carried out where the linefeeder was only allowed to fill up the stations according to the routes.

The first experienced problem was the lack of information available in the mornings. The Team leader had no information about how much had been produced so far in a batch and what materials was in the racks. During the pilot test the lack of information was handled through manual checks and by updating the replenishment notes in order to know what to replenish. The manual check was however time consuming, the ideal would be for the information to be available when the linefeeder arrives.

At first the new routes to be carried out were difficult for the linefeeder to understand but after a while they worked quite well. What was seen was that the routes cover the replenishment need however starting up routs were according to the linefeeder demanding since all materials needed to be filled up before the routs could start.

7.6.1 Improvements from the Pilot Test

From the pilot test it was clear that the notes were not simple enough to use since the linefeeder needed to browse through papers to see what route materials were part of. The notes were improved through the creation of a plastic plate with magnets where suitable sized linefeeding order cards could be fastened. This solution was perceived as a lot easier to use since the linefeeders could bring the cards with them to remember what material was needed. The cards were also laminated so that notes could be made on them simplifying the work even more for the linefeeder.

7.7 Improved Ergonomics

According to Karltun (2004) there are two main ways in which ergonomics can be improved, through engineering improvements and administrative improvements. The engineering improvements involve actions such as rearranging, modifying, providing new tools or equipment and redesigning processes. Administrative improvements on the other hand are based on improving work practices or organizing the work in different ways. Administrative improvements could be: (1) alternating heavy tasks with light tasks, (2) Providing variety in jobs to reduce repetition, (3) Adjust work schedule for a certain work pace, (4) Provide recovery time, (5) Modify work practice so that work is performed within the power zone, (6) Rotate workers. The administrative improvements can help reduce exposure to risk by limiting the amount spent doing certain tasks. (Karltun, 2004)

7.7.1 Linefeeding Ergonomics

In order to improve linefeeder ergonomics a focus was put to administrative improvements since they could be implemented without any big investment costs. However some minor engineering improvements were possible as well. There was during the study a couple of lifts available which could be used to reduce strain on the linefeeders. There was not enough lifts or space to put lifts everywhere, therefore a decision to put the lifts where conditions were the worst for the linefeeder was made. After an interview with linefeeders it was clear that the station that most frequently needed to be refilled was expander assembly, the boxes for this station was also quite heavy. Therefore the expander assembly was the most suitable place for a lift to be installed. The alternative to putting the lift at the expander assembly station was to put it at the RTX station, where the boxes were a little bit lighter but had to be lifted as frequent and higher. The problem in the RTX station was that the lift did not have the capacity to lift the boxes high enough; therefore another solution for the RTX station was needed.

The suggested administrative improvements was:

- Alternating heavy tasks with light tasks, which could be performed through the previously explained routes where some routes are heavy and other light.
- Providing a variety in jobs to reduce repetition which has been included in the linefeeding since less demanding tasks such as filling up notes has been implemented.
- Adjusting work pace for a certain schedule resulting in routes with a decreased rate of needed replenishment.
- Rotation of workers should be a future implementation to decrease strain to certain muscle groups and dependability on certain personnel.

By implementing the administrative improvements and the engineering improvement suggested the linefeeder work environment was believed to be considerably improved.

7.7.2 Assembly Ergonomics

The suggested improvements resulted in reduced movement for the assembly personnel at the pre-assembly and assembly stations. This meant that improved ergonomics was an important aspect to consider in order to decrease occupational injuries. Therefore it was suggested that TitanX:

- Provides a variety in jobs to reduce repetition by for example implementing rotation which would also decrease dependability of certain personnel.
- Adjust work pace for a certain schedule by working according to takt time and not only producing as much as possible.
- Provide recovery time.

8. Case Study Control

The control-phase is the final phase in the DMAIC methodology and where the improved process is standardized and the governance for this process is designed. Presented in the chapter are the expected financial benefits of the study followed by the control plan were the designed governance is described. Finally future work to further eliminate blocking and starving is presented.

8.1 Expected Improvement

During the study no control measurement were performed since implementation of the suggested solutions took longer time than expected. From the measurements performed in the beginning of the study it was however possible to estimate the result of the implemented improvements. If the suggested solutions are monitored so that the linefeeders operate as intended the process can be improved in many ways resulting in economic benefits. In order to calculate an estimate of the economic benefits a believed reduction of losses were discussed within the project group resulting in the following tables, see Table 8 and Table 9.

Table 8: Estimated economic benefit in the pre-assembly area

Activity (Pre-assembly)	Measured amount	Hours (1 person *16hours *253days	Estimated reduction	Gain (SEK) (Time*5369)
Handling paper notes	2,5 %	101	101 (100 %)	543 000
Material pick-up and drop-off	10,5 %	425	297 (70 %)	1 597 000
Total	13 %	526	398 hours	2 140 000

In the pre-assembly process the handling of paper notes was believed to have been reduced by the total amount of 2,5 % resulting in reduced direct costs of 30 300 SEK per year in personnel cost. The amount of time gained per year through the improvement is approximately 101 hours which if put to producing coolers could create a more balanced flow resulting in increased sales with a revenue of 543 000 SEK.

Material pick-up and drop-off stood for 10, 5 % of the total time available in pre-assembly. The replenishment of needed materials and the material center was believed to have reduced the time for material pick-up and drop-off by approximately 70 % resulting in a reduction in cost of personnel by 127 500 SEK each year. The extra time available would therefore be 297 hours per year which could be put into producing coolers with increased sales of 1 597 000 SEK.

Table 9: Estimated economic benefit in the assembly area

Activity (Assembly)	Measured amount	Hours (5 persons *16 hours*253days	Estimated reduction	Gain (SEK) (Time*5369)
Missing materials	1,3 %	263	184 (70 %)	988 000
Communication with Linefeeder	0,37 %	75	50 (66 %)	269 000
Sorting and cleaning	1,97 %	399	50 (25%)	269 000
Changeover	7 %	1417	283 (20 %)	1 500 000
Total	10,64 %	2153	567 hours	3 000 000

In SFI-assembly and TFI-assembly operators fetching materials was believed to have been decreased. In the SFI- and TFI-stations missing materials stood for 1,3 % of the total amount of production time, this amount was expected to be reduced by 70 % resulting in reduced personnel cost of 55 200 SEK which is equivalent to 129 hours which could be put into balancing the flow and producing coolers resulting in reduced indirect cost of 988 000 SEK.

