Improvements in Internal Logistics

A Case Study at SSAB Oxelösund – Logistics Development Department

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Abstract

Internal logistics is a combined performance of human resources, machines, transportation, and storage system. Thus, different elements and factors are involved in the internal transportation such as human factors and system functions. Moreover, Internal transportation is an important part of production activities because of its close cooperation with production processes. Since the largest portion of the logistics costs is related to transportation, improvements in transportation will lead to a significant increase in profits.

The purpose of this thesis is to make improvements in the internal transportation of SSAB. Improvements here means identifying involved wastes in internal transportation, then give recommendations and suggestions to eliminate those wastes. This is a single case study at SSAB Oixelösund. SSAB stands for Svenskt Stål AB formed in 1978 and is well-known because of its special steel products. This company produces steel products for both standard and special orders and uses. All the underproduction plates have to go through a chain of operations to become the finished products. Different operation can be mentioned as cutting, painting, sorting, etc. Material movements in this chain of operations are done with the help of special cassettes and carriers.

Cassettes are the main resources in the internal transportation of SSAB and availability of empty cassettes plays a key role in the whole production process of the company. There are three departments that are involved with internal transportation at SSAB Oixelösund. Four research objectives are designed to cover the purpose of this study. In the following, several interviews and observations are done to collect the qualitative part of data gathering. The quantitative part of data collection is done with exporting data series from company’s data base.

Theoretical frame work is mainly based on Lean and logistics theories. Analysing the collected data and comparing the results with theoretical frame work lead to identifying the wastes in different areas related to defined research objectives. Different wastes are identified in carriers and drivers’ performances, treatment stations, etc. Therefore, specific recommendations are given based on the identified wastes in order to eliminate those wastes. The recommendations are presented to have faster and optimized material flow. Additionally, areas for further research and an Impact/Effort matrix are provided for future implementations and analysis.

Key Words:

Internal Transportation, Lean, Logistics, Material Flow
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1. Introduction

1.1 Theoretical Background

Nowadays companies experience tough competition in the global arena, facing an increase in customers’ expectations and changes in technological developments (Vokurka et al., 2002). Most of the companies experiencing this competition have decided to accept the changes in technological advancement and adapt to manufacture high-quality products besides lowering the cost of production (Grimson and Pyke, 2007). Trying to have high quality and low cost creates long lead-time that makes the situation difficult to meet the customers’ demand on time (Ventana, 2006). The crucial role of logistics in companies with high production volume is undeniable (Goldsby and Martichenko, 2005). Optimization of logistics, which is neither easy nor cheap, help companies to be successful in managing the production, lead-time, and costs (Li and Jing, 2011). Logistics optimization leads to performance improvements by making better decisions.

In terms of strategy, logistics is an important business area. In addition, to be a competitive and profitable company, logistics is an essential factor (Waters, 2003). Due to the mentioned fact, some companies decide to outsource logistics since they do not have the proper logistics competence in-house. Therefore, these companies can have more concentration on their core business area besides having more divided responsibilities such as developing logistics strategies and optimizing products and flows.

Waters (2003) argues that, based on the crucial role of logistics in an organization, managers should make the flow of materials both efficient and effective. Logistics holds a remarkable position between suppliers and customers. Also, logistics is an essential function and it takes care of the movements. Responsibilities of logistics contain the transportation and storages of the materials which are moving from suppliers to the customers. Goods or services are the products of all organizations and they deliver these products to their customers. Operations that take the inputs and change them into the required outputs are located in the heart of an organization, as shown in the figure (1).

![Figure 1: Inputs and Outputs (Waters, 2003)](image-url)
All resources such as people, buildings, raw materials, equipment, information, and investments are parts of inputs. Operations contain transportation, manufacturing, serving, supplying, etc. Outputs are the products as either goods or services. Therefore, logistics also causes the flow of material between different parts of an organization moving from internal suppliers to internal customers, as shown in the figure (2).

![Figure 2: The role of logistics (Water, 2003)](image)

Inbound refers to the movements from a supplier, and outbound is moving out to the customers; materials management includes the movements of material within an organization.

