Lean study on the maintenance division at Sandvik Coromant
Resource utilization of work procedures

Victor Svensson
Fredric Sundin
Abstract

Lean study on the maintenance division at Sandvik Coromant - Resource utilization of work procedures

Fredric Sundin and Victor Svensson

Sandvik Coromant in Gimo, Sweden, is a world-leading supplier of tools and know-how for the metal cutting industry. This thesis was carried out on the maintenance division at the production plant producing tools for milling and drilling. The maintenance division is responsible for the maintenance of the machinery operating at all eight production units on the tool production plant.

This thesis aims to map the value flow and non-value adding activities on the maintenance division and come up with suggestions for improvement. The study only focuses on the organizations work procedures and routines.

The thesis began with a current state analysis of the maintenance division to find out how the activities, databases and service technicians interacts in daily operations. A time study showed that the proportion of non-value adding activities in some isolated cases was as low as 30%. The thesis ended in a root cause analysis, in form of a workshop, which aimed to, with help from the service technicians' expertise and the researchers' knowledge of lean production come up with solutions worth implementing on the maintenance division.

The root cause analysis resulted in three solutions, which the researchers along with the service technicians sees as simple actions that will reduce the non-value adding time associated with the use, and handling of documentation. The analysis also resulted in six actions seen as worth implementing, which however is more recourse demanding for the organization.

Handledare: Tommy Lindman and Lennart Jonasson
Ämnesgranskare: Claes Aldman
Examinator: Lars Degerman
ISRN UTH-INGUTB-EX-15-2014/05-SE
Sammanfattning

Sandvik Coromant i Gimo, Sverige, är en världsledande leverantör av verktyg och know-how för metallbearbetningsindustrin. Detta arbetet utfördes på underhållsavdelningen vid fabriken för tillverkning av verktyg för borrning och fräsningsbearbetning. Underhållsavdelningen är ansvarig för underhåll av maskinparken på alla de åtta produktionsavsnitten vid fabriken för verktygstillverkning.

Arbetet syftar till att kartlägga värdeflödet och icke värdeskapande tid vid underhållsavdelningen och komma med förbättringsförslag. Studien fokuserar enbart på organisationens arbetssätt och rutiner.

Arbetet började med en nuvärdesanalys av underhållsavdelningen för att undersöka hur aktiviteter, databaser och servicetekniker fungerar tillsammans i den dagliga verksamheten. En tidsstudie genomfördes för att undersöka hur mycket icke värdeskapande tid serviceteknikerna har vid en standardarbetsorder från produktionsavsnitten. Tidsstudien visade att andelen icke värdeskapande tid var så låg som 30% i vissa isolerade fall. Arbetet avslutades i en rotorsaksanalys i form av en workshop, vilkens syfte var att med hjälp från serviceteknikerna och deras expertis tillsammans med kunskapen om lean production hos forskarna undersöka vilka lösningar som skulle minska denna siffra ytterligare.

Rotorsaksanalysen resulterade i tre lösningar som forskarna tillsammans med serviceteknikerna ser som enkla åtgärder för att minska den icke värdeskapande tiden kopplad till användning och hantering av dokumentation. Analysen resulterade även i sex åtgärder som anses vara vård att implementera men som är mer resurskrävande för organisationen.

Nyckelord: Maintenance, Lean, TPM, CBM
Acknowledgment

We would like to express our appreciation to all those who have helped us during the performance of this thesis. First we give a special gratitude to our supervisors Tommy Lindman and Lennart Jonasson. You have always been patient and taken the time to provide us with useful information and feedback. Without your support this thesis would not have been possible to complete. Further we would like to show our gratitude to Anette Nilsson and Mikael Herdin for your support and encouragements when the execution of this thesis seemed impossible. Claes Aldman, responsible subject teacher, also deserves appreciation for his inputs to this project.

Last but not least the service technicians at the maintenance division deserve acknowledgments for their patience and for taking time to help us to perform the observations and surveys.

We hope that this thesis will be of as great value for the maintenance division as it has been for us. We hope that you pick up where we left off and continue to improve.

Gimo in June 2014

Fredric Sundin

Victor Svensson
# TABLE OF CONTENT

1. **INTRODUCTION** ......................................................................................................................................................... 1  
   1.1 SANDVIK COROMANT .................................................................................................................................................. 2  
   1.2 THE MAINTENANCE DIVISION GVM5 ..................................................................................................................... 3  
   1.3 BACKGROUND AND PROBLEM DESCRIPTION ....................................................................................................... 4  
   1.4 THESIS AIM ............................................................................................................................................................... 5  
   1.5 DELIMITATIONS .......................................................................................................................................................... 6  
   1.6 DESIGNATIONS AND CONCEPTS ............................................................................................................................. 6  

2. **METHODOLOGY** ............................................................................................................................................................ 9  
   2.1 RESEARCH METHODOLOGY ....................................................................................................................................... 10  
      2.1.1 Problem analysis ...................................................................................................................................................... 10  
      2.1.2 Analyzing philosophies ............................................................................................................................................ 10  
      2.1.3 Inductive and deductive methods .......................................................................................................................... 11  
   2.2 SCIENTIFIC TECHNICAL TRADITIONS ..................................................................................................................... 11  
      2.2.1 Positivism ............................................................................................................................................................... 11  
      2.2.2 Systems theory ......................................................................................................................................................... 11  
   2.3 COLLECTION OF DATA .................................................................................................................................................. 12  
      2.3.1 Literature study ......................................................................................................................................................... 12  
      2.3.2 Observations ............................................................................................................................................................. 13  
      2.3.3 Interviews ................................................................................................................................................................. 14  
   2.4 APPROACH OF THE STUDY ......................................................................................................................................... 15  

3. **THEORY** ........................................................................................................................................................................ 17  
   3.1 VALUE STREAM MAPPING ........................................................................................................................................... 18  
   3.2 TOTAL PRODUCTIVE MAINTENANCE ....................................................................................................................... 19  
      3.2.1 Background ............................................................................................................................................................. 19  
      3.2.2 Operational monitoring ............................................................................................................................................ 20  
      3.2.3 Maintenance by operators ...................................................................................................................................... 20  
      3.2.4 Improvement groups ............................................................................................................................................... 22  
      3.2.5 The maintenance divisions new role .................................................................................................................... 22  
      3.2.6 Maintenance prevention ........................................................................................................................................ 23  
      3.2.7 Implementation of TPM ....................................................................................................................................... 23  
   3.3 CORRECTIVE MAINTENANCE ....................................................................................................................................... 25  
   3.4 PREVENTIVE MAINTENANCE ....................................................................................................................................... 26  
   3.5 CONDITION BASED MAINTENANCE ........................................................................................................................... 26  
   3.6 LEAN ................................................................................................................................................................................ 28  
      3.6.1 History ........................................................................................................................................................................ 29  
      3.6.2 Lean production ......................................................................................................................................................... 30  
      3.6.3 The Lean house ......................................................................................................................................................... 32  

4. **CURRENT STATE** ........................................................................................................................................................... 37  
   4.1 THE SERVICE ORGANIZATION .................................................................................................................................. 38  
   4.2 THE MAINTENANCE STRATEGY .................................................................................................................................. 39  
      4.2.1 Aims and goals ........................................................................................................................................................... 39
4.2.2 The improvement procedure ................................................................. 40
4.3 WORK PROCEDURES .................................................................................. 41
  4.3.1 Corrective maintenance ....................................................................... 41
  4.3.2 Preventive maintenance ..................................................................... 42
4.4 TIME STUDY .............................................................................................. 43
  4.4.1 Time distribution .................................................................................. 43
  4.4.2 Value adding activity .......................................................................... 48
  4.4.3 Troubleshooting phase ......................................................................... 50
  4.4.5 Time consumption documentation ...................................................... 53
  4.4.6 Costs for documentation ..................................................................... 55
  4.4.7 Time consumption transportation ....................................................... 57
  4.4.8 Costs for transportation ...................................................................... 58
4.5 VALUE STREAM MAPPING ......................................................................... 60
  4.5.1 Preventive maintenance ...................................................................... 61
  4.5.2 Corrective maintenance ...................................................................... 61
5. FUTURE STATE .............................................................................................. 63
  5.1 FUTURE STATE VSM ................................................................................ 64
    5.1.1 Preventive maintenance ................................................................. 64
    5.1.2 Corrective maintenance ................................................................. 64
6. WORKSHOP AND VSM .............................................................................. 65
  6.1 WORKSHOP ............................................................................................. 66
  6.2 VALUE STREAM MAPPING ..................................................................... 72
    6.2.1 Corrective maintenance ................................................................. 72
    6.2.2 Preventive maintenance ................................................................. 73
7. DISCUSSION AND RECOMMENDATIONS .............................................. 75
  7.1 DISCUSSION ............................................................................................ 76
  7.2 RECOMMENDATIONS ............................................................................. 77
8. REFERENCES ................................................................................................ 79

TABLE OF FIGURES

Figure 1-1 Organization structure Sandvik AB .................................................. 2
Figure 1-2 Organizational structure the maintenance division GVM5 .................. 3
Figure 3-1 Thermographic picture of malfunctioned bearing .................................. 28
Figure 3-2 TPS or The Lean house according to leanblitzconsulting .................. 32
Figure 3-3 Example of PICK chart .................................................................. 35
Figure 4-1 Organizational structure GVM5 ..................................................... 38
Figure 4-2 The improvement process at GVM5 .......................................................... 40
Figure 4-3 Corrective maintenance process ................................................................. 41
Figure 4-4 Preventive maintenance process ................................................................ 42
Figure 4-5 Time distribution corrective maintenance ..................................................... 45
Figure 4-6 Time distribution preventive maintenance ..................................................... 46
Figure 4-7 Time distribution preventive maintenance ..................................................... 46
Figure 4-8 Time distribution value adding activity ......................................................... 50
Figure 4-9 Time distribution initial phase ..................................................................... 51
Figure 4-10 Time distribution initial phase ................................................................... 52
Figure 4-11 Time consumption documentation ............................................................. 54
Figure 4-12 Average transportation time ..................................................................... 58
Figure 6-1 Example of solution, binders back ............................................................... 67
Figure 6-2 GVM5 archive ......................................................................................... 67
Figure 6-3 PICK-chart workshop ............................................................................... 72

TABLE OF CHARTS

Table 4-1 Table of codes............................................................................................... 44
Table 4-2 Table of codes 2 ......................................................................................... 49
Table 4-3 Table of codes 3 ......................................................................................... 51
Table 6-1 Problems and solutions workshop ................................................................. 71
1. Introduction

The initial chapter starts with a shorter presentation of the organization where the thesis is carried out. Thereafter follows an introduction to the problems and difficulties that the company is facing. The thesis aim will be presented and the delimitations that constraints this project will be described. In conclusion designations, definitions and abbreviations that are continuously used throughout the thesis are presented.
1.1 Sandvik Coromant

Sandvik Coromant is a world-leading supplier of tools, tools solutions and know-how mainly for the metal cutting industry. Their product portfolio includes development and manufacturing of metal cutting and forming tools. Through their own production centers around the world they offer support and guidance regarding production and process development to customers in need of increasing their efficiency when it comes to working with metal cutting and forming. (Sandvik Communications, 2014)

Sandvik Coromant in Gimo is divided into two autonomous factory sites. One site, Gimoverken Production Tools, manufactures tools and tool holders, which are commonly used in operations such as grinding, milling and drilling. The other site, Gimoverken Insert production, manufactures cutting inserts, which are used for metal cutting processes. This thesis is performed at the maintenance division at the Production tool site.

At present Sandvik Coromant has around 8,000 employees and they are active in over 130 countries in total. Sandvik Coromant is a subdivision to Sandvik Machining Solution, which in turn is a subdivision to Sandvik. Figure 1.1 bellow illustrates the hierarchic structure of Sandvik from the top and down to the maintenance division where this project is performed. (Nilsson, Manager GVM5, 2014a)
1.2 The maintenance division GVM5

In order to understand the upcoming problem description, the aim of the thesis and the delimitations it is necessary to explain the maintenance division in general terms. This part is a superficial introduction to the maintenance division. Further and more detailed descriptions of the organization and their work procedures will be presented later in the thesis under the current state analysis.

The machinery at the plant that is maintained by the maintenance division at Gimoverken is mostly machines that perform cutting processes as milling, drilling and grinding of metal. The production equipment is complex which requires high skilled service technicians and a well functional maintenance division.

The maintenance division work with both preventive maintenance (PM) and corrective maintenance (CM). The preventive maintenance is the maintenance that is scheduled in advance and the corrective maintenance is the repairs, which are not. The corrective maintenance work orders are reported from the production units into the administrative database Corus. The maintenance division uses this database to get an overview over the machines, which are not working at the moment. Corus helps the manager and the corrective maintenance team leader to prioritize and decide the work sequence for the technicians. The preventive maintenance follows a predetermined schedule based on service intervals.

Bellow in Figure 1.2 follows an organizational structure that illustrates the division of labor between different functions within the maintenance division. As you can see, some of the technicians are responsible for a certain field. This enables the division to be rationalized and allows the technicians to develop expert knowledge within their field of expertise.

Figure 1-2 Organizational structure the maintenance division GVM5.
1.3 Background and problem description

The Sandvik Coromant Gimoverken Production Tool Plant is not operating at full capacity at the moment. The exact usage of capacity is constantly varying but in some cases the usage of capacity is as low as 40 - 50 %. The plant is suffering from low order input and the utilization of production equipment and resources are not as critical as when the plant is running close to its maximum capacity. Consequently the pressure on the maintenance division is low at the moment and they are able to maintain the machinery and to assure relatively high utilization rates.

Directives from the main division and the managers clearly state that the plant in general has to become more effective. In order to meet these expectations and to prepare for higher production rates and capacity usages in the future the plant has to make changes to increase the efficiency. Projects have been initiated that sequentially goes through all the departments, identifying and implementing improvement potentials to increase the competitiveness.

Besides these projects every part of the organization have goals to achieve in order to continuously improve themselves. The maintenance division for example has to minimize the number of critical work orders of highest priority for corrective maintenance by ten percent this year. Further goals are to increase the utilization rates for the Stama-machines, which are a certain commonly used machine type at the factory site. Besides this another goal is to educate the operators and EMO:s in maintenance. EMO:s are operators with special training in maintenance who works half of their time with maintenance tasks. They act as a filter between the operators and the maintenance division and are educated to handle easier kind of repairs by themselves. The EMO:s are employed by the production unit. (Nilsson, Manager GVM5, 2014b)

In order to achieve the goal of maximizing the utilization of the machinery the maintenance division has to eliminate non-value adding activities both for corrective and preventive maintenance. A more rational work procedure will also result in better use of resources, which also means higher efficiency.

As a complement to the ongoing improvement projects and continuous improvements in the organization the maintenance division believes that the help of students can increase the efficiency. The idea is to initiate a project that focus more on the work procedures of the maintenance activities. The maintenance division also believes that it can be stimulating to involve students from outside of the organization since they can look at the organization with fresh eyes. It is easy for the ordinary staff to become blind to flaws at home.

In detail the maintenance division wants help to investigate the time distribution for the service technicians. With an objective map of the time distribution the division between value adding and non-value adding activities can be identified and improved. The activities and work procedures can thereafter systematically be analyzed in detail. With
a solid current state analysis as a base, and by the use of accepted improvement concepts and theories, suitable improvement suggestions can be developed. The improvement suggestions are being presented as a plan with guidelines that will help the organization in the future development.

If the timeframe of the thesis allows it, the study can be slightly broadened to look at other working procedures than just the work of service technicians. For instance the time distribution study may show that the purchase and delivery of spare parts are problematic. The thesis can then superficially analyze the problems and suggest actions to resolve the problems or suggest further studies in the problematic field.

1.4 Thesis aim

The problem description above form a solid ground for the formulation of clear aims for the thesis. In order to measure the progress of the thesis quantified goals must also be defined.

With the problem description in mind one main question has been formulated. The main purpose of the thesis is to answer this question and to present the result in form of a plan with guidelines for the organization. To cover all aspects of the question and to concretize the work some sub-queries have been defined to support the work. The purpose of those sub-queries is to support the study in the search for answers to the main question.

Besides the aim to resolve problems for the organization the thesis also has educational purposes. It is highly important that the study enables the students to convert the theoretical knowledge from the university studies into practical experience. The aim of the thesis is to use a systematic scientific approach and recognized scientific concepts and theories to answer the main question. The thesis will examine time distribution and non-value adding activities that affects the productivity at the maintenance division.

**The main question: Which are the most significant improvement potentials regarding work procedures at the maintenance division and how can these potentials be converted into actions that increases the efficiency?**

**Sub-queries:** These questions will be the basis in answering the main question and will also work as support in this study.

- Which are the non-value adding activities at the maintenance division?
- Which are the opportunities to eliminate the extent of these activities through more efficient work procedures?
- Which tools from Lean production and modern maintenance theories could be used as support for the improvement work?
1.5 Delimitations

Given the conditions and time limits for the project certain limitations are necessary to constrain the work. The following delimitations have been made to assure the quality of the project:

The thesis constraints to the maintenance division and will not be concerned with the adjacent divisions, their procedures and improvement potentials. However, in some specific situations, it can be necessary to study the interface and communications between the maintenance division and adjacent departments. It is possible that interviews can be performed with staff from an adjacent department in order to analyze the communication and interaction between the present department and the maintenance division.

As described in section 1.2 the maintenance division consists of one group of service technicians whose primary work tasks are to relocate and reinstall machinery. The machinery is often transferred internally, but it can also be sold and transferred to external companies. Because of the fact that this is a small part of the daily operations it is not crucial to study the work of this group in detail. Therefore the project will exclude this group. Besides this group the maintenance division also includes one autonomous sheet metal worker, which will also be excluded from the study.

It is extremely important to point out that the aim of the thesis is not, under any circumstances, to study individuals, their individual performance or their own way of working. The study will focus on work procedures but exclusively from a more general organizational point of view.

It will not be possible, due to the extent and time limits of the thesis, to study every improvement aspect. Therefore the different improvements will be prioritized and aspects of particular importance will be selected for further investigations.

1.6 Designations and concepts

The following definitions, designations and abbreviations are commonly used throughout this thesis:

Definitions:

Maintenance: "Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function" (Swedish Standard, 2010)

Corrective Maintenance: “Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function” (Swedish Standard, 2010)
Preventive Maintenance: “Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item” (Swedish Standard, 2010)

Condition Based Maintenance: “Preventive maintenance which include a combination of condition monitoring and/or inspection and/or testing, analysis and the ensuing maintenance actions” (Swedish Standard, 2010)

**Designations:**

Corus: Maintenance system, a database and computer program for administration and planning of the work at the maintenance division.