Communication with linefeeder was believed to have been decreased since the information was available on the linefeeder order notes. Communication with linefeeder stood for 0,37 % of total production and is believed to have been reduced by 66 % resulting in a reduced cost of personnel that is not utilized by 15 000 SEK and indirect costs of 269 000 SEK.

Sorting and cleaning resulted in less boxes blocking production for operators stood for 1,97 % of total production time. This problem was believed to have been reduced by at least 25 % since time had been scheduled for the linefeeder to remove boxes and cardboard boxes. A reduction of 25 % results in a decreased cost of personnel of 15 000 SEK and availability in time of 50 hours where operators could perform other activities. The reduced indirect costs therefore stands for 269 000 SEK.

Time to prepare changeovers in SFI- and TFI-assembly were also reduced. The problem stood for 7 % of the total production time which was believed to have been reduced by 20 % through improved instructions. The improvement of 20 % results in reduced amount of wasted time of 283 hours resulting in reduced personnel costs of 84 900 SEK and a reduced indirect cost of 1 500 000.

The aim with the study was to decrease blocking and starving with 10 %, in this study a reduction of blocking and starving of approximately 50 % in pre-assembly is possible if the suggested improvements are used. In the assembly phase the blocking and starving was believed to be reduced by approximately 25 % resulting in a reached aim.

8.2 Control Plan

To make sure that the expected improvements were reached a control plan was created. The control plan should be used to make sure that the linefeeder is operating after best practice and that the implemented improvements are respected and followed through. It is also a way of continuously improving the linefeeding and its accompanying documents by controlling how the tasks are being performed. If a task is performed differently than described in the work instruction operator might need training or the documents might need to be updated since a better practice has been discovered.

What is being checked in the control plan is basically if the linefeeder follows instructions and if time to complete different tasks is correct. If the execution does not comply with instructions the supervisor needs to determine what needs to be done together with linefeeder and Team leader.

The linefeeder task should be controlled by visual checks performed by the supervisor. The visual checks should be performed with the help of the operator instruction sheet (OIS) and the work element sheets (WES) containing information of the different tasks performed by the linefeeder and time needed to perform the tasks, see figure 36. In order for the linefeeding to be considered ok the linefeeder needs to work according to instructions within a time interval of 20 %. This means that if a task is supposed to take 30 minutes it can take a maximum of 36 minutes and a minimum of 24 in order for the descriptions to still be considered accurate. The visual check should be performed once every three months in order for TitanX to detect changes to the process, understand why they occur and if needed update the instructions. Since all operations performed by the linefeeder is based on time, all needed to control the linefeeding process is a stopwatch where the time to perform tasks is measured. A visual control of how the tasks are performed together with measurement of the time it takes to perform the task should be enough to control if the process is performing as intended. If the process is not performing as intended actions need to be taken to adjust the process to a former state or control documents and work instructions need to be updated.

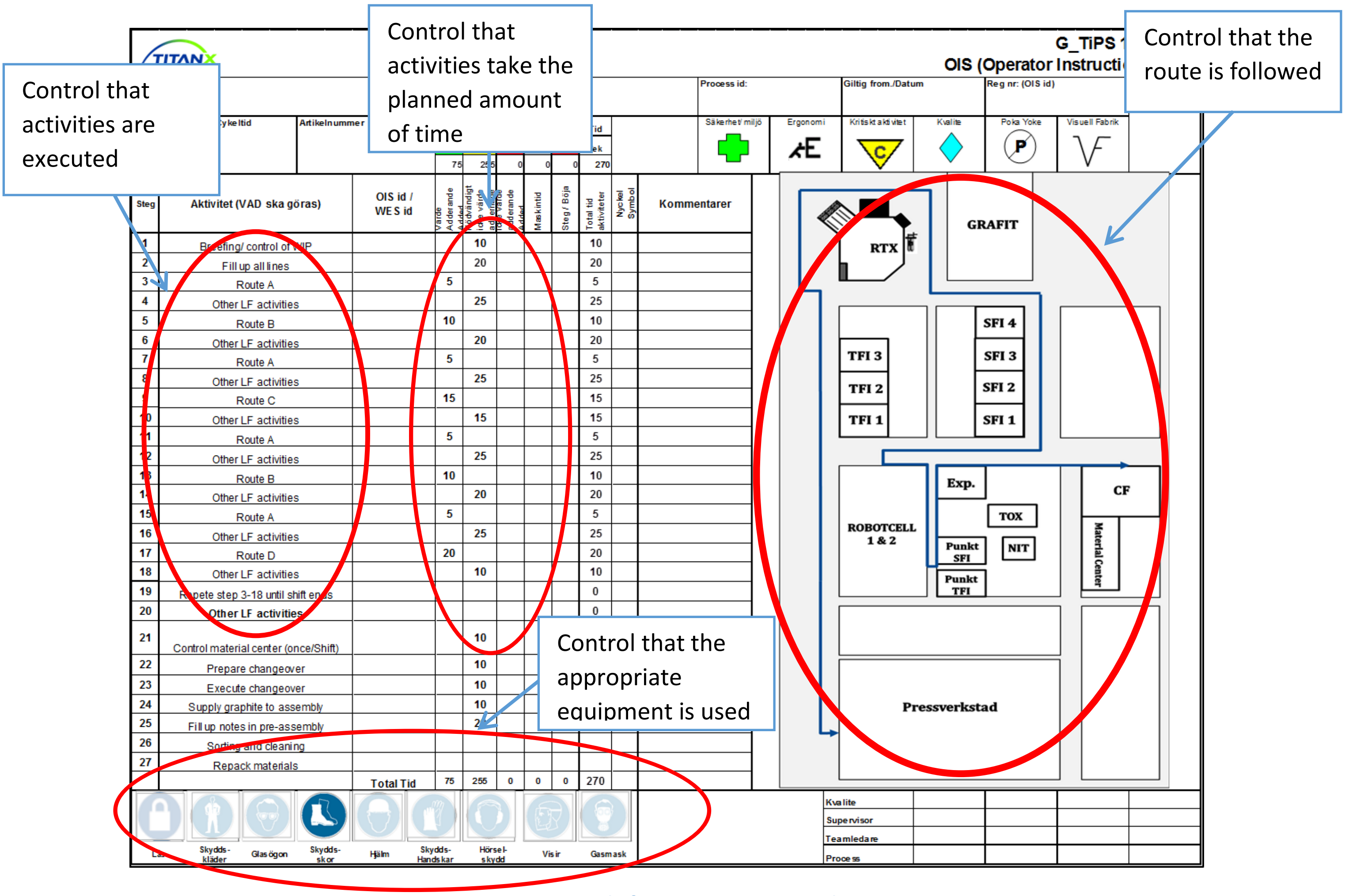

Figure 36: Control of operator instruction sheet

The control of the linefeeding process should continuously be evaluated and if necessary updated when there are changes to the process. The new way of performing a task might be more suitable than the way described in the standard. When other activities are performed these can be controlled using the work element sheet for the activity.