Christopher (1986) holds the idea that ‘logistics has always been a central and essential feature of all economic activities’. Shapiro and Heskett (1985) say, ‘there are few aspects of human activity that do not ultimately depend on the flow of goods from point of origin to point of consumption’. Logistics is necessary and important for all organizations and without it, materials do not move, operations cannot be done, products will not be delivered, and customers will not be satisfied.

Not only logistics is important, but it is expensive as well. Normally everyone wants to lower the logistics costs. Logistics managers want to make the costs as low as possible to be competitive in the market, and their customers want to pay for the products as little as possible. Organizations should keep their service level, while they are trying to lower the costs. Providing products and services for customers at the lowest cost is a definition for improved logistics. Therefore, it is essential to find the quality that customers need and the service level that they want to pay for. The key factor to find these features is lead-time, which is the total time from ordering point to have them available to use (Waters, 2003).
Internal transportation is an important part of production activities because of its close cooperation with production processes (Zaveršnik et al., 2015). Since the largest portion of the logistics costs is related to transportation, improvements in transportation will lead to a significant increase in profits (Li and Jing, 2011). Internal logistics is a combined performance of human resources, machines, transportation, and storage system. Thus, different elements and factors are involved in the internal transportation such as human factors and system functions (Goldsby and Martichenko, 2005).

Lean originates from the Toyota Motor Company, known as a concept to increase effectiveness in manufacturing (Sugimori et al., 1977; Womack et al., 1990; Womack and Jones, 2003). As Toyota became successful, a large number of companies around the world encouraged to start thinking about Lean. Womack et al., (1990) argue that Lean is a strategy or a way of thinking in order to run operations, and it includes companies’ management, fundamental principles, culture, etc. By implementing Lean, it means being close to a vision of perfection, actually it creates significant advantages with increasing productivity and effectiveness (Liker and Miere, 2006).

In recent decades, manufacturing companies have been adopting Lean principles in different forms and names (King, 2009). The initial principle of Lean is to understand the value, there is a concept that defines value as a combined performance of form, place, and time, which at least one of them should be improved (Gitlow, 2009). Form refers to utility and design, place refers to customer convenience, and time refers to delivery lead-time. Bicheno and Holweg (2009) claim that waste can be defined as activities which do not lead to value. The main goal of implementing Lean in logistics can be mentioned as eliminating waste to have an improved transportation system. As a result, it can lead to having a reduction in lead-time and cost, and a better use of resources. Ideally, having a reduction in transportation cost leads to having economic advantages as improvements (Baudin, 2005).

1.2 Problem Description

SSAB in Oxelösund has different product types known as Hardox, Strenx, Armox, Special Mild Steel, and Toolox. Based on these five types of steel, plates are produced in various thicknesses, widths, and lengths. Additionally, some types of raw plates as semi-finished products are delivered to the company by ships to become finished products. All the underproduction plates have to go through a chain of operations in different treatment stations to become the finished products. By different treatment stations, it means heat treatment, formatting, gas and plasma cutting, painting, blasting, and flatness stations which are located separately and far from each other.

During the production of plates in production processes, they are loaded on special flats known as cassettes (Figure 3). The maximum capacity of a cassette is sixty tones and there are different types of cassettes according to length and thickness of the plates. Cassettes need carriers (Figure 3) to move them between different stations. There are approximately 550 cassettes and 6 carriers in the company, and there are different drivers who drive these carriers in three shifts a day. It should be mentioned that the company works 24 hours a day and 7 days a week.
An IT-system known as Transportation System (TRS) connects production lines and treatment stations to the carriers. Personnel in production lines and stations can order a mission in the system when they need an empty cassette or they want to send a loaded cassette to other stations. Then drivers can see the mission on the screen of their carrier and decide to do the mission. TRS also provides different types of reports, and in this study, the focus is on the delay reports that are connected to the internal transportation. Delay reports are both daily and weekly reports that present the time and duration that at least one of operators and/or production lines and/or machines are idle because of the delay in the internal transportation. On the other words, these delay reports represent the downtime for both personnel and machines, and this downtime is waiting time for the carriers to do their missions.

Production planning department allocates priorities to different treatment stations and production lines based on company’s executive plan. These priorities are presented in the screen of carriers and drivers can choose to do the missions with different priorities from one to five. Number one in prioritization system has the highest priority and number five refers to the lowest priority. Therefore, drivers can see what the priority of each mission is and it helps them to decide which mission should be done first.