Maximo: Maintenance system, which will be implemented on Sandvik to replace Corus.

FUS: Computer program for documentation of completed service orders.

Value stream: The flow of physical products, material and information in the organization.

Cofur: This is a particular part of the maintenance system Corus that handles all aspects of inventory. The maintenance division uses Cofur when they are looking for and ordering spare parts.

**Abbreviations:**

GVM5: Gimoverken Metod 5

TPS: Toyota Production System

TPM: Total Productive Maintenance

TQM: Total Quality Management

CBM: Conditioned Based Maintenance

RCM: Reliability Centered Maintenance

CM: Corrective maintenance

PM: Preventive Maintenance

OEE: Overall Equipment Effectiveness
2. Methodology

The chapter starts with a theoretical part about research methodology and scientific technical traditions. The research methodology part includes philosophies about the process of approaching and analyzing scientific problems. Inductive and deductive methods, and the difference between them, are explained. After that follows a part about scientific technical traditions that includes explanations about positivisms and system theory. Thereafter follows a section about theories related to collection of data for the thesis, which includes literature study, observations, and interviews. In conclusion the approach of the study is described which revolves around the methodology for the execution process of this thesis.
2.1 Research methodology

Before solving a scientific problem the investigators need to analyze the problem to be able to choose the right tools, methods and philosophies when approaching the problem. There are many theories and concepts related to scientific approaches and bellow follows introductions to some of them.

2.1.1 Problem analysis

The first step in a study is to analyze what the problem is that needs to be investigated. This is then what controls the choice of theory, approach, methods and materials. (Wallén, 1993)

Problems can be observed in many ways, for example by occurrences of new phenomenon and deviations from previous knowledge. According to Wallén (1993) a problem in a scientific matter does not necessarily mean that a problem has to be something that an organization is suffering from. It can just as well be something the organization needs more information about in order to develop itself. To be able to define a relevant problem to study those who will perform the study need to have some sort of knowledge about the field of study. Knowledge about the field is important to choose the right methods and approaches for the problem. There are some questions that are good to consider before choosing methods for scientific works: (Wallén, 1993)

- What is it that makes this a problem?
- Is the problem area possible to research?
- Are there any appropriate theories and methods to approach this problem with?
- What is an acceptable answer?
- Which criteria are suitable for assessments of the results?

2.1.2 Analyzing philosophies

Depending on the purpose, ambitions, and the knowledge of the problem the study can be divided into four categories, with four different approaches. Explorative studies are usually used to seek basic knowledge of the problem; what is relevant variables and concepts etc.? The information from an important base for the following analyzing phase. Explorative studies should also look into what is not relevant information and therefore possible to exclude from further investigations. Descriptive studies are used when the aim is to determine the properties of the problem. It involves collection of data and systematization of it. Determination of relations between measured data is being made. Explanatory studies are used to seek deep knowledge in a subject (e.g. cause-effect, mechanisms etc.) Normative studies shall result in a proposal of actions. (Wallén, 1993)
2.1.3 Inductive and deductive methods

The choice of research approach depends on the actual projects relation between theory and empery. In general there are two methods, inductive and deductive, which are both used to connect empery and theory. The difference between the two methods is that inductive method connects the hypotheses with the theory while deductive method connects the theories with the hypotheses. In other words the methods are initiated from opposite directions. (Wallén, 1993)

**Inductive methods**

Inductive methods are used by collecting data and from this data draw general parallels and make theoretical conclusions. The collection of data is supposed to be unbiased. This is seen as one problem with an inductive method and it have therefore been criticized. The problem with an inductive method is that a study won’t present anything not presented in the theory. Therefore it is seen as impossible to collect data with inductive methods. (Wallén, 1993)

**Deductive methods**

Deductive methods, unlike inductive methods, use the empery to base the hypothesis on. A deductive hypothesis can therefore only be tested true or false by applying it on the empery. If the hypothesis correlates with theory it can be seen as true. Therefore the use of deductive methods demands a high level of expertise about the subject. (Wallén, 1993)

2.2 Scientific technical traditions

There are two different scientific technical traditions and they all have different connections to research methodologies. *Positivism* and *systems theory* are traditions, which are described in more detail bellow.

**2.2.1 Positivism**

Positivism states that a scientific thesis can only be seen as meaningful if it can be verified empirical. Everything that cannot be tested empirical such as feelings, personal values etc. do not belong in science. In other words positivism states that a thesis can only be true if it complies with reality. In positivism it is considered essential to be confident with and rely heavily on the scientific rationality. Objective measurements are used rather than estimations. The scientist should be objective and the results shall not be affected of his/her values. (Wallén, 1993)

**2.2.2 Systems theory**

Systems theory’s fundamental ideas are that during studies of a specific phenomenon every phenomenon has to be seen as a small part in the bigger picture. Every activity affects its successor and its predecessor. According to the systems theory an activity cannot act on its own, the study must take consideration of the whole system,
subsystems and its environment. Main features in systems theory are that there is an interaction between these subsystems, phenomenon’s and its environment. (Wallén, 1993)

2.3 Collection of data

This chapter revolves around the theoretical parts of the data, collection and the practical work of collecting data for the thesis is described in the next chapter. In order to produce qualitative data it is of high importance to initially study different methods of collecting data. By acquiring knowledge about different methods it is possible to choose methods that are most suitable for the current study. This chapter focuses on aspects that are related to literature studies, different kinds of observations and interviews since these methods are considered to be suitable for this thesis.

In this chapter data is used as the generic name for both raw data, such as data from time measurements, and information gathered from theories and concepts. However it is always possible to differentiate and classify data into categories. The data that is summarized through the literature study is often named as secondary data. The term derives from the fact that the literature is not written for the current study, it is formulated for another context. Data that is collected exclusively for the particular thesis, such as information from interviews and observations, is considered to be primary data. It is important to have in mind that secondary data can be angled differently depending on the context and the author and therefore it is necessary to be critical to sources. (Strömquist, 2006)

As described earlier one important aspect of scientific works is the objectivity of the study and the collected data. The work of collecting data is an empirical form of work which differences it from theoretical studies based on reasoning. It is essential that the nature of the collected data is objective and distinguished from selective influences and personal opinions. (Wallén, 1993)

2.3.1 Literature study

A thorough literature study is necessary to develop knowledge within the field of study. The available information is almost always voluminous and a selection of suitable parts of theories and concepts has to be made. Dealing with voluminous amounts of information is generally difficult and confusing and without structure it is easy to get lost. In order to rationally sort out relevant parts within a certain field of study the reading procedure has to be systematical. It will not be possible to examine every source in detail. Therefore it is necessary to use certain reading techniques to support and structure the process of the literature study. (Walliman, 2001)

One suitable technique for determining the relevance of information and sources is skimming. When skimming books, articles and reports the reader looks quickly at the table of contents and the chapter headings. If some parts are interesting the reader looks for summaries to further evaluate the relevance of the information. This technique is
suitable for initial sifting of a field of study. When the initial sifting is over the following step consists of in depth reading to acquire knowledge within the field. For in depth reading one suitable technique is reading to understand. Reading to understand means in depth reading of relevant parts of the document in order to absorb important theories and concepts. (Walliman, 2001)

2.3.2 Observations

The definition of observations is relatively vast. Almost any kind of documented data are directly or indirectly based on observations. An observation involves the registration of patterns and processes that is of relevance for the particular observer. (Kylén, 2004)

Observations are often performed by humans, but the measuring process can often be supported by technical equipment such as different sensors. As humans are almost always involved in the registration and filtering of data the results gets subjective in some extent. A familiar phenomenon is that several persons that observe the same incident often give different descriptions of what happened. This is because different people perceive things differently and focus on different aspects. (Kylén, 2004)

There are several accepted ways of categorizing different kinds of observations. For instance observations can be divided into planned and un-planned observations. Planned observations means that the observer has defined in advance what to register and how. In some cases the problems that are being observed are rather diffuse and it is hard to define in advance which aspects to register. In those cases un-planned observations are used which mean that the observer registers interesting aspects along the way, without defining the focus area of the observation in advance. (Kylén, 2004)

Observations can also be divided into structured and un-structured observations. There is no clear dividing-line between these two notions. Unstructured observations are characterized by freedom for the observer. The focus area of the observation and how to document the results are up to the observer and are defined continuously during the observation. Structured observations on the other hand are characterized by predefined focus areas, which tell the observer what aspects to focus on and how to document the observations. One way of minimizing the subjectivity of the observation is to make them more structured, so that the observation gets more mechanical. Certain forms are often used to structure the observation and to ease the registration activity for the observer. (Kylén, 2004)

The selection of the observer is important. Observers are often categorized as participating observers or non-participating observers. The main difference between these two is that the non-participating observer is not involved in the process that is being observed. Participating observations on the other hand means that the observer are part of the process that is being observed. One example is a meeting secretary, which is often involved in the meeting and takes note at the same time. (Kylén, 2004)
The presence of the observer often affects the person that is being observed. This is not automatically a huge problem, but it is important to keep in mind that the observer can affect the outcome of the observation. (Kylén, 2004)

S
erveys

A survey is an inquiry to the respondents. It can be performed with handed out paper forms or by digital forms answered with the help of computers. The forms can be sent out to the persons in the target group or handed out at a meeting. Before the respondent documents anything on the forms they should be well informed about the background and the purpose of the survey. This information can be attached to the survey by a complementing letter or by attaching ingress directly on the forms. If the survey is presented at a meeting the people responsible for the survey can introduce the survey and explain the purpose and relevance of the study. An advantage with an oral introduction is that it allows the respondents to ask questions. (Kylén, 2004)

It is essential that the information about the survey and the questions are adequate, so that all the respondents interpret the information in the same way. Another purpose with attaching a short section with background information to the survey is that it helps to motivate the respondents. It is more likely that the respondents get motivated to answer the forms if they know the purpose and understand the relevance of the survey. (Kylén, 2004)

The disposition of the form is important since it affects the results of the survey. It is important that the form looks pleasant. It is also essential that the form is easy to fill out, otherwise there is a great risk that some of the respondents decides not to submit the form. (Kylén, 2004)

2.3.3 Interviews

The length of an interview can vary widely from short interviews of 5 – 20 minutes up to longer interviews that lasts for a couple of hours. The short interviews are often in relatively structured while longer interviews are more un-structured. In structured interviews there are a number of predefined questions and the interviewer shall ensure that the responses are sufficient, so that all of the questions gets answered. In un-structured interviews the interviewer got some predefined question areas to cover, but the exact questions are defined during the interview and depends on the outcome of the interview. (Kylén, 2004)

The interviewer got an interview guide as support during the interview. If the interview is structured the guide includes a list of questions that the respondent should answer. If the interview is un-structured the guide includes key words and short descriptions of focus areas to cover. It is important to keep in mind that the situation and the relation between the interviewer and the respondent affect the outcome of the interview. (Kylén, 2004)
Chapter 2 - Methodology

There are several different kinds of methods for interview investigations. All the methods are compatible with a fundamental model called the funnel model. This model includes information about the sequence of the interview study in general terms. The funnel model is often used as a base for the formulation of the interview study. The funnel model suggests that the structure of the interview is based on the following six steps: (Kylén, 2004)

1. Introduction
2. The respondents free story tell
3. Clarification
4. Control
5. Information
6. Ending

2.4 Approach of the study

The thesis was initiated through a literature study that mainly covered Lean Production, modern maintenance techniques and scientific methodology. Since the literature study required processing of large amounts of information reading techniques were adopted to rationalize the work. The initial study of certain fields has often been made through skimming internet sources such as databases, articles and e-books. When important theories, concepts and aspects within the field have been identified the next step has been to borrow a selection of relevant physical literature from the university library. The theory chapter is mainly based on written books and the information has been acquired through reading to understand.

A current state analysis has been made to describe the organization and to enlighten problem areas. As described earlier the main focus of the thesis is the time distribution and the work procedures for the service technicians. The current state map is based on information from structured observations, unstructured interviews and the results from a value stream map. The practical performance and the outcome are of course explained in detail later in the thesis. The theoretical method of value stream mapping is explained in the theory chapter later in the thesis and the practical usage and outcome of VSM are described in the current state analysis. The purpose of the VSM is to enlighten the gaps between the organizations current work procedures and a desirable future state (Petersson et al., 2009).

With a map of the current state as a base analysis has been made to identify and rank problem areas and improvement potentials. To find root causes to certain problems a workshop has been held with some of the technicians. The initial phase of the workshop included a discussion about problems related to certain activities that had been proved to be time consuming in the current state. The workshop also involved discussions about possible solutions to the problems in order to increase the effectiveness of the activities. The current state has also been compared to accepted theories and concepts of Lean and modern maintenance. The purpose of these activities has been to develop
improvement suggestions that the organization can adapt to rationalize the work procedures. Since this study will give Sandvik Coromant a proposal for action it can be seen as a normative study according to Wallén (1993).
3. Theory

This section includes explanations of accepted theories which forms a ground of knowledge within the field of study which is valuable for the rest of the work. The chapter includes a brief introduction to Lean Production and TPM. It also includes information about corrective-, preventive-, and condition based maintenance. Furthermore the chapter also includes a theoretical part about Value Stream Mapping. The chapter is constrained to include theories and information that is estimated to be valuable for the performance of the thesis. Concepts and theories related to the methodology are placed in the previous chapter 2.
3.1 Value Stream Mapping

Value stream mapping is a systematic tool that helps organizations in the process of mapping the current state and to identify how the organization should work in the future. The purpose of VSM is to broaden the perspective when it comes to improvements. Instead of sub-optimizing the individual processes the method suggests a more general perspective of the whole organization. The method derives from the philosophies of Lean production and is nowadays accepted and widely spread in different research fields and organizations all over the world. (Petersson et al., 2009)

In short terms VSM can be divided into two different stages. The first stage is about mapping the current state. The map is produced by a group of individuals that together possess knowledge over the whole value stream. As a start the group trek the value stream backwards and identifies the different stages in the process. How detailed the notifications should be is different from study to study, but a general rule is that it is more important to get an uniform map that spans over the entire organization, rather than being to detailed and risk to get stuck. A map is drawn that shows the different stages in the process. Thereafter the back-tracking is repeated and detailed notifications about the process are being made. For instance it is common to document the cycle times, setup times, Overall Equipment Effectiveness figures (OEE) etc. (Petersson et al., 2009)

The different activities in the process should also be categorized as value-adding- or non-value adding activities. The classification system and the criteria's for what is considered value adding and non-value adding may however differ from study to study. It is common to use two categories; value adding- and non-value adding activities, but it is also possible to use three categories; value adding-, non-value adding but necessary- and non-value adding activities. What categorization system and criteria's to choose depends on what is suitable for the particular case and also on personal opinions of what is most logical. When formulating the criteria's for value adding and non-value adding activities it is however always important to consider it from a customer point of view. Which activities should be classified as value adding activities from the customer’s point of view? It is normal for processes that the value adding activities initially stands for just a few percent of the total amount of activities. (Petersson et al., 2009)

When it comes to the exact classifications of value adding and non-value adding activities it is important to consider the effects of different categorization systems. A categorization into three different categories can sometimes be more challenging than two categories. Two categories on the other hand may result in the fact that non-value adding activities are considered as value adding activities and vice versa. In that case there is a great risk that some necessary activities, which should be seen as waste activities, are classified as value adding activities. (Petersson et al., 2009)

In the second stage the current state is analyzed and a map of a desirable future state for the organization is drawn up. The future state is a desirable goal of how the organization
can work in a more optimal manner. With an accurate description of the current state and a map of the desirable future state it is then possible to analyze the gap between the two states. The gap indicates problem areas and enlightens areas with great improvement potentials. With the gaps as a ground the development of suitable improvements for the organization follows. (Petersson et al., 2009)

In the second stage it is often tempting to start direct with improvement suggestions and implementation of changes. However it is important not to rush through the analyze. The development of organizations and the implementation of improvements are dependent on accurate surveys of current value streams and a profound analysis of inefficiencies. Without the right background knowledge it is not possible to make correct decisions about what kind of improvements that is suitable for the organization. (Petersson et al., 2009)

To enlighten the importance of the groundwork in VSM some parallels to the reality is suitable. By drawing parallels to the process when doctors treat their patients in a hospital it is possible to visualize the importance of a thorough investigation of current states as a base for diagnostics, analysis and improvement suggestions. The process of treating a patient starts with the patient telling the doctor about the experienced symptoms. The doctor asks questions and run tests to investigate problem causes and to point out the root cause. With a clear picture of root causes it is then possible for the doctor to diagnose and to treat the patient. Since the treatment is based on the survey of the patient it is obvious that the survey itself and the analysis and process of finding the root causes is of high importance for the performance of the rest of the process. (Petersson et al., 2009)

**3.2 Total Productive Maintenance**

**3.2.1 Background**

*Total productive maintenance* (TPM) is a work procedure which main purpose is to increase the OEE figures. By involving every part of the organization TPM act as a vast tool for changing the organization and to increase the utilization of production-related resources. (Ljungberg, 2000)

TPM is based on the following three foundation stones which are described in detail later in the text: (Ljungberg, 2000)

- Monitoring of disruptions in the process.
- Maintenance by operators.
- Improvement groups.