8.2.1 Reaction Plan

If the linefeeders are not operating as intended and corrective actions are necessary in order to secure materials being delivered to the right place at the right time the supervisor of the linefeeder is responsible. If the linefeeder tasks are not executed in the intended way the work needs to be examined together with the linefeeder to realize why they are not being executed in the right way and if on job training should be performed by the supervisor or someone with the competency to educate linefeeders.

If problems occur with missing or blocking materials the linefeeding task might need to be revised. Over time cycle times might decrease or increase or other circumstances change resulting in blocking and starving, therefore it is important to continuously control the process. Decisions on whether documents need to be revised can be made in the control document (see table 10); the supervisor is then responsible for the change being made.

Table 10: Table of factors that the supervisor should control every 3 months

Control of line-feeding (Frequency: every 3 months)				
Control:	**Control using:**	**Yes/ No**	**Why?**	**Actions:**
Are the tasks being performed as intended?	OIS and WES			
Does a task take more or less time than expected?	OIS, WES and stopwatch			
Route 1	(4 – 6 min)			
Route 2	(8 – 12 min)			
Route 3	(12 – 18 min)			
Route 4	(16 – 24 min)			
Changeover	(16 – 24 min)			
Refill notes	(16 – 24 min)			
Supply graphite	(8 – 12 min)			
Control material center	(8 – 12 min)			
Last date checked:				

8.2.3 Communication Plan

If changes need to be made to the work instruction this needs to be brought up between the ones directly affected by the change along with the supervisor. The personnel directly affected by changes made to the linefeeder work instructions are the linefeeder and the Team leader since they are responsible for executing and supporting the linefeeder activities. In the same way the supervisor needs to communicate with linefeeder and Team leader if it is discovered that tasks are not performed as intended.

Communication between supervisor, Team leader and linefeeder is therefore crucial in order to continuously improve the process while at the same time supplying all needed materials. If other personnel need to be brought in to improve or educate should be decided and communicated by the supervisor, see Figure 38.

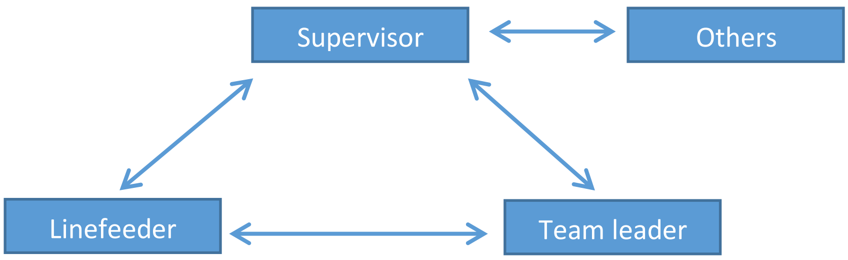

Figure 38: Communication plan when linefeeding conditions change

8.3 Future Work to Eliminate Blocking and Starving

During the project only a few causes to blocking and starving were examined and implemented since it was such a complex problem. Therefore improvement are still needed in order to minimize blocking and starving in the future.

From the performed root cause analysis (see 6.4 Root Cause Analysis) four root causes to the sources of blocking and starving were identified. Two of the root causes where not dealt with; Missing work instructions and Missing education in benefits of ergonomics.

Missing work instructions was during the study a problem since it often made it unclear who was supposed to do what resulting in double work and work not being performed. An example of where the responsibilities were unclear was responsibilities for getting the personnel from brazing to pick up the finished charge. Getting the personnel from brazing was most often handled by the operators however sometimes the Team leader performed the activity, there is probably a better way to handle the communication. Missing work instructions are also the case for control of inventory and control of graphite where no instructions are available.

Missing education in benefits of ergonomics was a problem resulting in a lot of unscheduled breaks because of bad ergonomics. At TitanX not a lot of focus was put to ergonomics since the benefits of ergonomics were not clear to them. However a lot of unscheduled breaks were most likely because of bad ergonomic conditions. Rotation might be part of the solution to reduce blocking and starving but focus should be put to designing the stations according to the operators. Rotation will also result in less dependability on certain personnel which means that production is not blocked when a key operator is missing.

9. Conclusion

In the following chapter the conclusions connected to the thesis work are presented. First the conclusions from the four aims will be presented followed by a general conclusion of the purpose.

The purpose of the thesis work was to study and illustrate how value stream mapping can be executed in a structured manner according to the DMAIC methodology. A secondary purpose of the thesis work was to, through the use of the "VSM-DMAIC approach", present and implement improvements in a production process. The purpose was to be answered through the use of four aims:

Aim 1: Review how VSM can be executed through the DMAIC methodology

As explained in the theoretical framework a VSM can be conducted through the DMAIC methodology in several ways. The way in which this study has been conducted is through using DMAIC methodology as the basis of the improvement project with VSM implemented simultaneously in order to strengthen the Six Sigma approach and its tools. Using DMAIC as the basis with VSM implemented simultaneously is according to Juan and Carretero (2010) the most suitable way to combine the two. There is however no possible way to determine if using DMAIC as the basis with VSM implemented simultaneously was the best way to conduct this study. Another approach might have led to more beneficial results or another conclusion.

Aim 2: Examine a production process and identify improvement opportunities using VSM and DMAIC

In the study TitanX production of oil coolers was examined where the VSM made it easier to identify problems that were not visible in data. The VSM also made it easier to find causes to problems since it gave visual indications of what the problem could be. DMAIC methodology with the use of a thoroughly defined problem a lot of data gathering and a root cause analysis made it a lot easier to find a focus areas and to minimize the problem in order for focus to be put where it is needed the most. Although the integration of VSM and DMAIC is beneficial to identify improvement opportunities it is also very time consuming.

Aim 3: Present and implement solutions to the identified problems

The improvements could be easily visualized through the use of current state maps and future state maps which made the need for certain improvement visible. The use of VSM helped create an understanding of the problem while DMAIC methodology provided economic incentive which created a push from management to implement solutions. The support from management made it easier to implement solutions since the support needed existed. The DMAIC methodology also made it possible to base decisions in underlying data which made it easier to identify true causes to blocking and starving. By using only the gathered data a lot of time could have been saved however if it would have had the same impact on management is difficult to say.