Each treatment station has a storage area outside of the station called Middle Storage (Mellanlager Plats). Since there is a limited space in each treatment station, cassettes should wait in a queue at the middle storages before entering the treatment station. It should be considered that for each movement of cassettes there is a need for a carrier and for having a carrier, operators should order a mission in the system. In addition, there is a storage area called
fishbone since its layout is similar to a fishbone, where finished products are waiting there to be delivered to the final customers (Figure 4). Both External suppliers and external customers are served through three different ways: ship, train, or trucks.

![A general Schematic of Material Flow](image)

**Figure 4:** A general Schematic of Material Flow

Since cassettes play a key role in the internal transportation of SSAB, lack of empty cassettes leads to a problem. Lack of empty cassette has direct effects on different parts of the production processes. Production lines and treatment stations need to have empty cassettes on time; otherwise, they have to stop producing and processing until having the empty cassette. Moreover, there should be approximately 50 empty cassettes of the correct type available at the predestinated time for unloading and loading the ships when they arrive, and lack of a proper number of empty cassettes creates a considerable cost and delay time.

In sum, regards to reaching efficient production and meet customers' demand on time, internal transportation has to be optimized and fast enough to handle the situation. Cassettes and carriers are the most important parts of the internal transportation of SSAB, and the performances of these two parts have both direct and indirect effects on the whole production processes.
1.3 Purpose and Research Objectives
The purpose of this study is to make improvements in the internal transportation system. Improvements here mean to have more empty cassettes available, prevent stopping the material flow because of the lack of empty cassettes, and reduce lead-time. With respect to this purpose, probable wastes in the internal transportation of SSAB will be identified. Some suggestions and recommendations will be given in order to eliminate or reduce identified wastes. To be more precise, cassettes are considered as the main resources of internal transportation. Also, drivers, carriers, and treatment station are the main parts of the company that are working closely with cassettes. According to the problem description, research objectives are divided into three different areas as Carriers, Treatment Stations, and Cassettes that are involved in the internal transportation of SSAB. The fourth research objective is designed to give recommendations to eliminate identified wastes.

**Research Objective 1:** Study the performance of carriers to identify wastes.

**Research Objective 2:** Study the different treatment stations in order to find out the wastes connected to the internal transportation of SSAB.

**Research Objective 3:** Identify the storage areas where cassettes are stocked more by studying the waiting times of cassettes in different storage areas.

**Research Objective 4:** Develop recommendations in order to eliminate or reduce the identified wastes based on theories.

1.4 Delimitations

1- Not reviewing production-planning part, since the company thinks that it is out of scope. Production planning is responsible for the both short term and long term production plan of SSAB. Studying the production planning and prioritization system could help to have more efficient and effective material flow; consequently less queues in middle storages.

2- Not reviewing the transportation routes between stations and production lines, because of high flexibility in production system and internal transportation.

3- Not getting involved in the prioritization of MTS or MTO in production and transportation system, however both MTS and MTO products are produced simultaneously.
2. Methodology
Generally, this chapter presents the way to reach research objectives besides the scientific explanations for research approach, research design, research philosophy, data gathering, credibility, and analysis method.

2.1 Method Approach
The method approach of this study contains four different phases: planning phase, data gathering phase, analysis phase, and recommendation and conclusion phase, that are presented in Figure (5). Each phase is divided to separate activities which are going to be explained more in detail.

2.1.1 Planning Phase
Planning phase consists of background, objectives, and methods as the base of the study, Figure (6). Background includes theoretical aspects which explain the role of logistics and its importance to help companies remain in today’s competitive market. It also explains the role and adaption of Lean principles for having improvements in logistics. Moreover, company background gives an overview of both production and transportation. Problem description is provided to give more detail information about how the internal transportation works and what the focus of this study is.

![Figure 5: Method Approach](image-url)
These mentioned parts lead to define purpose, research objectives and delimitations. The purpose and research objectives are designed to have improvements in internal transportation of SSAB.