In relation to other concepts and work procedures, such as TQM and Lean production, TPM is a unique concept since it focuses exclusively on the production equipment. Total Quality management (TQM) on the other hand focuses more on the organizations
relation to customers and suppliers. Lean production has a wider perspective than TPM and can be used at every part of the organization. Since the different concepts have slightly different perspectives they complement each other. Therefore it is common in organizations to work with multiple improvement concepts at ones. (Ljungberg, 2000)

3.2.2 Operational monitoring

The basic idea of operational monitoring is that the things that you do not measure are also out of your control, and the things you cannot control are obviously impossible to improve. In other words, without proper statistics it is hard to analyze and improve the organization. Therefore monitoring of disruptions and deviations is a central part of TPM. (Ljungberg, 2000)

There are several different ways of measuring the effectiveness of production equipment. Some examples are Mean Time Between Failure, Mean Time To Repair and Overall Equipment Effectiveness. TPM suggests that OEE should be used when it is possible since it gives a more complete picture of the performance of the equipment. (Ljungberg, 2000)

3.2.3 Maintenance by operators

The effectiveness of the maintenance division is highly dependent on the collaboration between the maintenance division and the production units. TPM promotes a high degree of maintenance performed by the operators, instead of having all the maintenance performed by service technicians. By gradually expanding the amount of maintenance tasks performed by operators the idea is to unburden the service technician from simpler maintenance tasks that can be done as easily by the operators. This division of labor allows the service technicians to focus on more challenging technical problems. The service technicians will have more time available to acquire knowledge about newly developed techniques and to get more involved in the process of investing in new production equipment. As the technicians get more time for challenging technical problems it is possible for them to develop valuable special-knowledge and to become experts in certain maintenance areas. (Ljungberg, 2000)

In order to gradually increase the involvement of operators the following “seven step stairway” has been developed:

1. Initial cleaning
   The operators are educated so that they understand why cleaning and inspection are important from a maintenance point of view. Initial cleaning activities are being performed where the operators, supported by the managers, clean the work place and the equipment thoroughly. The initial cleaning stage is performed to establish a norm for the level of cleaning at the work place. Before and after pictures are taken to document the progress. By the time the step is completed the operators systematically and continually clean their machines thoroughly in order to keep the work place as clean as the decided norm states. During the
cleaning process they are also searching for sources of dirt formation and defects in order to prevent abnormal tear. (Christer Nord et al., 1997)

2. *Fix cases to dirt formation.*
Sources of dirt formation are eliminated to the possible extent and the spreading of dirt is limited. (Christer Nord et al., 1997)

3. *Develop standards for cleaning and lubrication*
Develop checklists and systematical procedures for lubricating, cleaning and inspection. Since the tasks are performed by the operators the operators themselves should be active in the process of writing checklists and establishing routines. (Christer Nord et al., 1997)

4. *General inspection.*
The operators are being educated in maintenance techniques and get the opportunity to train their ability to perform certain maintenance tasks. Staffs from the maintenance division have a key role in this step as a teacher and mentor. (Christer Nord et al., 1997)

5. *Independent inspection.*
The standards and checklists are being revised and the operators responsibilities are widened. The purpose is to gradually increase the amount of service tasks performed by the operators themselves. The division of responsibilities between the maintenance divisions and the operators are clearly defined to assure that nothing is left out. (Christer Nord et al., 1997)

6. *Organize the workplace.*
Focus is on the development of standards for the operators whole work procedure and organization of the work place. The perspective is wider and covers more aspects than just the conventional maintenance aspects. A central part is 5S. (Christer Nord et al., 1997)

7. *Independent maintenance by operators.*
Through the previous steps the operators have developed a deep understanding of the production equipment, the maintenance tasks and aspects. The operator now has the ability to be responsible for ordinary maintenance tasks. For instance this includes lubrication, cleaning, simple troubleshooting and suitable preventive and corrective repairs. The work is however not finished when the seventh step is reached. TPM should be seen as a process rather than a project. The seventh step enlightens the importance of a continual transfer of maintenance tasks from the service technicians to the operators. (Christer Nord et al., 1997)
By gradually “walking” this stairway suitable maintenance tasks are transferred from service technicians to operators. This development is not easy and there is a great risk that the development will face great resistance both from service technicians, operators and other personnel. There is a great risk that operators show great resistance because they feel that they do not have the time or the knowledge required to take over maintenance tasks. It is also common that service technicians are skeptical to hand over the maintenance tasks. (Ljungberg, 2000)

3.2.4 Improvement groups

As mentioned above improvement groups are an important part of TPM. What characterizes improvement groups in TPM is that they are supposed to be production based and that their work should proceed continuously at all time. A production based improvement group consists primarily of operators and people in close relation to the production units, although it is advantageously to include one or several persons from the maintenance division. The main purpose of the improvement group is to improve the production equipment, but it also helps to stimulate and motivate operators to acquire new knowledge and to vent their creativity. (Ljungberg, 2000)

3.2.5 The maintenance divisions new role

The nature of maintenance is in many ways different from other industrial processes. The production processes for example are often easy to define and measure, while the process of maintenance is harder to understand. Today’s demanding characteristics of maintenance place special demands on the organization of maintenance in order to achieve high performance. It is clear that the role of the maintenance division has changed over the years. (Ljungberg, 2000)

In order to develop an effective maintenance division the management has to consider and work with many different aspects. Bellow follows some of the most important ones: (Ljungberg, 2000)

- Define quantified goals.
- Define a maintenance strategy.
- Establish and get acceptance for the maintenance strategy in the own organization.
- Develop a learning organization.
- Make sure to motivate the service technicians and encourage them to develop their skills.

Maintenance through external specialists

It’s not possible for the maintenance division to work with and have knowledge about every form of maintenance. The time and resources are limited and in it is necessary to prioritize what the maintenance division should and what they should not work with. It is important that the work-load is acceptable so that the maintenance division also has time to work with organizational improvements and improvements of the equipment. In
order to achieve an acceptable work balance it is necessary to distinguish between areas that are important and those that are not. Nowadays it is possible to purchase a wide verity of services in the maintenance area. (Ljungberg, 2000)

3.2.6 Maintenance prevention

In order to limit the amount of maintenance needed to assure high utilization it is of high importance to work preventive. It is said that approximately 75 % of the costs during the equipments lifetime are related to the operational phase. The maintenance needed during this operational phase stands for a great amount of these costs. The greatest part of the costs related to maintenance is a direct consequence of decisions in the developing stage of the machine. In order to avoid unnecessary maintenance it is vital to take count for the maintenance aspects when purchasing new production equipment. (Ljungberg, 2000)

Maintenance Prevention (MP) is a method that helps to prevent problems in the future by fixing the problems before they are built into the machines, products and processes. The method includes several tools and philosophizes that covers a wide range of areas in the organization. For example MP enlightens the importance of a maintenance perspective in the production development and construction phase. As the products shape, size, material, finish etc. defines the manufacturing procedures, it also limits the production equipments that can be used. If the product is developed so that it is easy to manufacture, the need for complex equipment is kept at a minimum. A lower degree of complexity makes it easier for the maintenance division to perform services and to be able to assure high utilization rates. (Ljungberg, 2000)

As the purchase of production equipment is closely related to the possibilities of maintenance prevention mapping tools are required as a base for evaluation. Life Cycle Cost is one method of mapping the total costs during a machines lifetime. The method is often used when calculations and evaluations of production equipment are being made. By giving a comprehensive picture of the costs LCC act as a base for evaluation in order to minimize not just the purchase cost but also the total maintenance needed during the lifetime. The results from LCCs are in many aspects more detailed than the results from a conventional investment calculation. (Johansson, 1997)

3.2.7 Implementation of TPM

In order to systematically and successfully implement TPM a twelve step stairway has been developed. Below follows a summarization of the twelve steps in short terms: (Christer Nord et al., 1997)

1. Inform the organization about the decision to implement TPM.
2. Educate and inform relevant staff that will be involved in the initial phase.
3. Develop an organization for TPM and direct the study to a smaller part of the organization, a pilot division.

4. Establish fundamental quantified goals and policies to enable measurement of the progress.

5. Formulate a main plan for the implementation process.

6. Arrange exceptional activities like kickoffs where the so far progress and outcomes are being analyzed. Educate more staff and inform about the upcoming parts of the implementation phase.

7. The seventh stage focuses on efficiency and includes the following four sub-activities:
   - Continuous improvements.
   - Maintenance by operators.
   - Maintenance by specialists.
   - Competence development.

8. Focus is on accession and the main purpose is to influence the development and construction phases in order to prevent unnecessary maintenance activities.

9. Quality maintenance. The purpose is to shift the perspective of quality from a total focus on the product itself to a wider perspective that includes monitoring of the quality through the equipment.

10. Expand the process of TPM to include administrative parts of the organization rather than just the operational parts.

11. Focuses on environmental and safety aspects.

12. The final step includes a review of the progress and a development of new objectives. The importance of continuity and the fact that TPM is formed as a continuous work procedure rather than a project with a clear finishing point is enlighten. The purpose is to reenact the implementation process with a wider focus on other parts of the organization as well.
3.3 Corrective Maintenance

In many organizations, where the maintenance function has not been fully developed, corrective maintenance stands for most of the costs related to maintenance. This is not desirable, but the corrective maintenance will however always be needed in some extent. (Hagberg and Henriksson, 2010)

The ability to resolve problems rapidly is crucial for the corrective maintenance. Sudden break downs results in un-planned downtime, which can be costly for the production unit. Therefore it is essential that sudden break downs can be fixed rapidly and that the downtime is kept at a minimum. (Hagberg and Henriksson, 2010)

It can be tricky to measure the quality and effectiveness of performed services since it depends on the quality of other processes and functions within the organization. In order for corrective maintenance to be rational and effective the preventive maintenance and machine investments have to be successful. To use the number of corrective work orders as a key performance indicator and try to decrease it is therefore not suitable. A better way of measuring the functionality of corrective maintenance is to measure the ability to perform the maintenance tasks that arises. Some other goals that are commonly used are the following: (Hagberg and Henriksson, 2010)

- Mean Waiting Time (MWT)
- Mean Time To Repair (MTTR)
- The number of recurrent problems for specific machines

It is important to use previous experience to resolve problems. A natural preparation activity for corrective maintenance should therefore be to look at documentation of previous problems. It is important that the search functions are so the documented information are easy to find. (Hagberg and Henriksson, 2010)

Information

Both corrective and preventive maintenance puts pressure on the quality and availability of information. It is common to categorize the information into the following categories: (Hagberg and Henriksson, 2010)

- Information about the equipment and machinery:
  Includes risk classification, which states the priority of the specific machines depending on how important it is for the production flow. It also includes information about the short and long term capacity usage for the machinery.

- Information about the work content:
  Includes clear instructions, preferably with illustrative pictures, about how to perform the particular service operation.
• Documentation and feedback about performed services:
  It is highly important to analyze the outcome of the service operation and to use the information about the observed conditions of the machines to update the service intervals and maintenance schedule.

3.4 Preventive Maintenance

There are different types of preventive maintenance. It is common to divide the preventive maintenance into the main categories of prescheduled maintenance and condition based maintenance. Condition based maintenance is considered to be the latest within modern maintenance techniques and are described in more detail in section 3.5 bellow.

A well-developed maintenance is dependent on high degrees of preventive maintenance. However it is not suitable to adapt preventive maintenance to all the components and machines in the factory. A crucial factor for determining if preventive maintenance is suitable for specific machines is the fail distribution and fail intensity. If components have a predictable life-span it is possible to formulate adequate service intervals. This is however not always the case. Sometimes the fail intensity can be higher directly after the installation of a new component. If problems occur it is likely to do so shortly after the installation, but after a period of time the fail intensity decreases and stabilizes at a constant level. For those kinds of components preventive maintenance is not suitable since there is a greater risk that newly replaced components breaks down than components that have been used for some time. (Hagberg and Henriksson, 2010)

For both corrective and preventive maintenance the information flow is essential for the effectiveness and quality of the process. The theories about the handling of information are the same for these different kinds of maintenance. Therefore the information aspects are described in the previous section 3.3 about corrective maintenance, even though it is adaptable for the preventive maintenance as well.

3.5 Condition Based Maintenance

Condition based maintenance are at the moment seen as the latest and most innovative concept within the field of maintenance. The foundation in condition based maintenance is to measure the condition of critical components and to use the information to take preventive actions against machine failures. The measurements of equipment conditions are often referred to as condition monitoring. By monitoring the state of the machine and the variations the key is to detect failure before the consequences get severe. When patterns are detected that can lead to failure it is possible to replace the components before they break down. This work procedure enables the maintenance division to plan the maintenance in advance and to avoid sudden machine break downs and unplanned downtime. (Hagberg and Henriksson, 2010; Johansson, 1997)

Condition based maintenance rests partly on the same grounds as traditional scheduled
preventive maintenance. The difference between these two concepts is that condition based maintenance enables more accurate service actions. Since the equipment are being monitored recurrently it is not just possible to replace components preventive, it is also possible to avoid replacement of functional components. In scheduled preventive maintenance there is always a risk of changing a component that would continue to be functional for a period of time in the future. Changing a component far before it becomes un-functional is of course better than sudden breakdowns, but it is not optimally. Condition based maintenance enables more accurate replacements of worn out components which results in a more effective preventive maintenance. (Hagberg and Henriksson, 2010)

Condition monitoring can be performed either through regular or continuous measurements. Regular measurement means that measurements are being made at certain times but not continuously. Continuous measurements on the other hand are measurements that are taken continuously in real-time. (Hagberg and Henriksson, 2010)

One important challenge of condition based maintenance consists of finding suitable condition monitoring methods that can measure both the normal state of the equipment and the deviations from that normal state. Which method to use depends on the components that are supposed to be monitored. Below follows a summary of some of the most commonly used measuring methods for condition monitoring. Since the purpose is just to introduce the reader to condition monitoring the summary is not entirely comprehensive. (Hagberg and Henriksson, 2010)

**Shock pulse registration**
This method is suitable for both periodic and permanent condition monitoring of rolling-element bearings. Rolling-element bearings are the generic name for bearings that are based on the principals of rolling, such as ball- and roll bearings. Periodic controls are performed with hand held instruments and permanent continuous monitoring is performed with the help of installed data systems. The principles behind this technique are measurements of shock pulse patterns. Worn out bearings sends out unique patterns of shock pulses that can be registered by the instruments. The technique also enables detections of whether the lubrications in the bearings are satisfying or not. (Hagberg and Henriksson, 2010)
**Thermo graphic cameras**

Every object emits infrared radiation, which can be detected by a thermo graphic camera. Increased temperatures are often an indication that something is not operating as it should. Since the intensity of the radiation is directly proportional to the temperature at the surface of the object the camera can calculate and illustrate the surface temperature as seen in figure 3-1.

The main advantage of this method is that it is possible to measure the temperature of an object without touching it. (Hagberg and Henriksson, 2010)

![Thermographic picture of malfunctioned bearing](Source: SKF.com)

**Figure 3-1 Thermographic picture of malfunctioned bearing (Source: SKF.com)**

**Ultrasound**

When metallic surfaces come in contact with each other emerges friction and heat problems. Early in this process low frequency mechanic vibrations occurs which causes ultrasound. Instruments for measuring ultrasound can detect this indications of problems earlier than conventional measurements of temperatures and vibrations. Measurements of ultrasound can also be useful to search for leakage in pressurized systems. (Hagberg and Henriksson, 2010)

**Vibration measurements**

Increased levels of vibrations is often related to problems and deviations from the normal state of the equipment. Vibrations are always present, even in normal conditions, but abnormal vibrations can be harmful for the machinery. Vibrations can accelerate problems and decrease the equipment lifetime. Measurements and analysis of vibrations can sometimes be useful to detect abnormal machine behavior. The measurements can either be performed periodically or continuously. (Hagberg and Henriksson, 2010)

### 3.6 Lean

*Lean* is a popular concept which main goal is to eliminate wastes of resources (Petersson et al., 2013). By eliminating waste it creates an efficient and stable value flow throughout the whole production process and maximizes the costumer value. Lean origins from Toyota productions system (TPS) and categorizes all activities which are not adding value from a customer point of view as waste. Thereafter it tries to eliminate
those activities. Principles of lean can also be applied on service organizations, for instance health and social care organizations. (Liker et al., 2009)

3.6.1 History

*Lean* or Lean production as a concept is an aftereffect of Henry Ford’s production system for the car production in the early 20th century with inspirations from Frederick Winslow Taylor and Benjamin Franklin. Henry Ford is the founder of Ford Motor Company and the inventor of the first assembly line on the Ford plant in Highland Park. Prior to the assembly line the process of assemble a car was slow and ineffective. Ford’s vision was to keep a high level of standardization, quality and short lead times throughout the assembly process. Ford achieved this by providing the constantly moving assembly line with material at the right place at the right time. This later became one of the principles of the Toyota Production System (TPS). (Liker et al., 2009; Petersson et al., 2009)

General Motors, a Ford rival, where able to offer its customers more customer options since they were more flexible. The high competitiveness affected Ford which abandoned its standardized production system in Highland Park. Ford started a new production unit, “The Rouge”, which was supposed to have control over the whole value stream (Ford even owned rubber plantations in Brazil to provide the tire production units). “The Rouge” used the same philosophies as the factory in Highland Park had used but with the difference that this production unit used a detail production organized functionally with focus on high utilization and high production volumes. (Petersson et al., 2009)

Sakichi Toyoda developed an automatic loom 1924 which were able to abort production automatically in case of thread breakage which minimized the risk of defect fabrics. It was from this event that one of the main principles of TPS arise which now are known as Jidoka. The principle with Jidoka is to abort the production in case an error occurs. The Toyoda family sold the patent on the loom and started the car manufacturer Toyota. While working on Toyota Sakichis son Kiichiro visited several other car manufacturers, for example Fords plant “The Rouge’. Kiichiro got inspired by Fords production philosophies and returned to a war-torn Japan with an ambition to develop Fords principles so that they would be more suitable for the industries in Japan. Kiichiro needed to develop a production system with short lead times which was easy to adjust between different car models. This system needed to be able to deliver the right component at the right time. This is the part of Lean now known as Just-In-Time (JIT). Toyotas plant manager Taiichi Ohno also studied the principle Ford used and created a philosophy and framework more suitable in Japan with its war-torn and poor society, this framework is known as Toyota Production System (TPS). (Bicheno et al., 2011; Petersson et al., 2009)

The advantages with TPS where spread in Japan when Toyota managed to handle the recession during the oil crisis in the 1970s which hit other companies, both foreign and
domestic, extremely hard. Massachusetts Institute of Technology (MIT) initiated a research program, which would study the difference between car manufactures all over the world and discovered a huge difference between Toyota and other manufacturers. The description of TPS as “Lean” was first used in the book written by James P. Womak and Daniel T. Jones as a result of this research study (Liker et al., 2009). Nowadays the Toyota production system is more known as Lean production and the content are basically the same. (Bicheno et al., 2011; Petersson et al., 2009)

3.6.2 Lean production

Lean is not a tool, Lean is a system. Taiichi Ohno once said: “The only thing we try to do is to reduce the time from order to payment” (Bicheno et al., 2011). If Lean is used as a tool you will not be able to adapt it to your organization. “Give a small boy a hammer, and he will find that everything he encounters needs pounding” (Kaplan, 1973). If you do not know what you want to achieve you can not use the tools that comes with Lean to achieve them. (Bicheno et al., 2011; Petersson et al., 2009)

Lean production system is based on five basic strategies. These strategies cannot be applied to all organizations but all organizations must try to use these five steps in the start-up of the implementation of Lean. All organizations should with and constantly trying to improve them over and over again. The strategies are supposed to be worked with in the following order: (Bicheno et al., 2011)

1. Specify value

Value in lean is what is valued by the customer. For example, a customer do not buy a wrench, they buy a loosened bolt. The value for the customer is not the wrench itself; it is the ability to loosen the bolt. The customer do not necessarily need to be the end-customer, it can also be the following process in manufacturing process or the customers costumer. A useful method for identifying the value for a customer is Quality Function Development (Bergman and Klefsjö, 2012). By identifying the value for the customer all the waste associated with the product or service can be eliminated without affecting what is valued by the customer. (Bergman and Klefsjö, 2012; Bicheno et al., 2011)

2. Value flow

The value flow is the flow of the, in a production process, raw material all the way from the start to the end-customer. The value flow should be looked at with focus on the customers value specified in the previous step. Map the value flow from start to finish, not by function but as a supply chain. The activities in the value flow can be categorized as value adding activities, non-value adding but necessary activities (Muda 1) and non-value adding activities (Muda 2) (Bicheno et al., 2011).
Muda is the Japanese word for waste and in Lean there are seven, or sometimes eight depending on the classification, different types of waste: (Bicheno et al., 2011; Keyte and Locher, 2008; Petersson et al., 2009)

- **Over production**
  Production of more components than needed. This is often seen as the worst kind of waste because it contributes to all other forms of waste.