Aim 4: Draw conclusion of how VSM can be executed through the DMAIC methodology

The VSM worked well through the DMAIC methodology. The VSM gives a wider perspective while Six Sigma tools allow a deeper understanding of the problem and its contributing factors. In the beginning of the case study the VSM worked well as a way of understanding the process and its issues, many issues were a lot clearer in the VSM while some issues was clearer in the gathered data. Analyzing with the VSM and process data as foundation is believed to have given a more holistic view of the problem allowing focus to be put where it is most needed.

Purpose: Study and illustrate how value stream mapping can be executed in a structured manner according to the DMAIC methodology. A secondary purpose of the thesis was to, through the use of the "VSM-DMAIC approach", present and implement improvements in a production process.

The secondary purpose with the thesis work was during the conducted case study obtained since improvement opportunities were identified, presented and implemented in order to improve the production process at TitanX. The suggested improvements are believed to have resulted in a lot of cost reductions within the flow and the case study can therefore be considered successful.

The conclusions connected to the primary purpose was that there is no possible way to determine if using DMAIC as the basis with VSM implemented simultaneously was the best way to conduct the study. If the study had been conducted in any of the other explained ways the result might have been completely different. Therefore it is impossible to conclude that VSM can be executed in a structured manner according to the DMAIC methodology. What can be concluded is that VSM can be conducted in a structured manner according to the DMAIC methodology with the DMAIC methodology as the basis and VSM implemented simultaneously.

Although only one way in which DMAIC methodology can be implemented with VSM was studied and illustrated further through the case study it is concluded that using DMAIC methodology as the basis with VSM implemented simultaneously provided a more visual picture of the problem, highlighting the importance of the problem compared to other problems in the flow.

Since VSM creates a visual picture of where changes are needed it provides a good way to determine what areas need to be improved. The DMAIC methodology focuses on basing decisions on underlying facts, this makes it easier to motivate needed improvements.

The integration of DMAIC and VSM results in a lot of needed information, it is therefore time consuming to conduct projects using the two. It can therefore be useful to use the integration when a problem is extensive and difficult to define since it provides a more thorough identification of problems using different data. The integration might however be impractical for smaller and easier projects where the problem is well known since it most certainly would result in a more time consuming project.

10. Discussion

This chapter will discuss the conclusion from the study, whether the conclusions can be trusted and what further research is necessary in order to reach a conclusion on the examined integration. Discussed in the chapter are also the validity and reliability of the thesis work along with a discussion of what could have affected the result.

The study could have been performed differently in many ways, more focus could have been put into creating the complete value stream maps with thorough information in all process steps and not only in the assembly processes. In this study focus was put into the problems perceived as most urgent according to the project group and project supervisor, however if more people had been included in the decisions other problem areas might have occurred resulting in a different focus.

When it comes to the utilization of tools the VSM could have been performed together with people from different departments and people from production through a workshop which according to Rother and Shook (2003) is the most appropriate way to conduct VSM. In this study there was no time to include personnel from all departments since personnel were very busy. Therefore the VSM is a compilation of conducted observations and interviews performed during the study. It is therefore possible that information has been excluded because it has not been seen or brought up during the interviews.

The changes that this project led to was by some considered a relief since the process improvements allow operators to do their jobs. For some change was considered a burden, operators wanted to fetch materials because it felt like a break from repetitive work for them. Changing work practice was during the project considered the most difficult change to handle, linefeeders want to supply material the same way they have always supplied materials. Most opinions during the project were positive; most negative response was connected to the linefeeder performing more tasks than before when it was already a heavy job which no one wanted to perform.

Another aspect which made the implementation even harder was the fact that new linefeeders were hired during the study which resulted in the need to try out improvements on personnel that were not going to replenish materials in the future. The personnel that was not going to replenish material in the future were therefore negative to change since it did not matter to them. In order to avoid negative personnel that did not want the change implementation was focused on the new linefeeders making the implementation more time consuming than expected.

The chosen linefeeders to work with were however positive to the change, at first it was a lot to take in and remember for the linefeeders however after a while the linefeeders noticed that there was a lot more time available in between routes. They also knew what to do with the excess time they had created. Instead of waiting and controlling inventory time was put to make sure all needed material was replenished and that the stations were in appropriate conditions resulting in less blocking and starving.

In the beginning the new standard for linefeeding activities lead to more work for the linefeeder but by continuously improving the replenishment of materials by working according to schedule the work was simplified allowing time to complete other tasks.

Although a lot could have been executed differently in the study the conclusion was believed to be similar, that the DMAIC methodology and VSM complement each other in many ways and that there is no reason not to use both tools apart from the lack of time.

Validity has been secured through the study by the use of information and data from several different sources, among them literature studies, observations, interviews and previously collected secondary data. Using existing secondary data can however have reduced validity in the study since it was not always possible to validate the collected data from other sources. Reliability can also have been reduced since the different sources of data was not always consistent with each other. The use of quantitative and qualitative data had a positive effect on reliability since the qualitative data reduces the risk of including perceptions. The secondary data used however reduces the reliability since the risk of perceptions cannot be excluded.

To secure a high reliability in the study measurements have been made in several occasions so that an average of the true case could be obtained. What could be argued to reduce the reliability is the amount of data collected. In the different stations three measurements was conducted for a minimum of three hours. The average amount of data for each station was therefore approximately 12 hours which can be considered as little since it was collected to understand wastes for the whole year.

10.1 Future Research

The presented thesis work contributed to further understanding within Lean Six Sigma, more specifically how VSM can be executed through DMAIC methodology, there is however more research needed in the area. Interesting to research further based on the results from the conducted study is whether implementation of VSM and DMAIC in the other ways explained in the theory chapter will result in different conclusions. The implementation of VSM as a complementary tool to DMAIC methodology and its tools might not be the best use of a DMAIC-VSM approach.

In order to increase credibility of the conclusions drawn studies should be conducted with the use of DMAIC-VSM approach on other types of problems. Blocking and starving is a problem more connected to Lean and wastes, it would therefore be interesting to conduct a study using DMAIC and VSM in quality control, SPC, MSA where VSM is not a common tool. In the cases where VSM is not a common tool value could be created through a more holistic view of a process and its problems, which is not always apparent when using quality controls, SPC and MSA..

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Appendix A – VSM of the Process Flow

Presented below are the different symbols that have been used in the value stream maps. Presented in the picture are also the symbols meaning (see Figure 39).