**2.1.2 Data Gathering Phase**

The second phase is data collection which contains three different steps as shown in Figure (7). In the first step, theoretical framework is going to be explained with the help of different theories that connect logistics and internal transportation to Lean. These theories are collected from academic journals and different sources of the library. These activities provide a base for collecting relevant information during the data gathering phase. Collecting documents, conducting interviews, and observations are done simultaneously as the second step of data collection phase.
2.1.3 Analysis Phase

This phase explains how to reach research objectives and move forward to give recommendations related to the defined problem. Hereby, gathered data from interviews, observations, and documents will be analyzed based on the presented theories in the theoretical framework.

**Research Objective 1:** Study the performance of carriers to identify wastes.

Regards answering this research objective, a combination of interviews, observations and studying documents should be done in order to have a clear vision of current state. Several unstructured and semi-structured interviews with coordinators and manager of the drivers are conducted to have an overview of how the carriers’ system is run today. After having a big picture of the way that drivers work today, there should be closer observations of the situation. These observations are done by going with different drivers in different shifts in order to understand their performance. Here drivers’ performance is related to how they decide to do the missions, how they follow the defined priorities, and how important the prioritization system is for them. In addition, Transportation System (TRS) provides documents such as delay reports. Studying gathered data from interviews, observations, and documents besides having theoretical framework as a support will lead to identifying probable wastes. Analysis of this research objective will be done by comparing presented theories in theoretical framework with gathered data, the gap between theories and findings will lead to identifying wastes.

**Research Objective 2:** Study different treatment stations in order to find wastes that are connected to the internal transportation system.

To understand the current situation in each treatment station, semi-structured interviews are conducted with responsible persons in each station. These interviews lead to a better understanding of how the working process is connected to cassettes and internal transportation system. To be more precise, on-site observations are done in order to compare the interviews with the practical way of working. Combination of interviews and observations provide more accurate information regarding different treatment stations. Additionally, documents about delay reports which are connected to the internal transportation system will be reviewed. Eventually collected data will result in identifying probable wastes in treatment stations by finding the gap between presented theories and collected data.

**Research Objective 3:** Identify the storage areas where cassettes are stocked more by studying the waiting times of cassettes in different storage areas.

In this research objective, waiting times of the cassettes in different storage areas are going to be calculated. The required data for this calculation is exported from the company’s database in the form of Excel sheets. Based on the scope of the project it is decided to limit the data series to the year 2017. In the first step, these data series will be separated based on different storage areas. The next step is to calculate for how long and where each specific cassette has waited. In order to analyze these data series with help of graphs, data should be moved to Minitab. Since this is a big data, there should be graphs and visual tools to make the results more understandable. With respect to the graphs, it will be clear that in which storages waiting
time is more than the others. Since waiting time is considered as a type of waste, graphs will help to identify this waste in the internal transportation.

2.1.4 Recommendations and Conclusion

This phase includes recommendations for having improvements in the internal transportation of SSAB. Conclusions here will be made through giving recommendations based on explained theories in the theoretical framework. The recommendations focus on eliminating identified wastes. In this phase research objective 4 will be answered.

**Research Objective 4:** Develop recommendations in order to eliminate or reduce the identified wastes based on theory.

Required data is already gathered from previous research objectives. Analyzing part is based on a comparison between collected data and theories related to Lean thinking and logistics. Therefore, recommendations connected to the theories and references will be given to eliminate or reduce the wastes. These recommendations will be given based on a deep literature review as presented in the theoretical framework.

2.2 Research Strategy

Case study research refers to understanding and exploration of complex issues. It is a powerful research method and it is particularly used for in-depth investigations (Saunders et al., 2009). Due to the boundaries and limitations of quantitative methods in investigations, case study is recognized as a research method. Case study method helps researchers to go further of the quantitative results and understand the statistical perspectives. With respect to both quantitative and qualitative data, case study describes and explains both processes and results of the defined problem by data gathering, investigations, and analysis (Saunders et al., 2009).

As Stouffer (1941) describes "single case study may provide valid tests in the same sense as can critical experiments". Based on the problem description and research objectives, researchers conduct either a single case or a multiple case study. A single case study is done when there are not any other similar cases to repeat the study. This case study is efficient, flexible, and used to make key improvements. One of the drawbacks of a single case study when the defined problem happens rarely is that, it is hard to provide a general conclusion. To overcome this drawback, different methods should be used to increase the validity of the study.