- **Waiting**
  Unused time waiting (e.g. no material, lack of information or other delays).

- **Transport**
  Transportation will not contribute to the value for the customer. Often the waste of transport is tried to be reduced by transporting goods with trolleys and conveyors, which won’t solve the problem. Instead eliminating the actual need of transport is the solution.

- **Inventory**
  Inventory is all the material in progress and finished goods that have not been fully processed. These big inventories can also be a big risk if a customer goes bankrupt or if a quality problem is discovered late in the process.

- **Motion**
  Motions that are not adding value for the customer are seen as wastes. Waste by motion can be everything from walking between machines and walking to get tools or documentation.

- **Over processing**
  Is when products for example are produced with tighter tolerances than necessary.

- **Defects**
  Are the wastes that occurs when producing products with substandard quality, which in turn leads to over production.

- **Skills**
  Are the sometimes used eight type of waste and are the waste by under-utilization of capabilities or the performance of task with inadequate training. If the staff does not have sufficient knowledge it will take more time for him to complete the task.
3. Pull

The meaning with a pulling system is to only produce what is needed at the moment and never over-produce. The production in a pulling system is triggered by a customer inside or outside the organization to produce new products via for example a kanban system. Kanban is explained later in this section. This gives the organization short time for response for changed order incomes. A organization with a pushing system easily produce more products than necessary and is forced to stock large amounts of products. (Bicheno et al., 2011; Petersson et al., 2009)

4. Perfection

When these steps are worked trough and the principles are established, perfection is not a non-realistic goal. The organizations can produce products to the right price, at the right time, with good quality and no waste. The idea is however that there is always something that can be improved to be more effective and reduce costs and add value for the customer. (Bicheno et al., 2011)

3.6.3 The Lean house

The Lean house or the TPS house is a well-known symbol of lean (Figure 3-2). The Lean house is what a lean organization is built of. The foundations of Lean, and the house, are the leveled production (Heijunka) and the continuous improvements known as kaizen. Without Heijunka and Kaizen the organization cannot implement lean, the house will fall apart without the solid foundation. The pillars of the house are JIT and Jidoka. The pillars are to support the house and to be the strong structure which supports the organizations goal.

The meaning of these notions are described below. The roof of the lean house is a high quality product or service and a high level of morale amongst the coworkers. An organization cannot build this strong house without all these elements together. If the organization fails on one of these elements the house will fall apart according to Fujio Cho, the inventor of the Lean house. (Liker et al., 2009)

Heijunka

Or production leveling are one of the basic presumptions for a Lean value stream and good quality. By leveling the production the utilization can be kept at a steady level throughout the whole production line (Petersson et al., 2009).
Chapter 3 - Theory

**JIT**

Just-In-Time is also one of the basic presumptions of Lean. JIT itself consists of tact time, pulling systems and a continuous flow. All this will contribute to a value flow that delivers the right amount of products at the right time at the right price for the customer. (Bergman and Klefsjö, 2012; Petersson et al., 2009)

**Jidoka**

In Lean Jidoka is the principle that strives to achieve a high and even level of quality. The purpose is that the quality is built into the process, which will ease to do all activities right the first time. Lean also advocates the stopping of the process in case of errors to minimize the waste and keep the level of quality high. (Bergman and Klefsjö, 2012; Petersson et al., 2009)

**Kanban**

Is a method for signaling need of material. The signal can be an empty box, a kanban card or anything that signals to the predecessor in the process the need of material to its successor. To share the benefits of kanban to a production process it must be characterized of a high and even level of demand and short replacement times. (Bergman and Klefsjö, 2012; Petersson et al., 2009)

**Kaizen**

Are the continuous work with improvements. There are several kinds of kaizens in the lean methodology. Kaizen is a controlled improvement work that is supposed to be worked through step by step. Kaizen is a process with focus on improving a specific process. Then there are kaizen events which are more a pinpoint improvement work where a group is gathered to a workshop and work on a bigger project to solve a greater problem during a longer period of time. A kaizen event of this kind can be going on for as long as 6-12 months. During a kaizen or kaizen event it is common to use the Demmings cycle known as the PDCA-cycle (Keyte and Locher, 2008). PDCA is short for Plan-Do-Check-Act and are a principle for structuring an improvement project. (Bergman and Klefsjö, 2012; Bicheno et al., 2011; Petersson et al., 2009)

**5S**

Is a method in lean which intent is to create a well-organized, clean and functional work space. In some organizations 25% of the time can be wasted on searching for tools, materials, documentations etc. (Petersson et al., 2009) This is the background to why 5S is so commonly used when implementing lean in an organization. The idea with 5S is to eliminate such waste by using these five constituents: (Bicheno et al., 2011)

- **Sort**
  
  The first step is to sort out the objects, which are used more commonly from the
ones used more rarely. The more rarely used objects shall be tucked away properly which reduces the risk of using wrong tools.

- **Systematize**
  All objects at the workplace should have its own designated place close to where it is used. This will minimize the waste of searching for tools or documentation. Documentation shall be organized with a structure and named according to a standard known by everyone.

- **Shine**
  Shine in the 5S method do not necessary mean clean. Shine is all about looking after that everything is in order and works as it is supposed to do.

- **Standardize**
  When the first three steps are worked through everything shall be standardized. If the workplace have an easy standard known for everyone it is easy to stick to it and to update it if necessary.

- **Sustain**
  The idea with 5S is that the co-workers are to enforce, improve and sustain the work with 5S. This requires a god attitude to 5S throughout the whole organization. If the management does not understand that the change of attitude will take time the involvement from the co-workers will run out in to the sand. The involvement of all co-workers in the organization can be the hardest one to achieve but it is also the most important.

**PICK**

PICK chart are used for categorizing which improvement ideas to continue working with. PICK is short for Possible, Implement, Challenge and Kill. These four categories are designated a quadrant in a two- axis chart as seen in figure 3-3. The axis is labeled with “Effort” on the Y-axis and “Effect” on the X-axis. This means the ideas which will contribute to huge effect with small effort will be placed in the implement- quadrant. (Petersson et al., 2009)
Figure 3-3 Example of PICK chart (Source: Petersson et al., 2009)
4. Current state

The chapter includes a presentation of the results from the mapping of the current state. Analysis of the current states is also described for some parts. As an introduction the maintenance organization, its overall strategy and its work procedures are described in detail. After that follows a relatively large section with detailed information about the different time studies performed for the thesis. Finally parts of the results from the value stream mapping are presented. The section focuses exclusively on the current state of the organization. The results from the other part of the value stream map, the desirable future state, are presented in later chapters.
4.1 The service organization

The maintenance division GVM5, generally speaking, consists of two teams: PM and CM which are illustrated in figure 4-1 below. The corrective maintenance consist of one team leader who distributes the work orders, order spare parts and are the information channel between the production units and GVM5 regarding CM. The CM team consists of 15 service technicians which main focus is to work with corrective service operations. The other part of the maintenance division is the preventive maintenance group. Just as the CM the PM consist of one team leader who distributes work orders between the five technicians.

As illustrated in the figure below the maintenance division also consists of one person that works with IT support, one sheet metal worker and two machine movers. These staffs are experts within their field and operate relatively autonomous. The IT service technician is normally included in the CM team and works primarily with industrial IT related problems and service orders. In other words this kind of IT support is different from the traditional IT support that people have in mind when they hear the words of IT support. The machine movers work with un-installations, machine moves, and installations when production equipment is transferred between factories within the concern. In some cases machines are also sold to and bought in from external companies. As described in the delimitation chapter the machine movers and the sheet metal worker are excluded from the study. (Aringskog, Team Leader PM, 2014; Ericksson, Team Leader CM, 2014)

![Organizational structure GVM5](image-url)
4.2 The maintenance strategy

As described in the early chapters about the background and the problem description there are increasing demands of higher efficiency in the organization in general. This puts pressure on the development of all parts of the organization and the maintenance division is no exception. In order to continuously develop the organization the maintenance division has formulated a strategy. Important improvement areas have been identified and chosen and goals have been established within these certain areas. The strategy includes some aims and complementing goals to measure the progress. The current strategy is valid during the time period 2014-2017. (Nilsson, Manager GVM5, 2014b)

4.2.1 Aims and goals

The first aim of the strategy is to improve the maintenance performed by operators and to develop a closer collaboration between the maintenance division and the EMO:s. Analysis of currents states and systematical improvement changes form a ground for gradual increasing of efficiency. Since there are many production units the plan is to focus on some of them at once. The first aim is to improve the maintenance by operators and the collaboration between the maintenance divisions and the EMO:s at three production units. By the end of this year the work should have resulted in significant improvements and a higher degree of efficiency. The three production units should have a functional process for maintenance performed by the operators and a closer relation between operators, EMO:s and the maintenance division. For 2015 the number of production units involved should have increased to a total of seven. By the end of 2016 all eight of the production units should have been included in the improvement process and all of them should have been significantly improved with respect to the aspects described above. (Nilsson, Manager GVM5, 2014b)

Besides the aspects above the strategy also includes the development of a more effective preventive maintenance. The organization wants to increase the utilization of certain important production machines. They also want to acquire knowledge about condition based maintenance so that they can implement this concept on selected machines. By focusing on a pilot project, where the important machine type Stama is included, the aim is to increase utilization and to try the concept of condition based maintenance. Initially a current state analysis will be made which will be finished by the end of 2014. By the end of 2015 the utilization of the Stama machines should have increased through more effective preventive maintenance. (Nilsson, Manager GVM5, 2014b)

As a complement to the part of the strategy described above quantified goals for two key performance indicators have also been formulated to measure the progress. The first goal is to reduce the number of corrective work orders by ten percent by the end of 2014. The second goal is to increase the utilization rate for the Stama machines by ten percent by the end of 2015. When the pilot project that includes the Stama machines is finished the aim is to broaden the development of the preventive maintenance. The
following step is to gradually involve every important machine in the factory. By the end of 2016 the utilization of all significant production machines should have increased as a result of a more effective preventive maintenance. (Nilsson, Manager GVM5, 2014b)

4.2.2 The improvement procedure

In order to structure the improvement work and to assure that progress is being made according to the strategy it is of high importance to work systematically. Figure 4-2 bellow illustrates the improvement process that has been formulated to support the improvement work. The idea with this process is to focus on three problems in parallel, which are referred to as top three in the figure, at ones. The top three problems are identified through statistics and gut feeling. Analysis of the top three problems generates activities and actions, which results in implementation of changes to solve the problem. The work of resolving these problems is then ventilated recurrently through pulse meetings. The important final step includes analysis of the outcome. If the results are satisfying the work gets documented in a report, but if the results are not satisfying the process continues until the problem is solved. When one problem is resolved a new problem is brought in to the top three and the process continues. (Nilsson, Manager GVM5, 2014b)

*Figure 4-2 The improvement process at GVM5*
4.3 Work procedures

In order to fully understand the thesis it is convenient to explain the work procedure for the corrective and preventive maintenance. Of course it would be possible to describe the service operations for both the corrective and the preventive maintenance generally at once. The processes are however different in many aspects and it is easier to describe the processes separately.

4.3.1 Corrective maintenance

Figure 4-3 below is a process chart that illustrates the working process of corrective maintenance activities: (Ericksson, Team Leader CM, 2014)

![Corrective maintenance process](image)

The service operation starts with an incoming work order which is written by the production unit. The work order consists of information about the machine that is broken, information about the problems and the symptoms, and the priority of the particular machine. Some machines are critical since the whole production flow goes through it. Other machines are not as critical since there is a redundancy in the production flow. (Ericksson, Team Leader CM, 2014)

The work order is sent in from the production unit through the computational system Corus. The order rests until the team leader checks the system. The new work orders are filtered and prioritized by the team leader who allocate resources and assign technicians. The allocation of resources and the assignment of technicians are referred to as division of labor in figure 4-3. The team leader prioritizes work orders related to critical machines and therefore some non-urgent work orders are put on hold until the critical orders are finished. The process for non-urgent orders is illustrated in the figure by the symbols within the dashed rectangle in the figure. (Ericksson, Team Leader CM, 2014)
When the division of labor is done the service technicians start their work. They troubleshoot the machinery to find root causes and how to resolve the problems. If parts are broken the technician goes to the stock and fetches the parts needed. In some cases the spare parts needed is not placed in stock. If the parts are not in stock the technician talks to the team leader who orders the spare parts needed for the job. The job is put on hold until the spare parts arrive and meanwhile the technician works with other orders. When the spare parts arrives the technician replaces the broken parts and perform the rest of the services needed. When the problems are resolved the work is documented in the computational program FUS, which are used by all the technicians to document the work. If the same problem occurs in the future the idea is to use the documentation of previous work orders as support and information source. Finally the working time is reported to Corus and the status of the work order is changed to finished. (Ericksson, Team Leader CM, 2014)

4.3.2 Preventive maintenance

Figure 4-4 bellow is a process chart that illustrates the working process of preventive maintenance activities: (Aringskog, Team Leader PM, 2014)

As you can see from figure 4-4 the process of preventive maintenance is different from the process of corrective maintenance. The preventive maintenance is planned in advance and follows predefined schedules. A preventive work order is trigged by defined service intervals which states when service is needed and which component that needs to be replaced. With the service intervals for all the machines as a base the team leader schedules the work in collaboration with the production units. The service operations are, in the possible extent, scheduled with respect to the production schedules. When the preventive service order is planned spare parts needed for the operation are ordered so that they will arrive in time for the service. The team leader allocates resources and assigns preventive service technicians to the planned orders. This is referred to as division of labor in the process chart above. Thereafter the service technician starts their work. First they prepare for the job by fetching spare parts and
writing out the service protocol for the particular job. The service protocol states what the technician should do and which parts that should be replaced. When the technician is prepared the actual service operation is performed on the machine. After the service has been performed possible feedback is ventilated with the team leader, who updates the service intervals if needed. For instance one kind of feedback can be that the technician changed the oil according to the protocol, but he also noticed that the quality of the oil was acceptable. A redefinition of the protocol is needed so that the oil is not changed without reason in the future. (Aringskog, Team Leader PM, 2014)

4.4 Time study

4.4.1 Time distribution

In order to perform a current state analysis a time study of service technicians have been carried out to map the time distribution. The time study also answer one of the thesis questions:” Which non value adding activities are there on the maintenance division?” and uses the results as a guide to answer the other question:” Which possibilities is there to reduce waste by a more effective way to work and which of these wastes shall be prioritized to eliminate? ”. This type of method is according to Wallén (1993) an inductive method associated with positivism to prove a statement or thesis.

Prior to the study a short internship was performed to establish a trustworthy relationship with the service technicians. This short internship was performed both because a deeper knowledge was needed to be able to perform the study and to gain trust from the service technicians to get more reliable results. The short internship is a crucial event according to Wallén (1993) to get the information needed to analyze the problem and use the right methods. After a trustworthy relationship was established a service technician was followed under a period of time and the activities conducted was timed and categorized according to a modified model used by Bicheno (2009), which can be seen in table 4-1 below. The categorization of activities into value adding- and several different non-value adding categories are essential for the performance and the results of the observations. The different categorizations that have been used for all of the observations have been evaluated thoroughly, using the knowledge of our supervisors and the suggestions from the theories of Lean. It is not easy to decide what categories to use in order to get the right results. Therefore discussions about the consequences of certain definitions have been performed continuously throughout the project. Most of the times there is no right or wrong classification of value adding and non-value adding activities, it is a matter of opinion. However it is often important to consider pros and cons with certain definitions and to discuss them from a logical and objective point of view. Since the results vary and since the observations are considered to be highly dependent on the classification of non-value- and value adding activities, different categorizations and focus areas have been used for different observations. The use of different classifications has been valuable, since it provides the same kind of results but with different perspectives. The results from the observations complement each other.
Petterson (2009) states that while doing a time study the difference between value adding activities and non-value adding activities can be hard to determine. The only activities which are value adding is the activity, which is value adding to the next customer in the process, in this study the production units. Therefore this study only categorizes the actual performance of value adding activities even though some planning and preparation activities for example are non-value adding but necessary for the service technicians. The activities are categorized in seven different categories: Value adding activities, planning and preparation, system activity, transportation, waiting, communication and other.

Value adding activities are delimited to the service activities, such as troubleshooting, refitting, dismantling and repair of machinery. Planning and preparation are activities associated with gathering tools; equipment and spare parts needed to perform the maintenance task. Planning and preparation can also be activities such as go through documentation and manuals to acquire knowledge about the problem. System activities are for example activities associated with the data bases corus and FUS. Transportation are time wasted when the service technician transport himself between different places inside the plant. Waiting are time wasted during the service e.g. wait for assistance or for operator who can run the machine. Communication is time wasted calling for help from the supplier of the machine, from colleagues or other verbal communication. Other is activities which cannot be specified under the former categories. Observations have been performed several times. The protocol from each study is attached as appendices in the back of the thesis along with pie charts that summarizes the time distribution between the different activities.

Results

The easiest way of presenting the summarized results from the time study is to use pie charts. The results from these time studies are presented as a whole in the appendix B1-B3. If the reader is interested in the detailed content of an individual slice of the pie it is possible to study this in the complete working documents in the above mentioned appendices.

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Value adding activity</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Planning and preparation</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>System activity</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Waiting time</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Other NVAs</td>
<td></td>
</tr>
</tbody>
</table>

Table 4-1 Table of codes
Figure 4-5 below summarizes the time distribution for the first of the observations, which had a total observation time of 4 hours and 21 minutes. The observation was performed by following a corrective service technician. As you can see the value adding activities for example stands for 72 percent of the total observation time, while transportation activities stands for 9 percent.

The observation described above is one of a total of three observations of this kind. The other two observations were performed at preventive maintenance. If we look at the first of these studies, shown in figure 4-6 below, we can for instance see that the value adding activities stands for 61 percent while planning and preparation stands for 13 percent. Further communication stands for 9 percent while transportation stands for 7 percent of the time.
Figure 4-6 Time distribution preventive maintenance

The results from the third and last observation of this kind, also performed at preventive maintenance, are illustrated below in figure 4-7. As you can see from this pie chart the value adding activities stands for 58 percent of the total time, while communication and waiting both stands for 11 percent individually. In this observation no time was spent on system activities and the green color is therefore not represented in the pie chart.