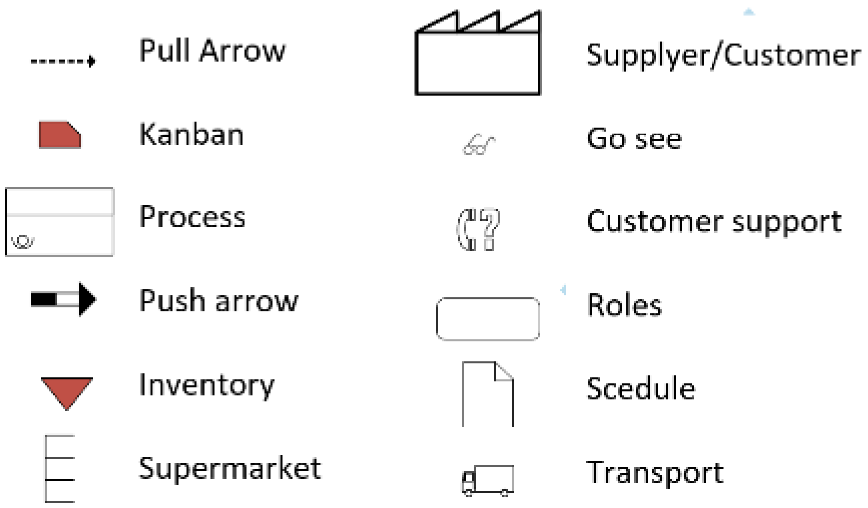


Figure 39: The different symbols used in the value stream mapping

Appendix B – Current State Maps

Presented in this appendix are the current state maps of MD 13 and HDE 13. The value stream map of Matdosan XL is not included in the appendix since it is presented in chapter 5.1 Current State Map.