Multiple case study refers to real life events with various sources of proofs by repeating the study instead of sampling. Generalization of results either from single or multiple case study is based on theory instead of populations. Multiple case study usually supports the results from previous studies; this will increase the validity of the study (Yin, 1994).

According to the presented definitions for case studies, it can be mentioned that this report is a single case study. Since there are not any other similar studies and the defined problem is specific.
2.3 Research Approach

Creswell (2014) claims, there are three essential type of study as convergent, explanatory, and exploratory. Convergent is a type of study in which both quantitative and qualitative data are collected, analyzed, and then integrate the results of analyses. The purpose of merging the results is to compare the results or in the other words, one set of results is going to validate the other set. Explanatory type of study is a straightforward method which uses quantitative methods and then gets help from qualitative methods in order to explain the set of quantitative results more in depth. Exploratory is related to a type of study in which first uses qualitative methods in order to explore a problem. Then these qualitative findings lead to the quantitative phase of the study. The quantitative part contains statistical trends and mathematical calculations. In the last phase, both quantitative and qualitative methods are used for gathering the data and analysis procedure.

This is an exploratory research since the problem was not defined clearly and this type of study leads to a better understanding of the problem. As explained in the research objectives, at first qualitative part of the study is done to explore and understand the problem area. Quantitative part is done after gaining more understandable findings from the qualitative part. Eventually, both qualitative and quantitative methods are used for data collection and analysis phase. This type of study helps to determined data collection methods and the most significant method for gathering primary data is semi-structured interviews (Saunders et al. 2009).

Inductive and deductive approaches are two different types of research in which a study can be approached in. Deductive approach develops a theory or hypothesis and provides a research strategy in order to test these theories or hypothesis. In other words, the investigation and study are narrowed down from more general to more specific one. On the opposite way of working, an inductive approach gathers data and after data analysis, it provides a theory as a result of the analyzed data. This study uses both inductive and deductive approaches in different aspects. It is a deductive research since it explores related theories and investigates the validity of these theories in the defined problem. In addition, it starts with a very general statement and works it down in order to reach a specific result. While conducted interviews and group meetings use the inductive approach in which the topic is flexible so can adapt and change based on outcomes of the discussions.

2.4 Research Philosophy

Research paradigm is determined to guide how the research objectives should be reached. Research paradigm is divided into positivism and interpretivism based on researchers’ opinion about essence of knowledge (Colliens and Hussey, 2013).

Interpretivism is considered as the opposite of positivism since positivism is a fix-structured design and can influence the results in a negative way, so it causes to lose some relevant parts of gathered data (Colliens and Hussey, 2013). Interpretivism design is completely influenced and formed by people (Crossan, 2003). Colliens and Hussey (2013) argue that the objective of interpretivism paradigm is to have a better understanding of the defined problem. In addition,
this paradigm uses different types of qualitative methods to define, describe, and translate the meaning of findings. As Orlikowski and Baroudi (1991) claim, 'interpretive researchers attempt to understand phenomena through accessing the meanings participants assign to them'.

This is an interpretive research that is proper to answer the research objectives based on the defined problem. As the internal transportation of SSAB Oxelösund involves different parts and contributors to function in a proper way, so it is considered as a complex system. In this study, at first topic and problem description are defined clearly. Then formulating research objectives, literature review, and forming the theoretical framework are done in parallel. In the following, data collection, analyzing, and interpreting data are represented to reach the findings and recommendations.

2.5 Research Design

Generally, there are two different types of information or data for a research called quantitative and qualitative (Creswell, 2014). Although these two methods are like the two sides of a coin, there is an opportunity to mix these two methods in a study. Mixed method approach includes a combination of quantitative and qualitative data; this method makes the problem description more understandable. Quantitative data includes statistical trends and measurable data in the form of numbers, and qualitative data includes interviews, observations, and documentation (Creswell, 2014).

Quantitative research is known as a structural way for data collection and data analysis. This type of research uses different tools such as mathematical, computational, and statistical tools in order to reach final results. Quantitative research transforms numerical data into understandable statistics and it is used to quantify different variables, opinions, and behaviors from a large data population. Purpose of a quantitative research is to find and understand the connection between an independent variable and dependent one in a limited population. This type of research is almost used in scientific researches (Creswell, 2014).