Figure 4-7 Time distribution preventive maintenance

When the similarities and differences between these three observations are analyzed there are some interesting aspects to consider. As you can see the first observation that covers corrective maintenance have more than 10 percent higher degree of value adding activities than the two later observations of preventive maintenance. The amount of
transportation is relatively stable between the cases and the difference is just two percentage points. The same applies to the category of other activities, where the difference is no more than three percentage points at the most. For the rest of the activities there are no stable pattern since the difference between the observations are widespread.

The fact that the amount of value adding activities is extensive in all three observations is of great interest. The average amount of value adding activities for these three cases are 63.7 percent of the total time which conflicts with statements from a previous report. The report was written by an external consulting firm and was associated to the implementation of a large improvement program at the factory in Gimo. The report states that the average rate of value adding activities in service organizations in general is around 20 percent. The report also states that if the service organization is extremely effective the value adding activities can be as high as 40 percent. (Herdin, manager GVM, 2014)

The sources of these percentages are however extremely vague. It is not clear whether these percentages are based on real observations by the consulting firm themselves or if they are based on secondary sources. If this numbers are an average from many cases or the results from a single observation are also not known. Therefore it is extremely dangerous to question the results from the observations in this project based on the fact that the results conflicts with the statements from this other survey. The only reason that this conflict of data is described here is that the numbers were presented as background information from the service organization. It is also the only numbers available that are possible to relate to the results from the time study and therefore it is of some interest.

Based on the pie charts it is possible to argue that the need for improvements are small since the work procedure for both the corrective and the preventive maintenance are highly effective. Such conclusions are however rather rash. The fact that the amount of value adding activities makes up an extensive part of the total observation time may also have other explanations. As the definition of value adding activities are relatively vast there is a great risk that waste activities are hidden in the value adding activities. The definition of value adding activities is partly based on the limitations of the observer. Since the knowledge about the service operation is limited for the observer it is considered hard to use another definition of value adding activities. It is impossible for the observer to determine whether certain aspects of the service operations are to be considered as waste or value adding activities.

When we look at the results from the observations the large amount of value adding activities becomes rather problematic. Since the value adding activities consists of both troubleshooting, mounting, dismounting etc. it gets impossible to distinguish these activities from each other in the pie charts. However it is possible in some extent to manually distinguish these activities by studying the form that was used to document the activities during the observation. As mentioned earlier these forms are part of the working documents, which are attached in the appendices.
The results from these time studies are important for the project and parts of it are possible to use for further analysis, but the results are also problematic. The initial idea was to perform many observations of this kind to get a representative average of the time distribution. A representative average pie chart would form a solid ground for further studies by acting as a guideline for the determination of which problem areas to focus the improvement work on. However it become clear that the variations between the different cases where very large and an average pie chart would never be fully representative for the service operations. This depends heavily on the fact that every service order has a unique work content which affects the time distribution. The wide definition of the value adding activities was also problematic. It meant that a small part of the total time was left over for improvement works since more than half of the pie where considered to be value adding and therefore highly effective.

When all the problems where considered and put in relation to the fact that this kind of observations are heavily time consuming, it become clear that the contributions of these studies were not as great as they were meant to be. The initial observations had to be complemented with further time studies with a different approach. After discussions with the organization and the supervisor at the university it was decided to try to complement these initial time studies with a survey and with similar time studies but with another focus area. It was also decided to use VSM as a complement to the time study. The methodology and the results from these other studies are presented in detail in the following sections.

4.4.2 Value adding activity

As the initial studies, described in the section above, did not provide sufficient information about the distribution of activities within the value adding activities, it was considered important to map the content of this single slice of the initial pie charts. This study has a higher resolution. The same approach was used as in the previous time study but the focus was different. In this study the only activities of interest where those activities that where considered as value adding activities in the previous time study. The purpose of this study was to acquire knowledge about the slice of the pie charts that symbolized value-adding activities in the previous study.

A new categorization of activities was defined, which is illustrated in table 4-2 below. As you can see from the figure the value adding activities have been further categorized into more detailed value adding and non-value adding categories.
The only activity that is considered as value adding in this study is when the service technician is solving the problem. Disassemble includes the moments when the technician detaches components necessary to access the broken parts of the machine. Troubleshooting means that the service technician is searching for root causes to the problem and for broken parts. Communication involves communication with colleagues and the operator of the machine. Reassembly involves the activities where the technician is restoring the machine to its original condition after the problem has been fixed. Testing means that the technician, often with the support of the operator, runs the machine to assure that the problem has been resolved and that the functionality of the machine is acceptable.

The result from this study indicates that 20 percent of the observation time is considered as value adding while reassembly stands for 36 percent. Further testing stands 28 percent and communication for 12 percent. In order to make any conclusions from this the same observations would have to be performed several times on different service operations. Figure 4-8 below illustrates the results from the study through a pie chart.

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixing the problem</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Disassemble</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Troubleshooting</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Reassembly</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Testing</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Other NVAs</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4-8 Time distribution value adding activity

However there were great problems with this kind of study. Since the knowledge about maintenance is strictly limited for the observer it is often almost impossible to determine whether an activity should be seen as for instance troubleshooting or fixing the problem. Often these activities are performed simultaneously. For instance if there are problems related to the software of the machinery the technician often troubleshoots and changes parameters at the same time. The troubleshooting gets mixed up with the fixing of the problem and the results from the study get deceptive. For those reasons this observation was stopped after just 25 minutes and it was decided that other kinds of observations would contribute in greater extent.

4.4.3 Troubleshooting phase

Even though the problems related to the observation types that were used in both the previous time studies where well known by now it was not fully motivated to change the approach of the studies totally. Before doing so it was decided that the same kind of observation should be performed again but with a focus on the initial part of the service operation. When it comes to corrective maintenance the time from the work order is received until the root causes to the problem are known is often critical. It is of high importance that critical production equipment is fixed fast, since the downtime is costly. Therefore it is interesting to measure the time from that the work order is received until the root causes are known and the technician can start to fix the problem. If any improvement potentials could be detected in this initial phase it would be of great value for the organization.

The approach of this observation was the same as the previous studies. The observer followed a corrective service technician, and the study was initiated when the technician arrived to a new mission. The observation continued until the technician knew the root causes to the problem and how to solve it. The part of the work where the technician
was fixing the problem was excluded from the study. A new definition of code designations where used which are shown in table 4-3 below.

Table 4-3 Table of codes 3

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Troubleshooting</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Verifying test</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Other NVAs</td>
<td></td>
</tr>
</tbody>
</table>

In the previous tables green color has indicated value adding activities and red color has indicated non-value adding activities. As you can see in table 4-3 above all of the selected activities for the study are seen as non value adding. The purpose of this kind of observation was to map the average time that it takes for a technician to find root causes and decide how to solve the problems. Troubleshooting and communication includes the same activities as in the previous time studies. The category verifying test includes test runs of the machinery that where performed to trigger the problems. The technicians often use this method so that they can see with their own eyes how the problems occur and so they can see the alarm codes that are presented by the machine. The verifying test category also includes verifying tests that are performed when the job is finished to assure that the problems are resolved and that the functionality of the machine is acceptable.

In total two observations of this kind where performed. The results from the first of these studies are presented in figure 4-9 below.

Figure 4-9 Time distribution initial phase
As you can see from this pie chart troubleshooting stands for more than half of the total observation time. Verifying tests stands for 26 percent, other non-value adding activities for 11 percent and communication stands for 4 percent. The total observation time of the study was 1 hour and 6 minutes. The results from the second of these two studies are presented in figure 4-10 below.

![Pie Chart](image)

**Figure 4-10 Time distribution initial phase**

As you can see from the figure communication stands for 42 percent of the total observation time in this particular case. Troubleshooting stands for 36 percent while other non-value adding activities stand for 22 percent. No verifying tests were run during the study and therefore this category stands for zero percent in the pie chart.

The observation technique used in all the previous time studies and in the last time study described above has proven to be problematic. The problematical aspects are described earlier and they are almost the same for all the observations. The researchers have tried to use the same technique but with different approaches to see if the results can be used as ground for the further work. However after the different kind of time studies it has become clear that other methods probably would be more suitable for this thesis. It is important to enlighten the fact that all the results from these previous studies are valuable for the project and many aspects are used for the following analysis. The thing is that these time studies needs to be complemented with other studies to assure that no aspects are neglected.

With the problematic aspects as a ground it was decided to continue the observations by studying certain activities. The approach of these studies and the results are presented in the following section.
4.4.5 Time consumption documentation

As described earlier it was hard to determine which problem areas to choose for further analysis. The pie charts from the initial time study of the maintenance task indicated some problem areas to attack, but it also become clear that important aspects where not covered by the initial time study. For instance the activity where the service technicians are searching for documentation is known by the organization to be very time consuming. However this was not detected by the initial time studies and it became clear that the study had to be complemented by further studies to assure that important problem areas where not neglected.

It was decided that a suitable method for complementing the results from the time studies would be to perform a survey. The survey was performed by the use of handed out forms that the technicians filled out by themselves. The technicians documented how much time they spent on searching for different kind of documentations. They also documented the time they spent on searching for information within the documentation. In this case documentation can be information in papers in the maintenance divisions own archive, information in their own database, information in the control systems of the machinery etc. The forms where distributed on a pulse meeting and the researcher explained during the meeting how the technicians would fill out the form. Background information and the purpose of the study were also presented. According to the theories about surveys, which are described theoretically in the methodology section, it is necessary to introduce the survey. This assures that all of the respondents have understood how to fill out the form. They will also be more motivated if they understand the purpose of the survey.

The structure of the form and the results from every filed form can be studied in detail in appendix C, where the forms are attached as a whole. By letting the technicians fill in the forms by themselves larger amounts of data could be collected at ones, providing a more accurate average time for documentation related activities.

In figure 4-11 bellow follows an example of the results from one of the forms that was submitted by a corrective service technician.
As you can see in the pie chart 35 percent of the total time during the observation day was spent on activities related to documentation. The detailed form (see appendix C.5) states that the technician spent 4 hours and 15 minutes on these activities. The observation covered one whole working day, which had an effective length of 12 hours. Effective working day length means that this was the effective time available for the technician when the time had been adjusted by excluding the breaks.

The purpose of this survey was to measure the average time that the technicians spend on the search for information in documentation. The idea to complement the previous time studies by observing targeted problem areas is in some ways problematic. On one hand it feels natural to use the competence and everyday experience from the organization to support the determination of which aspects of the organization to focus further improvement investigations on. On the other hand this approach is extremely dangerous since the guidance of the study is not unbiased. This conflicts with the foundation stones of positivism, which clearly enlightens the importance of objectivity in the research process and confidence in the rationality of science. As described earlier Positivism states that all subjective data, such as feelings and opinions, does not belong in scientific projects.

Even though this kind of studies conflicts with the philosophies of positivism one can argue that the approach is suitable and motivated. Since previous studies have failed to detect all the possible problems and improvement potentials complementing methods are necessary to fully answer the sub queries and the main question of the thesis. This approach can be seen as that the organization provides a thesis; they believe that documentation related activities take too much time from the technicians. The survey that is being performed with the help of the forms helps to investigate this statement further. This can be seen as an deductive approach since the hypothesis is tested against empery. By measuring the actual time that the technician spends on the search for
documentation the subjective statement is evaluated objectively. If the documentation related activities are considered to be very time-consuming the statement from the organization is correct. Such results would objectively indicate that the search for documentation is time consuming and therefore necessary to analyze further in the improvement work.

4.4.6 Costs for documentation

If it can be shown that the costs related to documentation are extensive it becomes easier to motivate different improvement suggestions, even those that needs larger amounts of allocated resources. With the time study as a base it is possible to visualize the costs related to this non-value adding activity of finding the right documentation. By converting the time-based results into costs for the organization it is easier to illustrate the critical extent of certain problem aspects. If an activity is time consuming it is also costly for the organization and therefore it is motivated to allocate resources to rationalize the activities.

The following chapter includes calculations for the total costs related to documentation at the maintenance division. The calculations are based on data collected through the time study of documentations (see section 4.4.5). The average time that the technicians have used for documentation related activities during one effective working day is used as a ground for estimating the costs for those activities per day and technician. The costs for one technician are then multiplied with the number of corrective technicians to get an estimation of the total costs for the organization during an average month.

In order to understand the following calculations some explanations are necessary. At first the time for documentation is related to the effective time of the working day. Effective time of working day refers to the working hours for the service technician during the day of study. It is called the effective time since the time has been adjusted, so that the breaks are excluded from the study. Further the documentation of each observation is performed on a predefined excel document. Some calculation, that is performed in the same way for all the observation cases, are performed automatically by the standardized excel document. Therefore some numbers are brought directly from the attached forms and used in the further calculations. If the reader is interested in studying those numbers in more detail all the forms that the calculations are based on are attached in appendix C. The costs for the organization to employ a service technician are roughly estimated to be 350 kr / h, including the salary and social fees (Nilsson, Manager GVM5, 2014a). Below follows the calculations step by step with explanations in between.

The average time ratio of searching for documentation in relation to the total time of observation. The average time is based on the mean value of the four different observations.
\[
\left( \frac{0.354 + 0.204 + 0.07 + 0.246}{4 \text{ pcs}} \right) \cdot 100 = 21.85 \%
\]

Mean time effective working day:
\[
\frac{(11 \text{ h} + 7.06 \text{ h} + 7.06 \text{ h} + 7.06 \text{ h})}{4 \text{ pcs}} = 8.045 \text{ h}
\]

The following calculation step is performed to estimate the documentation ratio in relation to a standard working day, which has an effective working length of 7 hours excluding breaks. As you can see the average effective working time for the observation cases are longer than an average working day of 7 hours. In other words follows the calculations of the percentage ratio for documentation activities in relation to a working day of 7 hours below:
\[
\frac{8.045 \text{ h}}{7.06 \text{ h}} = 1.130 \rightarrow \frac{21.85 \%}{1.130} = 19.33 \%
\]

Hours spent on documentation activities per service technician and day:
\[0.1933 \cdot 7.06 \text{ h} = 1.36 \text{ h}\]

Costs per service technician and day for documentation activities:
\[1.36 \text{ h} \cdot 350 \text{ kr} = 477.8 \left( \frac{\text{kr}}{\text{service technician} \cdot \text{day}} \right)\]

Cost for documentation activities for all the CM technicians per day:
\[477.8 \text{ kr} \cdot 15 \text{ pcs} = 7167 \left( \frac{\text{kr}}{\text{work day}} \right)\]

Cost for documentation activities for all the CM technicians per month:
\[7167 \text{ kr} \cdot 20 \left( \frac{\text{work days}}{\text{month}} \right) = 143340 \left( \frac{\text{kr}}{\text{month}} \right)\]

As you can see from the calculations above the resources spent on searching for documentation and searching in documentation are significant. By putting this cost per month in relation to the prize of a service technician during one month it is easier to understand the benefits of improving these activities.

The average salary for a technician is 28 000 kr / month. If you take costs for social fees etc. into account a rough estimation of the costs for the organization to employ a technician is the double of the salary per month. This means that a service technician cost around 56 000 kr / month. (Nilsson, Manager GVM5, 2014a)
The estimation indicates that the costs of documentation activities are equal to the costs of employing 2.56 service technicians. These estimations are highly valuable since they motivate the improvement work. It is easy to understand that the costs for documentation activities can't be decreased to zero. The service technicians will always need to use documentation as a source for information and support in the daily work. However by improving the handling of the documentation the documentation activities can be rationalized from unnecessary waste that takes time from the technicians.

As you can see from the calculation the estimated costs are based on the numbers from a total of five forms. One can argue that the number of forms is to small and that the average numbers are not representative for the organization. Of course it is true that the calculations would be more accurate if they were based on more statistics. Even though the estimations are far from accurate it is useful and gives a hinge about the extent of costs for the activities. The estimations prove that the costs related to these activities are high, which can be used to motivate improvement changes that require large amounts of resources.

It is important that the discussions about cost reductions and time savings are not misinterpreted. Cost reductions are important to keep the organization competitive, but it is even more important to keep in mind that cost reductions are compliant with time savings. Time savings in turn means that the time that is being saved by a more rational way of working can be used more wisely. The organization will get the most out of timesaving by investing it in improvement work and education. This will result in a positive spiral with accelerating rationalization.

4.4.7 Time consumption transportation

As the results from the study of time consumption for documentation where proven to be useful as a ground for the improvement process it was decided to make similar cost estimations for transportation activities. The purpose of the calculations is to illustrate the resource consumption, which motivates the improvement work. If the extent of the costs can be illustrated it gets easier to motivate more expensive improvement suggestions.

The calculations of transportation activities are not based on a survey like the study of time consumption for documentation. Instead the calculations are based on the first of the time studies regarding time distribution, see appendix B.1. The observation documents the work of a corrective service technician. The results from that study states that the technician made 6 round-trips between the maintenance department and the machine that he was working on during the observation time. The machine that was repaired in that particular study was located close to the maintenance department and
therefore the transportation time was limited. The number of round-trips is however of greater interest, since the time had been higher if the machine was located somewhere else in the factory.

As the machine in the observation was one of the closest to the maintenance department it would not be suitable to use the transportation time from the study for the calculations. Instead the researchers have performed their own measurements of the average transportation time. The average numbers of round-trips that are used in the calculations are however based on the observation of the service technician. Figure 4-12 below shows how the measurement of the time was performed.

![Figure 4-12 Average transportation time](image)

The researcher used a kick bike and timed the transportation time from the maintenance department, marked green in figure 4-12, to the machine located in the approximate center of the factory. This transportation time was thereafter used as the average time in the calculations.

### 4.4.8 Costs for transportation

Estimation of average transportation time one way: 01:50 [mm:ss] (See figure 4-12 above).

Average transportation time round-trip expressed in minutes:

\[ 01:50 \cdot 2 = 03:40 \text{ [mm:ss]} \quad 03:40 \text{ [mm:ss]} \rightarrow 3.66 \text{ [min]} \]

The results from the time study, which are presented as a whole in appendix B.1, states that the technician made 6 round-trips during the observation. The total observation time was 4 hours and 21 minutes, which is equal to 4.35 hours (expressed in parts of hours instead of hours and minutes).
The total time spent on transportation between the department and the machine during the observation (expressed in minutes):

\[ 6 \text{ (round-trips)} \cdot 3.66 \left( \frac{\text{min}}{\text{round-trip}} \right) = 21.96 \text{ min in total} \]

In the following calculation it will be more convenient to use the total time spent on transportation expressed in parts of hours. Therefore the number is being converted as followed:

\[ \frac{21.96 \text{ (min)}}{60 \text{ (min/h)}} = 0.366 \text{ h} \]

As the observation does not cover the whole working day it is necessary to calculate the covering rate of the observation. The total time spent on transportation is thereafter adjusted with respect to the covering rate of the observation.