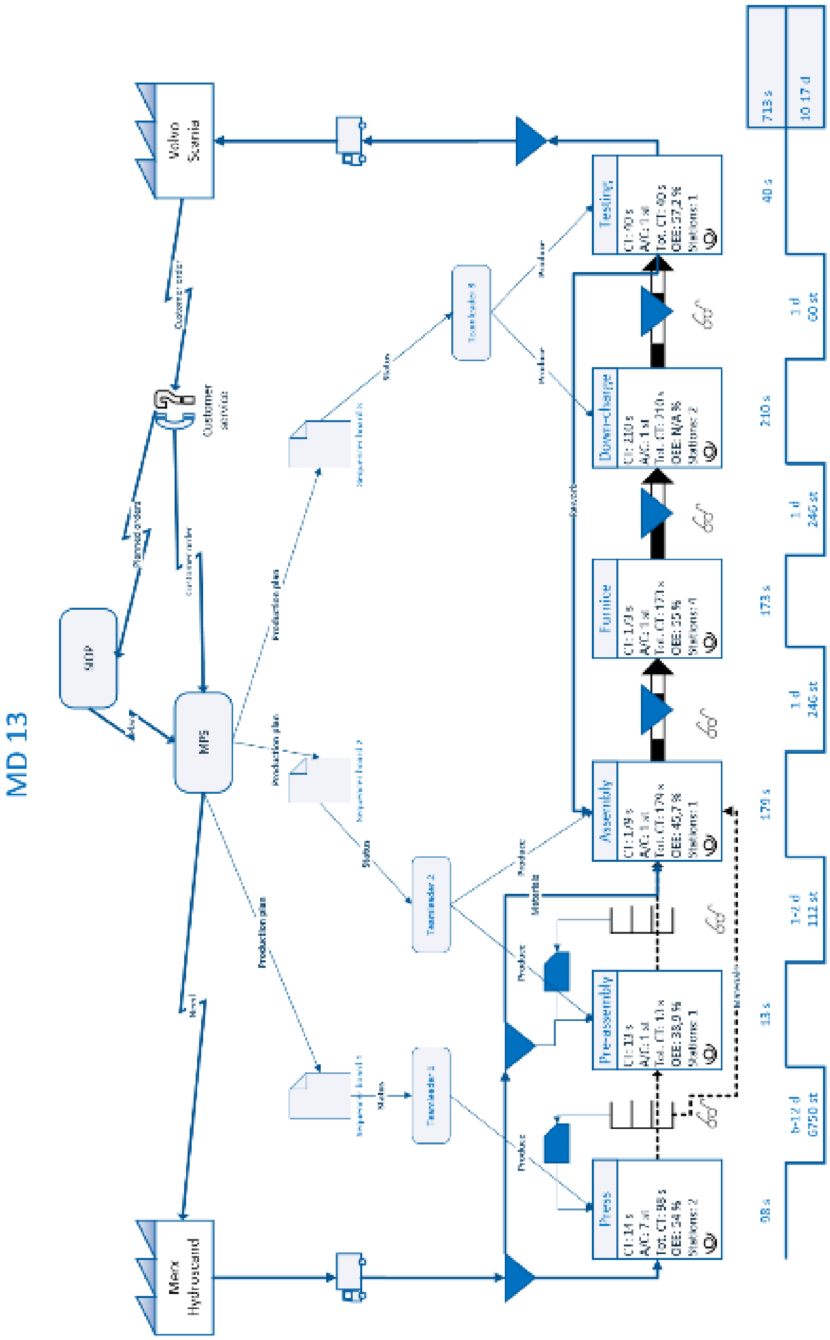


Figure 40: Current state map of MD 13

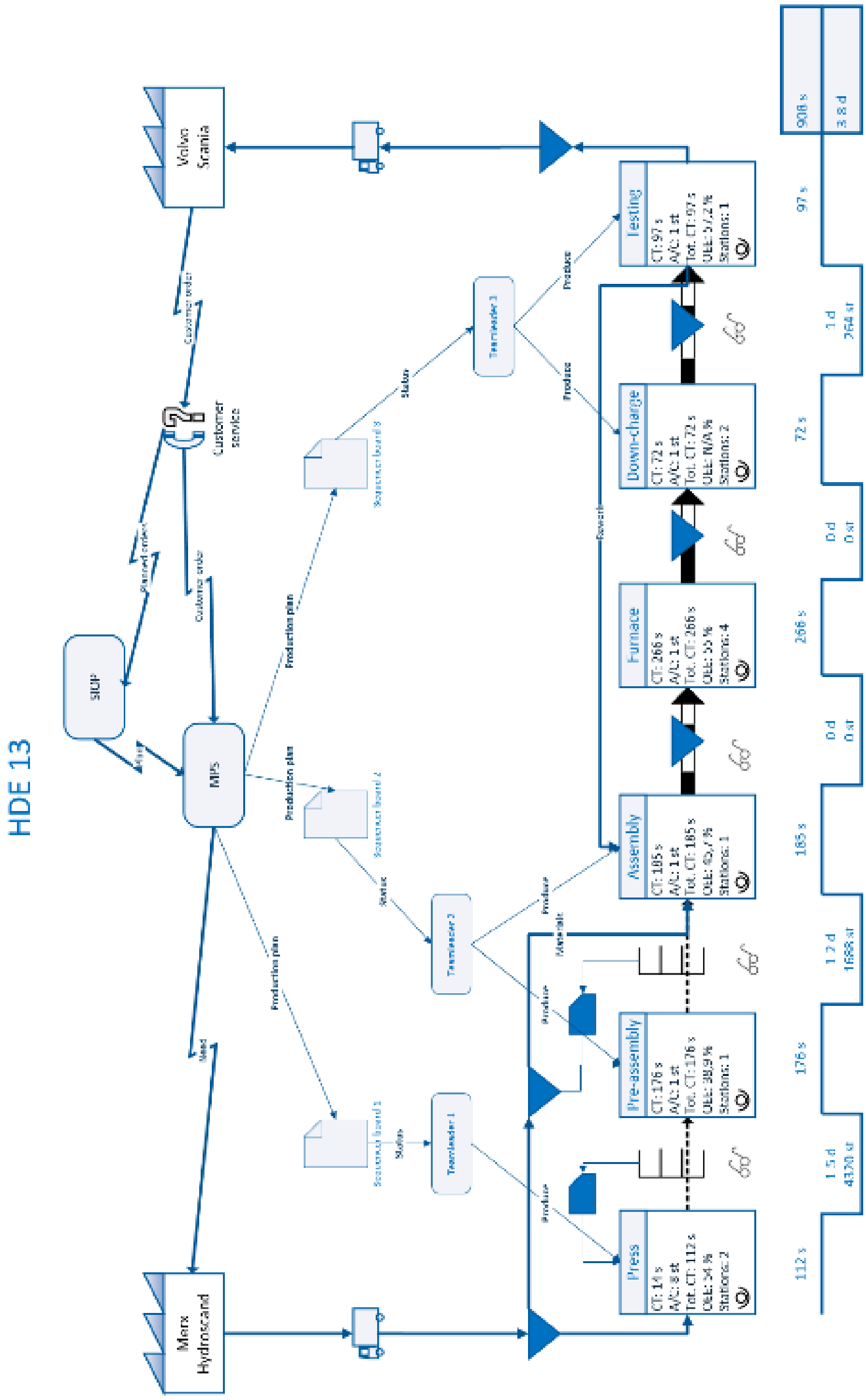
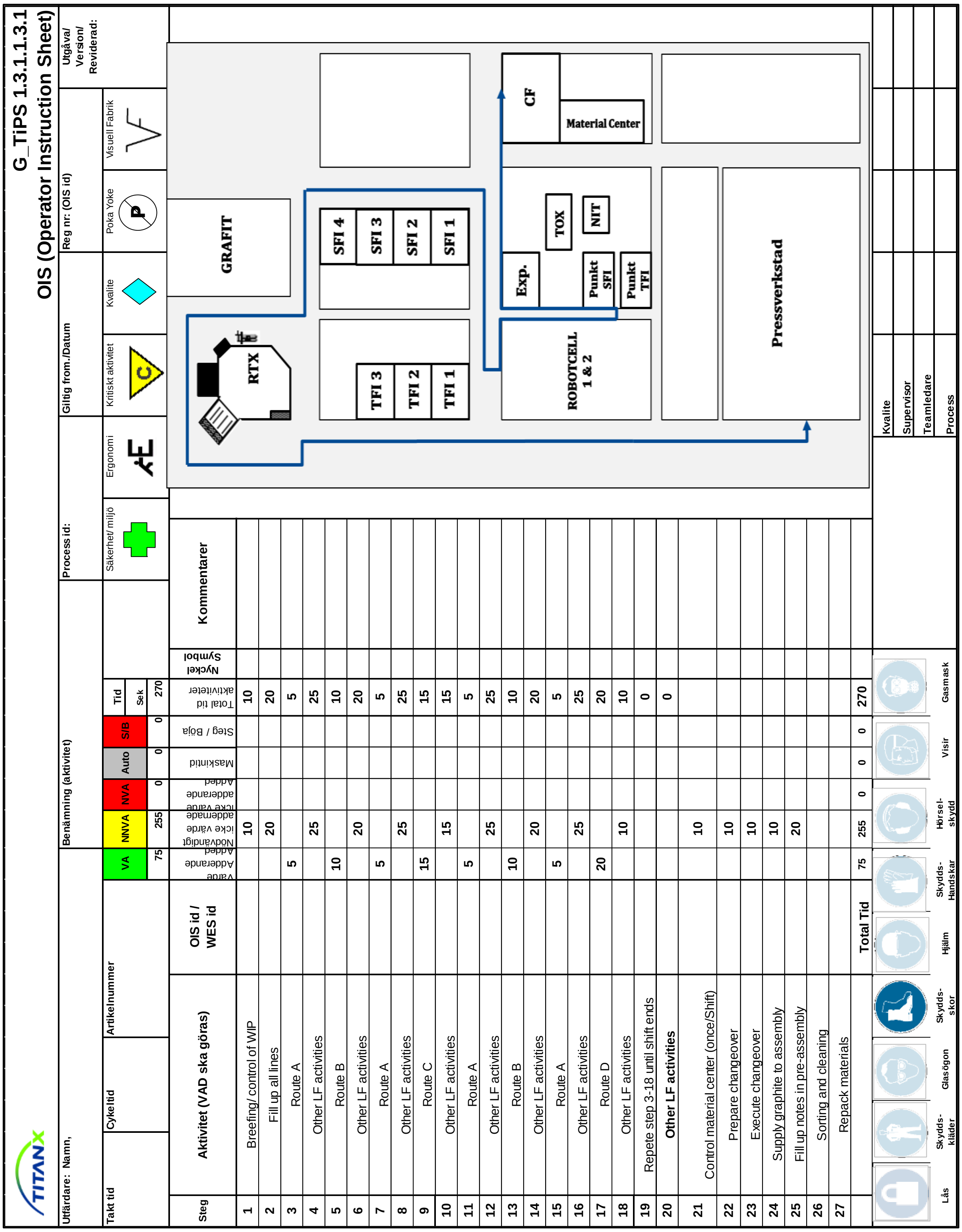