Covering rate of the observation:

\[ \frac{4.35 \text{ h}}{7 \text{ h}} = 0.621 \rightarrow \text{ The study covers } 62.1 \% \text{ of the effective working day} \]

Estimation of time spent on transportation for the whole working day:

\[ \frac{0.366 \text{ h}}{0.621} = 0.589 \text{ h spent on transportation per technician and day} \]

The costs for the organization to employ a service technician are roughly estimated to be 350 kr / h, including the salary, social fees etc. (Nilsson, Manager GVM5, 2014a). Bellow follows the calculation of costs. First the hours spent on transportation per technician and day along with the cost for a service technician per hour are used to estimate the cost per technician and day for transportation.

\[ 0.589 \left( \frac{\text{h}}{\text{technician} \cdot \text{day}} \right) \cdot 350 \left( \frac{\text{kr}}{\text{h}} \right) = 206.15 \left( \frac{\text{kr}}{\text{technician} \cdot \text{day}} \right) \]

Total cost for all the 15 corrective service technicians:

\[ 206.15 \left( \frac{\text{kr}}{\text{technician} \cdot \text{work day}} \right) \cdot 15 \text{ (technicians)} = 3092.3 \left( \frac{\text{kr}}{\text{work day}} \right) \]

Total cost per month:

\[ 3092.3 \left( \frac{\text{kr}}{\text{work day}} \right) \cdot 20 \left( \frac{\text{work days}}{\text{month}} \right) = 61845 \left( \frac{\text{kr}}{\text{month}} \right) \]
The average salary for a technician is 28 000 kr / month. If you take costs for social fees into account a rough estimation of the costs for the organization to employ a technician is the double of the salary per month. This means that a service technician cost around 56 000 kr / month. The following calculation puts the costs for employing a full-time service technician in relation to the costs for transportation.

\[
\frac{61 845 \text{ kr}}{56 000 \text{ kr}} = 1.10 \text{ full-time employees}
\]

As you can see transportation costs is equal to the employment of 1.10 full-time service technicians on a monthly basis. The expenses related to transportation are significant and it would be interesting to analyze the improvement potentials. Of course it would be impossible to eliminate all the costs for transportation. The technicians will always need to transport themselves between the machines and the maintenance department. However it is still interesting to analyze if the numbers of round-trips could be decreased somehow. If the time spent on transportation could be decreased with for instance ten percent, the benefits would be significant for the organization.

A serious disadvantage with the estimations of the costs for transportation is that they are based on data from just one observation. Of course this is not statistically reliable and there is a great risk that the average number of round-trips is not representative for standard service operations. Even though the data used for the calculations are not as representative the estimations gives a hinge of the costs related to transportation.

As described in the last paragraph of the previous section about estimations of costs related to documentation it is important that these sections about costs and time savings are not misinterpreted.

### 4.5 Value stream mapping

A tool for mapping the value stream in a production plant or an organization is the tool VSM or Value Stream Mapping. By following the value stream in the organization a map of the current state can be shown in one picture. The value stream of the actual service at the maintenance division can be seen in appendix A.2 for PM and appendix A.3 for CM. Later the picture of the whole VSM can serve as basis for improvements of the value stream as described in section 5.

The value stream at the maintenance division where based on the knowledge from the internship prior to the time study and by informal unstructured interviews. The symbols used in the value stream mapping are influenced by symbols from Bicheno et al., 2011. As the maintenance division is not a production unit with a distinct customer the mapping was divided into two different value streams, one mapping the preventive maintenance and one mapping the emergency repairs. Both have the same customers, the productions units, but they have so different value streams that it would be hard to
handle in one value stream map. The value stream mapping has been carried out in order to answer the thesis question: ”Which possibilities are there to reduce waste by a more effective way to work and which of these wastes shall be prioritized to eliminate?” This study also supports the work on answering the thesis main question: ”Which improvement potentials are there on GVM5 and how shall the improvement work be carried out?”

4.5.1 Preventive maintenance

The result of the value of the current state and its future state of the preventive maintenance can be seen in appendix A.4 and A.5. The preventive maintenance starts with an order from one of the production units based on a prognosis and service intervals from the supplier of the machinery. The team leader of the preventive maintenance handles the order. Some work orders shall be conducted more rarely than others. The leader plans the work order and ensures that there are spare parts in stock that needs to be changed. Most commonly the leader contacts the purchasing department, which handles the purchase of spare parts to the internal stock. In rare occasions the team leader contacts the supplier directly which ensures that the right spare parts are ordered. The maintenance is conducted by one of the five preventive service technicians at the maintenance division. The maintenance phase mainly consist of preparations where the documentation of the work order is looked through and the right equipment is gathered, a service phase and the final phase, which is reporting to the production unit and the team leader that the work is done. (Alingskog, Team leader PM, 140415)

4.5.2 Corrective maintenance

The corrective maintenance starts with a work order from the production units written by an operator and submitted to the work order database Corus. The team leader of the corrective maintenance distributes the work orders to one of the 15 service technicians at the maintenance division. Occasionally the team leader does not have the time to distribute all the work order. In that case it is also possible that a service technician picks a work order directly from Corus. The work orders are categorized according to the following priority system:

- Prio 1 - A prioritized machine with a breakdown.
- Prio 2 - A non-prioritized machine with a breakdown.
- Prio 3 - A machine not functioning as it should but it can still be run.

The corrective maintenance group has very small possibilities to plan their work more than on a daily basis. Therefore it is difficult for the team leader of the corrective maintenance group to plan the purchase of spare parts. This results in parallel processes for purchasing of spare parts. If there is time the purchase of spare parts goes through the purchasing department, but if the spare parts are needed with short notice, the team leader can purchase the spare parts needed. In those cases it happens that the spare parts are delivered to the factory by taxi to rush the delivery process.
During the troubleshooting phase the service technician can use the database FUS and look if the same problem has occurred before and how it was solved then. If the service technician after the troubleshooting phase realizes that there is a need for spare parts and those are not in stock the parallel rushed process can be needed and the parts being delivered by taxi directly to the maintenance division.

After a conducted service it is documented to FUS for guidance if the problem occurs again. After the report to FUS the status of the work order is changed to finished in Corus and the service technician reports to the production unit that the machine is up and running. (Ericksson, Team leader CM, 140414)
5. Future state

This chapter consists of a future state of the work procedures on the maintenance division GVM5. This future state is to be seen as a guideline for the maintenance division to strive towards and not as an absolute solution. This future state is only one part of the VSM, which also includes the current state described in the previous section.
5.1 Future state VSM

5.1.1 Preventive maintenance

The future value flow of the PM as seen in appendix A.4 starts with a work order from the production based on systematic analysis and from former work orders. The intervals shall not only be based on the service intervals from the supplier of the machinery. Service actions that are shown in previous preventive maintenance work orders to be executed even though they were not necessary are supposed to be questioned and updated. The process of updating the service intervals should be an ongoing process in the organization. The PM also needs to report information back to Maximo both during the preparation and the reporting of the finished work order. This will help to analyze revised service intervals. Only the purchasing department shall handle the purchase of spare parts in the future state in order to ease the workload from the PM team leader and to assure that the purchase department is well aware of the flow of products into the organization.

5.1.2 Corrective maintenance

The future value flow of the CM team may, as seen in appendix A.5, start with a work order from the production units via the new maintenance system Maximo to the CM team leader. In a best-case scenario shall all the purchases of spare parts go through the purchasing division and as far as it is economically justifiable the spare parts needed shall be in stock. In order to analyze which parts that are economically justifiable to store internally the reporting phase of the service is an activity of great importance. Reporting and documentation are also of great importance for the service technicians; a good basis from FUS is a great way to shorten the time of troubleshooting a machine.
6. Workshop and VSM

Chapters six consist of analysis and results of test carried out during this thesis such as results of formal- and informal interviews, time studies and workshops. The theory behind these methods can be found in the method and theory- chapter. This chapter will only be an analysis of the execution and results. The results shall not be seen as an absolute truth, the reader has to consider that the information in this chapter is supposed to answer the thesis question and its subqueries.
6.1 Workshop

To be able get a deeper knowledge of the problems the service technicians at the maintenance division is facing more or less every day, regarding the search for documentation, a workshop have been carried out. The focus of this workshop was to expose and uncover the problems related to documentation activities and to come up with possible solutions to these problems. This method can according to (Wallén, 1993) be seen as a scientific inductive method when the researchers uses collected data to draw parallels to make conclusions.

The workshop is an after-effect of the survey with forms that the service technicians filled out where they wrote down the time wasted searching for documentation and searching for information within the documentation. The workshop was carried out to answer the thesis main question: “Which are the most significant improvement opportunities at the maintenance division and how could these improvements be implemented?” and the sub-query: “Which are the opportunities to eliminate these activities through more efficient work procedures?”

Three CM and one PM service technicians were part of the workshop with the researchers as moderators. The workshop started with a short presentation of the result of the survey, why this workshop is performed and how it was supposed to be carried out. The first step in the workshop was to identify the problems to why the search for documentation takes so much time from the service technicians. This event where performed as a brainstorming activity. The service technicians themselves discussed what the problems where and the researchers wrote down these problems on a white board. The researchers made sure that all the databases and activities connected with documentation where handled in the workshop. This resulted in eleven problems, which causes the service technicians to waste time searching for documentation. Both the problems and its solutions are presented below:

The first of these problems was that it is hard to find the right binder in the maintenance divisions’ own archive. The maintenance division has a large archive with documentation and manuals for all the machinery and one machine can have up to a dozen of binders with information and drawings, which makes it hard to find the right binder for the service technician. For instance one technician may need electrical wiring diagrams, which is placed in one of these binders. In some cases the technician has to look through all of the binders to find the one where the circuit diagram is attached.

A picture of the archive can be seen in figure 6-1. The binders most commonly used are the binders with electrical wiring diagrams, mechanical drawings and in some cases hydraulic/pneumatic diagrams. The binders are often poorly marked and the fact that there is often no table of contents makes it even harder to find the right binder and to find the right information within these binders. Possible solutions to this are to mark the binders back with some sort of coloring scheme that visualizes the content of the binders. The binders with the electrical wiring diagram can for example be marked with
a red dot on the binders back, the mechanical drawings with blue and hydraulic/pneumatic with yellow. An example of this can be seen in figure 6.2. By using some kind of marks on the binders the time wasted in the archive looking for the right binder could dramatically be shortened. This can be seen as a way of doing the archive more structured for everyone and more adapted to 5S.

![Figure 6-1 GVM5 archive](image)

**Figure 6-1 GVM5 archive**

The second problem is that it is hard to find the right spare parts in the binders and in the PDF manuals on the G drive. The part number connected to all the spare parts is located in binders in the archive and in PDF- files on the G; drive which all the service technicians have access to. Part of the solution to the problem of finding the spare part numbers in the archive is the same as for the previous problem, it will be easier to find the numbers if the binders are marked. The problem with the PDF-manuals is in some
ways similar to the problem with the binders. The PDF-manual for one machine is not
one PDF-file; it can be dozens, which makes it hard to find the right one to go through.
The file names are also often written in German, which makes it hard to determine
which of the PDF-files that is relevant in a particular case. One possible solution
discussed was to merge all the PDF manuals for one machine to one single PDF-
document. This allows the service technician to open the PDF-document for one
machine and then use the software search function to quick and easy find the right page
by searching for certain spare part numbers or other kinds of information.

The next problem discussed was that today it takes time to find the electrical wiring
diagrams for the machinery. The service technicians have to walk from the machine in
the workshop to the maintenance department and look for the binder that contains the
electrical wiring diagram. As mentioned earlier the electrical drawings are placed in the
binders in the archive and in digital form on the G drive. Most of the technicians uses
the electrical wiring diagrams from the archive rather than those that are stored digitally
on the G drive. This procedure is a waste of time, especially since the structure of both
the archive and the G drive are not optimal. One solution to this problem is to print out
all the electrical wiring diagrams and put them in a plastic pocket inside the electrical
cabinets located at every machine. This will not only reduce the time wasted when
searching for documentation in the archive and the G-drive, it will also reduce time
wasted when the technician has to transport himself between the machine in the
workshop and the archive at the maintenance department. It is also common that an
operator with other machinery problems, or another service technician in need of
assistance, interrupts the service technicians when he walks between the machine and
the archive. With these aspects in mind time will also be reduced since the service
technician will not be interrupted as often.

When the service technicians search for documents on the G-drive time is often wasted
just searching for the right document. The problem is that the service technicians
experience that the map structure and the system of name the PDF files is messy. The
map structure has many subcategories and this makes it hard for the service technicians
to get an overview and to determine which folder to look into. After finding the right
folder it is also a problem to determine which file to open when the structure of the file
name is hard to understand sometimes and it can also be written in German. The
discussed solutions to these problems were to reduce the number of subcategories and
use a more structured map system. One solution is also to rename the PDF-files so that
the name of the file is understandable and describes the content of the document. The
5S method can be used here to make the structure clear for everyone. The problems
with file names in German are not seen as a problem for the maintenance division to
solve, but on the other hand, they are affected by it and should raise this problem with
the supplier of the machine. It should also be taken into consideration in the
procurement of new machinery. It is not seen as necessary from the service technicians
participating in the workshop that the language is Swedish because translations to
Swedish is often done poorly and therefore the information inconsequent and confusing.
When the service technician starts a work order they look in the data base FUS where they can search for information if this problems have occurred earlier and how this problems were solved. The service technician therefore, after a work order, uses this database to write down how he solved the specific problem that he just worked with. The problem is that FUS is very unstable and crashes, which makes these activities more time consuming than necessary. During this workshop no one could come with a specific solution to the problem. The fact is that Sandvik Coromant is just about to launch new maintenance software, Maximo, which probably includes this feature. Therefore it was decided not to continue with detailed solutions to this problem.

The service technicians can often find useful information from the machineries own computer and control system. Information that can be found in the control system is alarm codes and explanations of the meaning of those alarm codes. Notes and information about electrical components can also be found. The problem is, just like with the map structure on the G; drive, that the information is often written in German. One possible solution is to demand when investing in new machines that relevant information in the machines computer systems should be written in English. To have this information in English is essential for the technicians since they use this information to solve problems and to troubleshoot.

Cofur, the part of the maintenance system that handles inventory, is used for ordering spare parts if it is not in stock in the internal stock in Gimo. When the order is placed the service technician can see a date when the spare part is supposed to arrive to the internal stock. The problem is that the date is just a note and it does not get updated if the arrival date of the spare parts is changed. In other words the information about the arriving date for the particular spare part is not reliable. This means that the service technicians have to go to the stock and see for themselves if the spare parts needed have arrived yet. Sometimes the spare parts have arrived earlier than expected which results in unnecessary downtime for the broken machine, which needed this spare part. Often the service technician walks to the stock when the estimated date passes and finds out that the spare part did not arrive at time. This is annoying and time consuming for the maintenance division. It also makes it difficult to indicate to the production units when the maintenance division expects to have the machine fully operational. During the workshop it is discussed whether Maximo can solve this problem or not. Therefore it was decided not to dig deeper in this problem at the moment.

Another problem discussed related to Cofur was that when the service technicians are to order spare parts it is hard to determine which spare part to order. For example there are a huge amount of relays in one machine and it is hard to determine which one it is in Cofur just by looking at short product information. A possible solution to this problem is to attaché pictures of those components that are hard to find, such as relays, contacts and other electrical components. Hopefully pictures can be attached in the new maintenance system Maximo. Since this solution is related to Maximo it is not investigated further.
The last problem discussed in this workshop was the problem of signing into the database Corus. When the service technician is about to take on a specific work order they uses Corus. The problem is that there is many computers, both laptops and stationary computers, used for Corus activities. The maintenance division service technicians have one single username and one password, but they all use different prefixes when signing in. This prefix is a single letter or number used so that more than one technician can be signed in simultaneously with one username. If someone tries to sign in with the same prefix already in use the database will be locked for this person for up to ten minutes. A solution to this problem is to give all the computers, which are used for Corus activities, designated prefixes.

The first and second phase of the workshop, described above, form a ground for evaluation of the possible solutions. Below is the table with all the problems and solutions described in short. The number designated to each solution used in the PICK-chart can be seen in table 6-1.
Table 6-1 Problems and solutions workshop

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard to find the right binder in the archive.</td>
<td></td>
</tr>
<tr>
<td>Mark binder (4)</td>
<td></td>
</tr>
<tr>
<td>No coverage of when spare parts will arrive to GV internal stock.</td>
<td></td>
</tr>
<tr>
<td>Maximo (6)</td>
<td></td>
</tr>
<tr>
<td>Hard to find the right spare part in cofur cause of lack of pictures.</td>
<td></td>
</tr>
<tr>
<td>Prepare for the implementation of Maximo (9)</td>
<td></td>
</tr>
<tr>
<td>The signing in progress in corus can take up to 10 minutes.</td>
<td></td>
</tr>
<tr>
<td>Assign prefix to service technicians and computers (10)</td>
<td></td>
</tr>
<tr>
<td>FUS is unstable and crashes often.</td>
<td></td>
</tr>
<tr>
<td>Maximo (6)</td>
<td></td>
</tr>
<tr>
<td>The machineries control system is often written in German or Spanish.</td>
<td></td>
</tr>
<tr>
<td>Demand English when procurement of machinery (7)</td>
<td></td>
</tr>
<tr>
<td>The digital PDF manuals of the machinery are single sided. (One page, one PDF in a worst-case scenario).</td>
<td></td>
</tr>
<tr>
<td>Merge PDF- files (8) Searchable PDF- files (5)</td>
<td></td>
</tr>
<tr>
<td>Hard to find the sections with spare parts in the binders.</td>
<td></td>
</tr>
<tr>
<td>Mark binders (4) Searchable PDF- files (5)</td>
<td></td>
</tr>
<tr>
<td>The map structure on the G; drive is messy.</td>
<td></td>
</tr>
<tr>
<td>Less subcategories (1) Structured file naming system (2)</td>
<td></td>
</tr>
<tr>
<td>There are no wiring diagrams in the electrical cabinets and no one knows in which one there is and which one there is not.</td>
<td></td>
</tr>
<tr>
<td>Place wiring diagram in all electrical cabinets (3)</td>
<td></td>
</tr>
</tbody>
</table>

The third phase in the workshop was to evaluate all the solution with a PICK-chart. The PICK-chart will ease the process of categorizing which solutions that is worth implementing and which one that is not. Each solution designated a number is categorized in one of the four quadrants in order to get a good overview of which one to implement primarily. The result of phase three’s PICK-chart can be seen in figure 6-3 below.
This chart shows that the solutions most worth implementing are solution 3, 4 and 10. That is placing the wiring diagrams in the cabinets, mark the binders in the archive and assign a designated prefix to every computer that uses Corus logins. Only one solution, solution 6, was determined to belong in the kill quadrant. This was the problem with possible solutions related to Maximo. This was not because Maximo is not recommended to be implemented; it was because there is, at the moment, a lack of information of whether Maximo can solve it or not. The rest of the solutions where placed in the “challenge” quadrant and the recommendation is to look into these if time permits and the solutions are seen as valuable for the organization.