Figure 41: Current state map of HDE 13

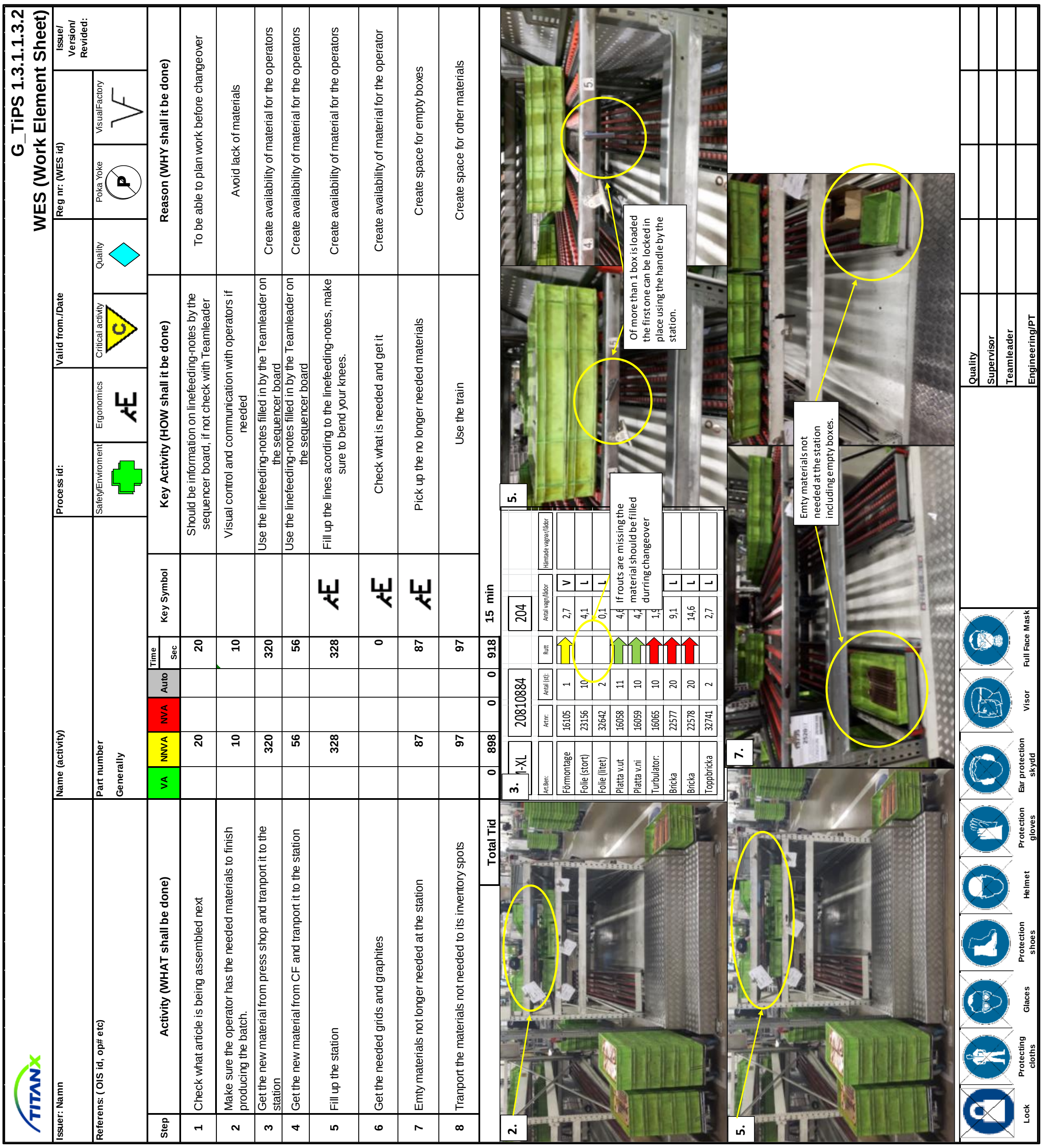
Appendix C – Operator Instruction Sheet and Work Element Sheet for the Linefeeder

Presented below is the operator instruction sheet designed for the linefeeder along with the work element sheets for the different activities the linefeeder need to perform.



Steg	Aktivitet (VAD ska göras)	OIS id / WES id	VA (Adderande Värde)	NNVA (Nödvändigt icke värde adderande)	NVA (icke värde adderande)	Auto (Maskintid)	S/B (Steg / Böja)	Tid Sek (Total tid aktiviteter)	Nyckel Symbol	Kommentarer
			75	255	0	0	0	270		
1	Breefing/ control of WIP			10				10		
2	Fill up all lines			20				20		
3	Route A		5					5		
4	Other LF activities			25				25		
5	Route B		10					10		
6	Other LF activities			20				20		
7	Route A		5					5		
8	Other LF activities			25				25		
9	Route C		15					15		
10	Other LF activities			15				15		
11	Route A		5					5		
12	Other LF activities			25				25		
13	Route B		10					10		
14	Other LF activities			20				20		
15	Route A		5					5		
16	Other LF activities			25				25		
17	Route D		20					20		
18	Other LF activities			10				10		
19	Repete step 3-18 until shift ends							0		
20	**Other LF activities**							0		
21	Control material center (once/Shift)			10						
22	Prepare changeover			10						
23	Execute changeover			10						
24	Supply graphite to assembly			10						
25	Fill up notes in pre-assembly			20						
26	Sorting and cleaning									
27	Repack materials									
		Total Tid	75	255	0	0	0	270		

Figure 42: Operator instruction sheet of the activities performed by the linefeeder