6.2 Value stream mapping

6.2.1 Corrective maintenance

If the VSM of the current state of CM, visualized in appendix A.2, is compared to the future state in appendix A.3, it is shown that there are several improvements that will be implemented automatically in conjunction with the implementation of Maximo. All the reporting to the older systems FUS and Corus will be replaced with reporting's to Maximo. The procurement of spare parts is an issue for the maintenance division, therefore the future, dream state, shows that the procurement of spare parts never shall occur during the service. This contributes to down time of the machinery for the production unit, which in turn means lower utilization. The future state therefore wants all the procurement to occur prior to the service. This puts pressure on the purchasing department, internal stock and the CM Team leader. The researchers are aware about
the fact that this may mean that more spare parts needs to be stored in the internal stock. Which spare parts that may be stored should therefore be evaluated thoroughly. This can also be solved through shortening the delivery time. Of course this can be difficult to accomplish, but the theories of Lean enlightens the importance of just in time deliveries and close collaborations with the suppliers.

### 6.2.2 Preventive maintenance

The VSM of the PM team do not show that big of change. The future state can be seen in appendix A.5 and the current state in appendix A.4. Just as the CM value flow the new maintenance system Maximo will contribute to some of the changes. One big differentiation between the current and the future state is that in the future state there are more emphasis on the analysis and reporting activities. These activities can help the maintenance division to evaluate the condition of the machinery. A service interval based on the condition of the machinery can help the maintenance division to keep the production units machinery at high utilization- and quality rates. Theories regarding condition-based maintenance are covered in the theory chapter.
7. Discussion and recommendations

This chapter is the last part of this thesis. This section includes a discussion where the thoughts of the researchers are ventilated. This part also discusses whether or not the main question and its subqueries were answered. The last part of this chapter is the researchers recommendations for the organization.
7.1 Discussion

As part of the introduction to the project some previous results were presented from the organization. As described earlier a external consulting firm stated that the amount of value adding activities normally are around 20 percent for service organizations. After the first observations of time distribution the results from our study stated that the amount of value adding activities fluctuated between a little over 50- and 70 percent. When considering the previous experience from the organization these results were not expected and at first we got a little confused. After discussions it became clear however that the differentiation between the previous study and our study where not crucial, other problems where more crucial. A more comprehensive discussion about the problems and thoughts concerning the relation between the previous study and our study can be find in the previous section of 4.4.1.

To complement the study it was decided to complement the initial time studies with surveys and a value stream map. The choice to hand out surveys to the service technicians where they were to fill in how much time the used for searching for documentation gave us useful information. As an aftereffect to the surveys we conducted the workshop where the service technicians where to help us come up with possible solutions to the problems they are struggling with on a daily basis. The workshop ended with a list of possible solutions, which where categorized in a PICK-chart. We recommend GVM5 to use this information to evaluate which solutions worth implementing and which one isn’t.

To summarize the outcome of the overall study it is interesting and important to discuss the outcome in relation to the predefined questions in the introduction chapter. At first the main question was formulated as followed: Which are the most significant improvement potentials regarding work procedures at the maintenance division and how can these potentials be converted into actions that increases the efficiency? With the results from the studies in mind it is clear that the thesis manage to answer this question properly. The time studies, the survey and the VSM manage to answer the first part of the question, while the following workshop manage to answer the second part.

When it comes to the sub-queries that support the main question all of them are considered to be answered in accepted extent. One can argue that the most important thing is that the main question gets answered. This is not totally true; since the purpose of the sub-queries is to make sure that the study covers all aspects of the main question. It is clear that the time studies, the survey and the VSM form a solid ground for identifying the non-value adding activities. This enables the first sub-query to be answered. Further the estimations of cost gives a hinge about the extent of some crucial activities, while the workshop provides practical actions to reduce the problems. This covers the second question. The workshop also involves the usage of specific tools from Lean production and modern maintenance techniques, for example a systematic approach for finding root causes and the use of PICK charts. The workshop acts as a good example and we believe that the methodology is suitable and adaptable for
improvement work in the organization. Therefore the final sub-query is considered to be fully answered.

The time frame only allowed us to focus on some improvement areas. One can argue that the questions are not fully answered if you look at all of the problem areas at the maintenance division. This is however considered to be totally natural, delimitations has to be made and we believe that the thesis has been constrained to study the most crucial aspects.

7.2 Recommendations

In short terms the following aspects are recommended for the organization to work actively with after the completion of this thesis.

- It is recommended that the organization use the results from the workshop to initiate the improvement process for the handling of documentation. The organization should convert the improvement suggestions into practical actions according to the priorities in the final step of the workshop. It is important that the progress of every activity is measured and that there are clearly defined deadlines for when the different activities are supposed to be finished. It is also important that every activity is assigned to one person that is responsible for the progress. Shared responsibilities are not desirable since there is a great risk that the division of responsibilities gets diffuse, which may result in unfinished activities.

- Because of the timeframe of this thesis it was not possible to study the problems and come up with improvement suggestions for the transportation activities. It is recommended that the organizations uses the estimations of costs related to transportation as a ground for improving the transportation activities and thereby continuing where the thesis stopped. If it is possible to accomplish the accuracy of the estimations can be increased by the use of more statistics for the calculations. This is however not considered as crucial since the estimations give a hinge about the extent of the possibilities. As the methodology of the workshop about documentation where considered to be very successful it is recommended that the organization uses the same kind of approach for analyzing the transportation activities. The workshop uses brain storming for the analyzing process but it would be just as suitable to use similar methods like Ishikawa diagrams.

- Further it is recommended that the organization looks closer at some sections of the theory chapter. The section about maintenance by operators, which includes the seven steps stairway, can be closely related to the collaboration between production units and the maintenance division. Therefore this section is considered to be valuable for the improvement work at the maintenance division. Further it is also recommended that the organization uses the theory
section about condition based maintenance, since the implementation of CBM is known to be one of the next steps for the organization to take.

- During the introduction of the time studies it became clear for the researchers that the organization's knowledge about Lean production is limited. Since the philosophies of Lean production are considered to be useful for all kinds of improvement work it is recommended that all staffs read the theory section about Lean production. If the level of knowledge about Lean is increased in the organization it would be easier to use theories and concepts for the improvement work. The theories of Lean states that every part of the organization should be involved in the improvement process. However, Lean states that this is a very difficult step for every organization working with lean. Therefore, it is important that every member of the organization gets the opportunity to educate themselves in Lean. By involving the whole organization it is possible that the staff starts pushing each other to be part of the development. It also helps to motivate the staff.
8. References

Printed books


Oral communication


Web pages


Standards


Unpublished sources

9. Appendices
Appendix A - VSM charts

Appendix A.1 - VSM charts symbols and indications

- Outside sources
- Manual information flow
- Electronic information flow
- Process/ activity
- Pushing flow
- Transport direction
- Vehicle transport
- Value stream inside GVM5
- Value stream inside Sandvik AB
- Value stream outside Sandvik AB
- Inventory GV
Appendix A.2 - Value flow chart CM, current state

The current state map for the corrective maintenance.
Appendix A.3- Value flow chart CM, future state

The future state map for the corrective maintenance
Appendix A.4 - Value flow chart PM, current state

The current state map for the preventive maintenance
Appendix A.5- Value flow chart PM, future state

The future state map for the preventive maintenance
### Appendix B – Time distribution study

#### Appendix B.1 Time study CM

Results from the only overall time study of corrective maintenance.

<table>
<thead>
<tr>
<th>Time</th>
<th>From [hh:mm]</th>
<th>To [hh:mm]</th>
<th>Observation</th>
<th>Comment</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:49</td>
<td>09:50</td>
<td>00:01</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>09:50</td>
<td>09:55</td>
<td>00:05</td>
<td>Service (UVA)</td>
<td>Continuing started workorder</td>
<td>1</td>
</tr>
<tr>
<td>09:55</td>
<td>09:57</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>09:57</td>
<td>09:58</td>
<td>00:01</td>
<td>Discussion with colleague</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>09:58</td>
<td>09:59</td>
<td>00:01</td>
<td>Service (UVA)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>09:59</td>
<td>10:00</td>
<td>00:01</td>
<td>Gathering tools</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>10:03</td>
<td>00:03</td>
<td>Service (UVA)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10:03</td>
<td>10:04</td>
<td>00:01</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>1</td>
</tr>
<tr>
<td>10:04</td>
<td>10:57</td>
<td>00:53</td>
<td>Service (UVA)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10:57</td>
<td>10:58</td>
<td>00:01</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>10:58</td>
<td>11:01</td>
<td>00:03</td>
<td>Restore/cleaning</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>11:01</td>
<td>11:02</td>
<td>00:01</td>
<td>Reporting time/ completed work</td>
<td>Corus</td>
<td>3</td>
</tr>
<tr>
<td>11:02</td>
<td>11:07</td>
<td>00:05</td>
<td>Helps colleague</td>
<td>Looking for spare parts</td>
<td>7</td>
</tr>
<tr>
<td>11:07</td>
<td>11:13</td>
<td>00:06</td>
<td>Document the service</td>
<td>FUS (?)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:55</td>
<td>11:58</td>
<td>00:03</td>
<td>Choosing new workorder</td>
<td>Corus</td>
<td>3</td>
</tr>
<tr>
<td>11:58</td>
<td>11:59</td>
<td>00:01</td>
<td>Preparation for new service</td>
<td>Gathering tools etc.</td>
<td>2</td>
</tr>
<tr>
<td>11:59</td>
<td>12:01</td>
<td>00:02</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>12:01</td>
<td>12:02</td>
<td>00:01</td>
<td>Looking for the operator</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>12:02</td>
<td>12:03</td>
<td>00:01</td>
<td>Discussion with operator</td>
<td>about the machine problem</td>
<td>6</td>
</tr>
<tr>
<td>12:03</td>
<td>12:07</td>
<td>00:04</td>
<td>Waiting for machine to finish</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>12:07</td>
<td>12:38</td>
<td>00:31</td>
<td>Service (STAMA)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12:38</td>
<td>12:50</td>
<td>00:12</td>
<td>Service (measuring machine)</td>
<td>Same prod division. While waiting for test STAMA.</td>
<td>1</td>
</tr>
<tr>
<td>12:50</td>
<td>12:52</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5. Brings part</td>
<td>4</td>
</tr>
<tr>
<td>12:52</td>
<td>13:00</td>
<td>00:08</td>
<td>Service (measuring machine)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td>13:02</td>
<td>00:02</td>
<td>Gathering tools</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>13:02</td>
<td>13:10</td>
<td>00:08</td>
<td>Service (measuring machine)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13:10</td>
<td>13:11</td>
<td>00:01</td>
<td>Phone call</td>
<td>Problem test STAMA</td>
<td>6</td>
</tr>
<tr>
<td>13:11</td>
<td>13:13</td>
<td>00:02</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>13:13</td>
<td>13:15</td>
<td>00:02</td>
<td>Looking for the operator</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>13:15</td>
<td>13:18</td>
<td>00:03</td>
<td>Discussion with operator</td>
<td>about problems STAMA</td>
<td>6</td>
</tr>
<tr>
<td>13:18</td>
<td>13:30</td>
<td>00:12</td>
<td>Service (STAMA)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13:30</td>
<td>13:31</td>
<td>00:01</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>13:31</td>
<td>13:48</td>
<td>00:17</td>
<td>Service (measuring machine)</td>
<td>Re-prioritizing. MM more important</td>
<td>1</td>
</tr>
<tr>
<td>13:48</td>
<td>13:51</td>
<td>00:03</td>
<td>Restore/cleaning</td>
<td>sorting tools</td>
<td>7</td>
</tr>
<tr>
<td>13:51</td>
<td>13:55</td>
<td>00:04</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>13:55</td>
<td>13:56</td>
<td>00:01</td>
<td>Service (measuring machine)</td>
<td>Mount back part</td>
<td>1</td>
</tr>
<tr>
<td>13:56</td>
<td>13:58</td>
<td>00:02</td>
<td>Service (STAMA)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13:58</td>
<td>14:02</td>
<td>00:04</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>14:02</td>
<td>14:06</td>
<td>00:04</td>
<td>Discussion with colleague</td>
<td>about problems STAMA</td>
<td>6</td>
</tr>
<tr>
<td>14:06</td>
<td>14:09</td>
<td>00:03</td>
<td>Studying documentation</td>
<td>Historical problems with</td>
<td>2</td>
</tr>
<tr>
<td>14:09</td>
<td>14:10</td>
<td>00:01</td>
<td>Discussion with colleague</td>
<td>about problems STAMA</td>
<td>6</td>
</tr>
<tr>
<td>14:10</td>
<td>14:12</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>14:12</td>
<td>14:15</td>
<td>00:03</td>
<td>Helps colleague</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>14:15</td>
<td>14:16</td>
<td>00:01</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>14:16</td>
<td>14:52</td>
<td>00:36</td>
<td>Service (STAMA)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Compilation of structured observation regarding time distribution

Observer: Fredric and Victor

Date: 2014-04-08

Observation time [hh:mm]: 04:21

Value adding activity time [hh:mm]: 03:09

None value adding time [hh:mm]: 01:12

Value adding time [%]: 72.4
### Table of code designations

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Tot. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Value adding activity</td>
<td>03:09</td>
</tr>
<tr>
<td>2</td>
<td>Planning and preparation</td>
<td>00:07</td>
</tr>
<tr>
<td>3</td>
<td>System activity</td>
<td>00:10</td>
</tr>
<tr>
<td>4</td>
<td>Transportation</td>
<td>00:23</td>
</tr>
<tr>
<td>5</td>
<td>Waiting time</td>
<td>00:04</td>
</tr>
<tr>
<td>6</td>
<td>Communication</td>
<td>00:11</td>
</tr>
<tr>
<td>7</td>
<td>Other NVAs</td>
<td>00:17</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>04:21</td>
</tr>
</tbody>
</table>

#### Explanation

- **1 Value adding activity**: 72%
- **2 Planning and preparation**: 3%
- **3 System activity**: 4%
- **4 Transportation**: 9%
- **5 Waiting time**: 2%
- **6 Communication**: 4%
- **7 Other NVAs**: 4%
Appendix B.2 – Time study PM 1

Results from the first overall time study of preventive maintenance.

## Compilation of structured observation regarding time distribution

<table>
<thead>
<tr>
<th>Observer:</th>
<th>Victor</th>
<th>Date: 2014-04-09</th>
<th>Observation time [hh:mm]: 02:46</th>
<th>Value adding time [%]: 60.8</th>
</tr>
</thead>
</table>

### CM: PM: X

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>09:37</td>
<td>09:39</td>
<td>00:02</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>09:39</td>
<td>09:53</td>
<td>00:14</td>
<td>Service (Danobat)</td>
<td>Continuing started workorder</td>
<td>1</td>
</tr>
<tr>
<td>09:53</td>
<td>09:57</td>
<td>00:04</td>
<td>Instructing the operator</td>
<td>operator involved in service</td>
<td>6</td>
</tr>
<tr>
<td>09:57</td>
<td>10:15</td>
<td>00:18</td>
<td>Service (Danobat)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:15</td>
<td>10:16</td>
<td>00:01</td>
<td>Helping operator</td>
<td>Measuring a product</td>
<td>7</td>
</tr>
<tr>
<td>10:16</td>
<td>10:18</td>
<td>00:02</td>
<td>Service (Danobat)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:18</td>
<td>10:19</td>
<td>00:01</td>
<td>Calling a colleague</td>
<td>Asks for a tube to oil-trolley</td>
<td>6</td>
</tr>
<tr>
<td>10:19</td>
<td>10:21</td>
<td>00:02</td>
<td>Looking for the tube</td>
<td>In the oil-room</td>
<td>7</td>
</tr>
<tr>
<td>10:21</td>
<td>10:27</td>
<td>00:06</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:27</td>
<td>10:30</td>
<td>00:03</td>
<td>fetching oil</td>
<td>In the oil-room</td>
<td>2</td>
</tr>
<tr>
<td>10:30</td>
<td>10:34</td>
<td>00:04</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:34</td>
<td>10:37</td>
<td>00:03</td>
<td>Fetching more oil</td>
<td>not enough first time</td>
<td>2</td>
</tr>
<tr>
<td>10:37</td>
<td>10:49</td>
<td>00:12</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:49</td>
<td>10:50</td>
<td>00:01</td>
<td>Looking for compressed air outlet</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>10:50</td>
<td>10:54</td>
<td>00:04</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:54</td>
<td>10:58</td>
<td>00:04</td>
<td>Tapping oil</td>
<td>Holds the tube during tapping</td>
<td>5</td>
</tr>
<tr>
<td>10:58</td>
<td>11:15</td>
<td>00:17</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>11:15</td>
<td>11:17</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:08</td>
<td>12:10</td>
<td>00:02</td>
<td>Transportation</td>
<td>From GVM5 to machine</td>
<td>4</td>
</tr>
<tr>
<td>12:10</td>
<td>12:12</td>
<td>00:02</td>
<td>Instructing the operator</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>12:12</td>
<td>12:15</td>
<td>00:03</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12:15</td>
<td>12:17</td>
<td>00:02</td>
<td>Fetch trolley with hydraulic-oil</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>12:17</td>
<td>12:23</td>
<td>00:06</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12:23</td>
<td>12:37</td>
<td>00:14</td>
<td>Tapping trolley with hydraulic</td>
<td>not enough first time</td>
<td>2</td>
</tr>
<tr>
<td>12:37</td>
<td>12:52</td>
<td>00:15</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12:52</td>
<td>12:53</td>
<td>00:01</td>
<td>Restore/clean</td>
<td>sorting tools on the cycle</td>
<td>7</td>
</tr>
<tr>
<td>12:53</td>
<td>12:56</td>
<td>00:03</td>
<td>Discussion with operator</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>12:56</td>
<td>12:58</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>12:58</td>
<td>13:03</td>
<td>00:05</td>
<td>emptying waste oil</td>
<td>at GVM5</td>
<td>7</td>
</tr>
<tr>
<td>13:03</td>
<td>13:05</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>13:05</td>
<td>13:09</td>
<td>00:04</td>
<td>Discussion with colleagues</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>13:09</td>
<td>13:11</td>
<td>00:02</td>
<td>Transportation</td>
<td>From machine to GVM5</td>
<td>4</td>
</tr>
<tr>
<td>13:11</td>
<td>13:14</td>
<td>00:03</td>
<td>Reporting time</td>
<td>Corus</td>
<td>3</td>
</tr>
</tbody>
</table>

*End of study*
### Table of code designations

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Tot. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Value adding activity</td>
<td>01:41</td>
</tr>
<tr>
<td>2</td>
<td>Planning and preparation</td>
<td>00:22</td>
</tr>
<tr>
<td>3</td>
<td>System activity</td>
<td>00:03</td>
</tr>
<tr>
<td>4</td>
<td>Transportation</td>
<td>00:12</td>
</tr>
<tr>
<td>5</td>
<td>Waiting time</td>
<td>00:04</td>
</tr>
<tr>
<td>6</td>
<td>Communication</td>
<td>00:14</td>
</tr>
<tr>
<td>7</td>
<td>Other NVAs</td>
<td>00:10</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td></td>
<td><strong>02:46</strong></td>
</tr>
</tbody>
</table>

- **1 Value adding activity**: 61%
- **2 Planning and preparation**: 13%
- **3 System activity**: 6%
- **4 Transportation**: 9%
- **5 Waiting time**: 2%
- **6 Communication**: 2%
- **7 Other NVAs**: 2%
Appendix B.3 – Time study PM 2

Results from the second overall time study of preventive maintenance.

<table>
<thead>
<tr>
<th>Time [hh:mm]</th>
<th>Observation:</th>
<th>Comment:</th>
<th>Code:</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:36 - 09:39</td>
<td>Clean</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>09:39 - 09:41</td>
<td>Transport</td>
<td>To job</td>
<td>4</td>
</tr>
<tr>
<td>09:41 - 09:42</td>
<td>Start new job</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>09:42 - 09:43</td>
<td>Call for help</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>09:42 - 09:47</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>09:47 - 09:54</td>
<td>Communication operator</td>
<td>Consultation</td>
<td>6</td>
</tr>
<tr>
<td>09:54 - 10:11</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:11 - 10:19</td>
<td>Waiting for help</td>
<td>Needs consultation</td>
<td>5</td>
</tr>
<tr>
<td>10:19 - 10:20</td>
<td>Phone call</td>
<td>Consultation</td>
<td>6</td>
</tr>
<tr>
<td>10:20 - 10:29</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:29 - 10:31</td>
<td>Transport</td>
<td>New job</td>
<td>4</td>
</tr>
<tr>
<td>10:31 - 10:56</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:56 - 10:57</td>
<td>Transport</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>12:06 - 12:07</td>
<td>Communication operator</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>12:07 - 12:08</td>
<td>Transport</td>
<td>To job</td>
<td>4</td>
</tr>
<tr>
<td>12:08 - 12:18</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12:18 - 12:19</td>
<td>Transport</td>
<td>To wash plate</td>
<td>4</td>
</tr>
<tr>
<td>12:19 - 12:25</td>
<td>Clean filter</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12:25 - 12:31</td>
<td>Gather tools</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>12:31 - 12:54</td>
<td>Service</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>12:54 - 12:56</td>
<td>Search for operator</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>12:56 - 13:07</td>
<td>Phone call</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>13:07 - 13:08</td>
<td>Communication</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>13:08 - 13:09</td>
<td>Clean</td>
<td>Former job</td>
<td>7</td>
</tr>
<tr>
<td>13:09 - 13:12</td>
<td>Communication</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>13:12 - 13:13</td>
<td>Clean</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>13:15 - 13:21</td>
<td>Clean</td>
<td>Empty oil containes</td>
<td>7</td>
</tr>
<tr>
<td>13:21 - 13:22</td>
<td>Transport</td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Compilation of structured observation regarding time distribution

Observer: Fredric
Date: 2014-04-09
CM: PM: X

Value adding activity time [hh:mm]: 02:38
Value adding time [%]: 58.2

\[End of study\]
Bachelor thesis: LEAN STUDY ON THE MAINTENANCE DIVISION AT SANDVIK COROMANT- RESOURCE UTILIZATION OF WORK PROCEDURES

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Tot. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Value adding activity</td>
<td>01:32</td>
</tr>
<tr>
<td>2</td>
<td>Planning and preparation</td>
<td>00:06</td>
</tr>
<tr>
<td>3</td>
<td>System activity</td>
<td>00:00</td>
</tr>
<tr>
<td>4</td>
<td>Transportation</td>
<td>00:12</td>
</tr>
<tr>
<td>5</td>
<td>Waiting time</td>
<td>00:17</td>
</tr>
<tr>
<td>6</td>
<td>Communication</td>
<td>00:17</td>
</tr>
<tr>
<td>7</td>
<td>Other NVAs</td>
<td>00:14</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>02:38</td>
</tr>
</tbody>
</table>
Appendix B.4 – Time study PM 3

Results from the only time study of higher resolution that exclusively focuses on the content of the value adding activity. This study has a new definition of value adding and non-value adding activities compared to the previous studies.

<table>
<thead>
<tr>
<th>Time From [hh:mm]</th>
<th>Time To [hh:mm]</th>
<th>Observations</th>
<th>Comment</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:17</td>
<td>14:22</td>
<td>00:05</td>
<td>Mount hatch</td>
<td>5</td>
</tr>
<tr>
<td>14:22</td>
<td>14:24</td>
<td>00:02</td>
<td>Test machine</td>
<td>Needs ajustement</td>
</tr>
<tr>
<td>14:24</td>
<td>14:25</td>
<td>00:01</td>
<td>Troubleshooting</td>
<td>3</td>
</tr>
<tr>
<td>14:25</td>
<td>14:26</td>
<td>00:01</td>
<td>Making ajustements</td>
<td>1</td>
</tr>
<tr>
<td>14:26</td>
<td>14:28</td>
<td>00:02</td>
<td>Test machine</td>
<td>6</td>
</tr>
<tr>
<td>14:28</td>
<td>14:32</td>
<td>00:04</td>
<td>Making ajustements</td>
<td>1</td>
</tr>
<tr>
<td>14:32</td>
<td>14:34</td>
<td>00:02</td>
<td>Test machine</td>
<td>6</td>
</tr>
<tr>
<td>14:34</td>
<td>14:35</td>
<td>00:01</td>
<td>Discussion colleague</td>
<td>4</td>
</tr>
<tr>
<td>14:44</td>
<td>14:48</td>
<td>00:04</td>
<td>Mount hatch</td>
<td>Other job</td>
</tr>
<tr>
<td>14:48</td>
<td>14:50</td>
<td>00:02</td>
<td>Discussion colleague</td>
<td>4</td>
</tr>
<tr>
<td>14:50</td>
<td>14:51</td>
<td>00:01</td>
<td>Test machine</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>00:00</td>
<td>PAUS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>00:00</td>
<td>End of study</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Tot. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixing the problem</td>
<td>00:05</td>
</tr>
<tr>
<td>2</td>
<td>Disassemble</td>
<td>00:00</td>
</tr>
<tr>
<td>3</td>
<td>Troubleshooting</td>
<td>00:01</td>
</tr>
<tr>
<td>4</td>
<td>Communication</td>
<td>00:03</td>
</tr>
<tr>
<td>5</td>
<td>Reasembly</td>
<td>00:09</td>
</tr>
<tr>
<td>6</td>
<td>Testing</td>
<td>00:07</td>
</tr>
<tr>
<td>7</td>
<td>Other NVAs</td>
<td>00:00</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td>00:25</td>
</tr>
</tbody>
</table>
1 Fixing the problem
2 Disassemble
3 Troubleshooting
4 Communication
5 Reassembly
6 Testing
7 Other NVAs
Appendix B.5 – Time study PM 4

Results from the first time study of higher resolution that exclusively focuses on the critical initial part of the service task until the root causes of the problem are known.

### Compilation of observations regarding value adding time

<table>
<thead>
<tr>
<th>Time From [hh:mm]</th>
<th>Time To [hh:mm]</th>
<th>Observation:</th>
<th>Comment:</th>
<th>Code:</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:34</td>
<td>09:35</td>
<td>00:01</td>
<td>Discussion with operator</td>
<td>2</td>
</tr>
<tr>
<td>09:35</td>
<td>09:38</td>
<td>00:03</td>
<td>Troubleshooting</td>
<td>1</td>
</tr>
<tr>
<td>09:38</td>
<td>09:43</td>
<td>00:05</td>
<td>Looking for operator</td>
<td>4</td>
</tr>
<tr>
<td>09:43</td>
<td>09:44</td>
<td>00:01</td>
<td>Discussion with operator</td>
<td>2</td>
</tr>
<tr>
<td>09:44</td>
<td>09:47</td>
<td>00:03</td>
<td>Troubleshooting</td>
<td>1</td>
</tr>
<tr>
<td>09:47</td>
<td>10:02</td>
<td>00:15</td>
<td>Running the cell</td>
<td>3</td>
</tr>
<tr>
<td>10:02</td>
<td>10:25</td>
<td>00:23</td>
<td>Troubleshooting</td>
<td>1</td>
</tr>
<tr>
<td>10:25</td>
<td>10:35</td>
<td>00:10</td>
<td>Troubleshooting/Solving problem with colleague</td>
<td>1</td>
</tr>
<tr>
<td>10:35</td>
<td>10:37</td>
<td>00:02</td>
<td>Verifying test</td>
<td>3</td>
</tr>
<tr>
<td>10:37</td>
<td>10:39</td>
<td>00:02</td>
<td>Looking for operator</td>
<td>4</td>
</tr>
<tr>
<td>10:39</td>
<td>10:40</td>
<td>00:01</td>
<td>Discussion with operator</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>00:00</td>
<td></td>
<td>End of study</td>
<td></td>
</tr>
</tbody>
</table>

### Table of code designation

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Tot. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Troubleshooting</td>
<td>00:39</td>
</tr>
<tr>
<td>2</td>
<td>Communication</td>
<td>00:03</td>
</tr>
<tr>
<td>3</td>
<td>Verifying test</td>
<td>00:17</td>
</tr>
<tr>
<td>4</td>
<td>Other NVAs</td>
<td>00:07</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Sum</strong></td>
</tr>
</tbody>
</table>
Bachelor thesis: LEAN STUDY ON THE MAINTENANCE DIVISION AT SANDVIK COROMANT - RESOURCE UTILIZATION OF WORK PROCEDURES

- Troubleshooting: 59%
- Communication: 4%
- Verifying test: 26%
- Other NVAs: 11%
Appendix B.6 – Time study PM 5

Results from the first time study of higher resolution that exclusively focuses on the critical initial part of the service task until the root causes of the problem are known. The purpose is to study the troubleshooting process in detail.

<table>
<thead>
<tr>
<th>Time</th>
<th>Observation:</th>
<th>Comment:</th>
<th>Code:</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td><strong>Start of new work order</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:21</td>
<td>Looking for EMO</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>10:28</td>
<td>Fetching electrical drawing</td>
<td>While waiting for EMO to</td>
<td>4</td>
</tr>
<tr>
<td>10:31</td>
<td>Discussion with colleague</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>10:32</td>
<td>Troubleshooting</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>10:38</td>
<td>Calls colleague</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>10:39</td>
<td>Discussion with colleague</td>
<td>Get help/background</td>
<td>2</td>
</tr>
<tr>
<td>10:49</td>
<td>Gives a colleague advise/info</td>
<td>About another job</td>
<td>2</td>
</tr>
<tr>
<td>10:50</td>
<td>Start troubleshooting another machine</td>
<td>The same problem on this one</td>
<td>1</td>
</tr>
<tr>
<td>10:53</td>
<td>Calls colleague</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>10:57</td>
<td>Restarts the machine</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>10:58</td>
<td>Calls colleague</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>10:59</td>
<td>Troubleshooting</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>11:02</td>
<td>Calls colleague</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>11:04</td>
<td>Troubleshooting</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>11:10</td>
<td>Discussion with operator</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>11:11</td>
<td><strong>End of study</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Talked to the technician afterwards. He estimated that he worked on this job order until 15:55. The work order was thereafter handed over to another technician with background knowledge. The other technicians had worked on the same machine with the same kind of problems just days before this order was initiated.
Bachelor thesis: LEAN STUDY ON THE MAINTENANCE DIVISION AT SANDVIK COROMANT- RESOURCE UTILIZATION OF WORK PROCEDURES

<table>
<thead>
<tr>
<th>Code</th>
<th>Explanation</th>
<th>Tot. Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Troubleshooting</td>
<td>00:18</td>
</tr>
<tr>
<td>2</td>
<td>Communication</td>
<td>00:21</td>
</tr>
<tr>
<td>3</td>
<td>Verifying test</td>
<td>00:00</td>
</tr>
<tr>
<td>4</td>
<td>Other NVAs</td>
<td>00:11</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>00:50</td>
</tr>
</tbody>
</table>

Table of code designation

Pie chart showing the percentage of time spent on each task:
- 1 Troubleshooting: 42%
- 2 Communication: 36%
- 3 Verifying test: 22%
- 4 Other NVAs: 0%
Appendix C – Time study documentation

Appendix C.1 – Time study documentation 1

Shows the results from form one in the study of time consumption for activities related to documentation.

<table>
<thead>
<tr>
<th>Tid</th>
<th>Från [hh:mm]</th>
<th>Till [hh:mm]</th>
<th>Total time [hh:mm]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>09:30</td>
<td>09:45</td>
<td>00:15</td>
<td>Searched for instructional manual to Schmid in the archive</td>
</tr>
<tr>
<td></td>
<td>12:40</td>
<td>12:55</td>
<td>00:15</td>
<td>Searched for spare part number to Schmid in the archive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00:00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00:00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00:00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00:00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00:00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00:00</td>
<td></td>
</tr>
</tbody>
</table>

Date: 2014-04-24
PM: CM: X

Total time documentation [hh:mm]: 00:30
Rest of working time [hh:mm]: 06:36
Total time working day (effective) [hh:mm]: 07:06
Time dedicated to doc. [%]: 7.0

Total time documentation: 93%
Rest of working time: 7%
Appendix C.2 – Time study documentation 2

Shows the results from form two in the study of time consumption for activities related to documentation.

<table>
<thead>
<tr>
<th>Tid</th>
<th>Från [hh:mm]</th>
<th>Till [hh:mm]</th>
<th>Total time [hh:mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:12</td>
<td>16:24</td>
<td>00:12</td>
<td>Collected information from FU schedule.</td>
</tr>
<tr>
<td>17:03</td>
<td>17:19</td>
<td>00:16</td>
<td>Collected information at the machine.</td>
</tr>
<tr>
<td>18:42</td>
<td>19:25</td>
<td>00:43</td>
<td>Searched for info in ladder (fanuc)</td>
</tr>
<tr>
<td>20:54</td>
<td>21:10</td>
<td>00:16</td>
<td>Searched for info about machine alarm in ladder (fanuc)</td>
</tr>
</tbody>
</table>

No need for information search in the archive during the day/evening
Appendix C.3 – Time study documentation 3

Shows the results from form three in the study of time consumption for activities related to documentation.

<table>
<thead>
<tr>
<th>Tid [hh:mm]</th>
<th>Total time [hh:mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:00</td>
<td>09:00</td>
</tr>
<tr>
<td>12:30</td>
<td>14:00</td>
</tr>
<tr>
<td>15:00</td>
<td>15:45</td>
</tr>
<tr>
<td>17:00</td>
<td>18:00</td>
</tr>
</tbody>
</table>

Cell/Vision PC, User PW etc. Searched for and looked into documentation.

Looking for Temp-marking documentation everywhere (online, archive etc). Does not exist.

Searched in the documentation for the Östling Lazer.


Time consumption searching documentation

Date: 2014-04-24
PM: CM: X

Total time documentation [hh:mm]: 04:15
Rest of working time [hh:mm]: 07:45
Total time working day (effective) [hh:mm]: 12:00
Time dedicated to doc. [%]: 35.4

Time dedicated to doc. [%]:

Total time documentation [hh:mm]:

Rest of working time [hh:mm]:
Appendix C.4 – Time study documentation 4

Shows the results from form four in the study of time consumption for activities related to documentation.

### Time consumption searching documentation

<table>
<thead>
<tr>
<th>Date: 2014-04-24</th>
<th>PM: X</th>
<th>CM:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total time documentation [hh:mm]:</td>
<td>00:00</td>
<td></td>
</tr>
<tr>
<td>Rest of working time [hh:mm]:</td>
<td>07:06</td>
<td></td>
</tr>
<tr>
<td>Total time working day (effective) [hh:mm]:</td>
<td>07:06</td>
<td></td>
</tr>
<tr>
<td>Time dedicated to doc. [%]:</td>
<td>0,0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tid</th>
<th>Total time [hh:mm]:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Från [hh:mm]:</td>
<td>Till [hh:mm]:</td>
</tr>
<tr>
<td>00:00</td>
<td>Did not need to look for documentation at all</td>
</tr>
</tbody>
</table>

- **Total time documentation [hh:mm]:**
- **Rest of working time [hh:mm]:**
Appendix C.5 – Time study documentation 5

Shows the results from form five in the study of time consumption for activities related to documentation.

<table>
<thead>
<tr>
<th>Time consumption searching documentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
</tr>
<tr>
<td>PM: CM: X</td>
</tr>
<tr>
<td>Total time documentation [hh:mm]:</td>
</tr>
<tr>
<td>Rest of working time [hh:mm]:</td>
</tr>
<tr>
<td>Total time working day (effective) [hh:mm]:</td>
</tr>
<tr>
<td>Time dedicated to doc. [%]:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tid</th>
<th>Total time [hh:mm]:</th>
<th>From [hh:mm]:</th>
<th>Till [hh:mm]:</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15</td>
<td>01:30</td>
<td>10:15</td>
<td>11:45</td>
<td>Searched for information in a drawing</td>
</tr>
<tr>
<td>13:00</td>
<td>00:15</td>
<td>13:00</td>
<td>13:15</td>
<td>Searched for information in a drawing</td>
</tr>
</tbody>
</table>

- Total time documentation [hh:mm]: 01:45
- Rest of working time [hh:mm]: 05:21
- Total time working day (effective) [hh:mm]: 07:06
- Time dedicated to doc. [%]: 24.6

75% Total time documentation [hh:mm]:
25% Rest of working time [hh:mm]:
Appendix D- Workshop

A1- Problems connected to the search for documentation