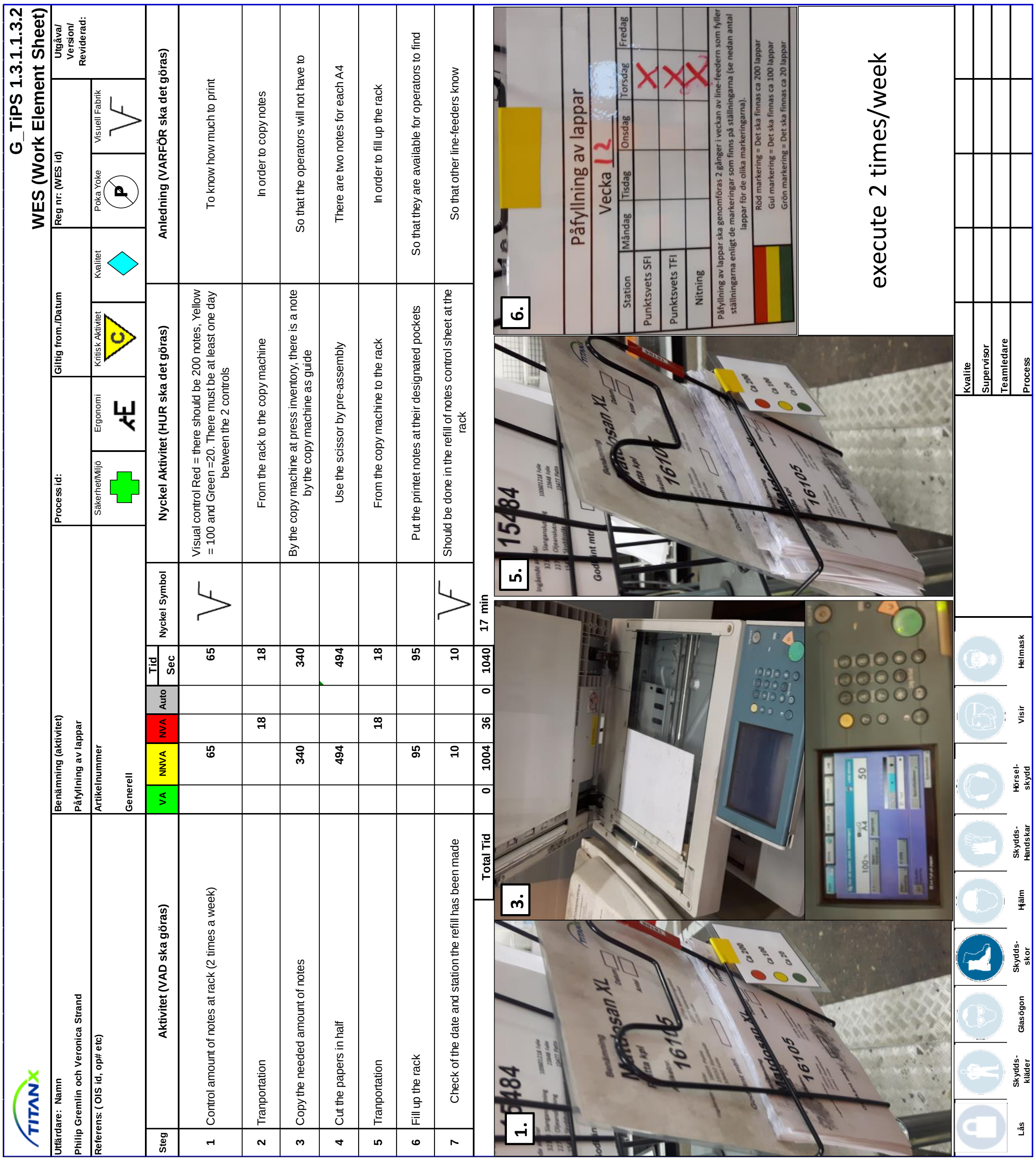


G_TiPS 1.3.1.1.3.2
WES (Work Element Sheet)

Issuer: Namn	Name (activity)	Process id:	Valid from./Date	Reg nr: (WES id)	Issue/ Version/ Revided:
Referens: (OIS id, op# etc)	Part number Generally	SafetyEnviroment / Ergonomics	Critical activity / Quality	Poka Yoke / VisualFactory	

Step	Activity (WHAT shall be done)	VA	NNVA	NVA	Auto	Time Sec	Key Symbol	Key Activity (HOW shall it be done)	Reason (WHY shall it be done)
1	Check what article is being assembled next		20			20		Should be information on linefeeding-notes by the sequencer board, if not check with Teamleader	To be able to plan work before changeover
2	Make sure the operator has the needed materials to finish producing the batch.		10			10		Visual control and communication with operators if needed	Avoid lack of materials
3	Get the new material from press shop and tranport it to the station		320			320		Use the linefeeding-notes filled in by the Teamleader on the sequencer board	Create availability of material for the operators
4	Get the new material from CF and tranport it to the station		56			56		Use the linefeeding-notes filled in by the Teamleader on the sequencer board	Create availability of material for the operators
5	Fill up the station		328			328	Ergonomics	Fill up the lines acording to the linefeeding-notes, make sure to bend your knees.	Create availability of material for the operators
6	Get the needed grids and graphites					0	Ergonomics	Check what is needed and get it	Create availability of material for the operator
7	Emty materials not longer needed at the station		87			87	Ergonomics	Pick up the no longer needed materials	Create space for empty boxes
8	Tranport the materials not needed to its inventory spots		97			97		Use the train	Create space for other materials
	Total Tid	0	898	0	0	918	15 min		

Figure 43: Work element sheet on how changeovers should be executed



G_TiPS 1.3.1.1.3.2
WES (Work Element Sheet)

Utfärdare: Namn	Benämning (aktivitet)	Process id:	Giltig from./Datum	Reg nr: (WES id)	Utgåva/ Version/ Reviderad:
Philip Gremlin och Veronica Strand	Påfyllning av lappar				
Referens: (OIS id, op# etc)	Artikelnummer: Generell	Säkerhet/Miljö, Ergonomi	Kritisk Aktivitet, Kvalitet	Poka Yoke, Visuell Fabrik	

Steg	Aktivitet (VAD ska göras)	VA	NNVA	NVA	Auto	Tid Sec	Nyckel Symbol	Nyckel Aktivitet (HUR ska det göras)	Anledning (VARFÖR ska det göras)
1	Control amount of notes at rack (2 times a week)		65			65	Visuell Fabrik	Visual control Red = there should be 200 notes, Yellow = 100 and Green =20. There must be at least one day between the 2 controls	To know how much to print
2	Tranportation			18		18		From the rack to the copy machine	In order to copy notes
3	Copy the needed amount of notes		340			340		By the copy machine at press inventory, there is a note by the copy machine as guide	So that the operators will not have to
4	Cut the papers in half		494			494		Use the scissor by pre-assembly	There are two notes for each A4
5	Tranportation			18		18		From the copy machine to the rack	In order to fill up the rack
6	Fill up the rack		95			95		Put the printet notes at their designated pockets	So that they are available for operators to find
7	Check of the date and station the refill has been made		10			10	Visuell Fabrik	Should be done in the refill of notes control sheet at the rack	So that other line-feeders know
	Total Tid	0	1004	36	0	1040	17 min		

Figure 44: Work element sheet on how the linefeeder should refill notes at pre-assembly