Qualitative research is a type of explorative research based on gathering verbal and observational data. Qualitative data collection has a wide scope and is reached in regards to interviews, observations, and literature review (Saunders et al., 2009). With respect to the research objectives, qualitative research is almost done before quantitative research. Not only this type of research leads to having a better understanding of the defined problem, but also it gives new ideas related to quantitative research. In addition, it helps to be clearer about thoughts and opinions, and go deeper in the problem area (Creswell, 2014).

With the defined problem, a combination of methods is necessary. This study in some aspects is quantitative, as it is going to gather and analyze the data from the internal transportation system (TRS) in the form of numbers and data series. Minitab and Excel programs are the main tools for analyzing the gathered quantitative data. On the other hand, this project in some other aspects is an interpretive study; so, in these aspects it follows non-quantitative data, which
needs discussions and clear explanations in depth. These qualitative data will be gathered from interviews and searching the related documents besides conducting observations.

2.6 Data Gathering Methods

In this thesis, both primary and secondary data are used. Primary data is gathered from interviews and observations, and secondary data is gathered from literature review and internal documents in order to complete the data gathering. In addition, there is another classification for data gathering divided as quantitative or qualitative. This study uses a combination of both quantitative and qualitative data, so collected data are in different types which are going to be explained more.

2.6.1 Primary Data

Conducting interviews as a primary source of data collection with responsible persons is the first method of data gathering for this study. Conducting interviews cause a lot of clarifications and explanations for the researchers. In terms of time and resources, conducting interviews in comparison to other methods of data gathering are economical (Ramsay and Silverman, 2007). Furthermore, on-site observations are part of primary data.

2.6.2 Secondary Data

Regards to the secondary data, Desk Research approach is used. In general, desk research refers to secondary data or the data that can be gathered without experimentation (Hague et al., 2004). Desk research uses the available information from the company data, websites, published sources, and previous researches (Yadin, 2002).

2.6.3 Interviews

Kahn and Cannell (1957) mentioned ‘Interview is a purposeful discussion between two or more people’. Interviews are conducted in order to collect reliable and valid data related to research objectives. Additionally, in the case that research objectives are not formulated, conducting interviews will help to reach them. As Doody and Noonan (2013) claim, there are three types of interviews; structured, semi-structured, and unstructured in which semi-structured and unstructured are almost related to qualitative data and structured represent quantitative one (Saunders et al., 2009).

Structured interviews use questionnaires based on exact questions to all interviewees (Doody and Noonan, 2013). Interviewer reads the questions from questionnaire one by one and records the interviewee’s responses. Interviewer should ask the questions completely the same as what is written on the questionnaire and in the same tone of voice to all interviewees. To gather quantifiable data, structured interviews are used, so this type of interview is called quantitative research interviews (Saunders et al., 2009). As Creswell (2014) argues, this type of interview is the most time efficient way to gather data and it describes boundaries for interviewees’ subjectivity, also it makes the analysis of results easier.
Semi-structured interview is a non-standardized type of interview known as qualitative research interview (King, 2004). In semi-structured interviews the interviewer has some questions related to the defined problem and these questions will vary from one interview to another. In the other words, in some interviews the interviewer must delete some questions and ask other related questions. In addition, the order of asking questions will be different from one interview to another depending on the conversations and outcomes. On the other hand, in order to explore research objectives some extra questions may be asked. The interview must be recorded, and some notes can be taken during the interview (Saunders et al., 2009). This type of interview is a combination of structured and unstructured interviews while it is flexible. The analysis part of semi-structured interview is more time consuming as outcomes can be different (Doody and Noonan, 2013).

Unstructured interviews work in the opposite way of structured interviews and they almost start with a wide question (Doody and Noonan, 2013). This type of interview is informal and is used to generally study an area of interest in depth. Therefore, this type of interview is known as in-depth interview. This is the case that although there is not a list of questions, there is a clear vision and logical idea about what is going to explore. This type of interview sometimes is known as non-directive interview since interviewer had the opportunity to have a free discussion related to the topic. Gathered data from this type of interview is more in detail, however it is difficult to make correlation between outcomes (Creswell, 2014). As Doody and Noonan (2013) claim, this type of interview is also time consuming compared with structured interviews.

This study includes both unstructured and semi-structured interviews. Unstructured interviews are conducted in order to have a clear understanding of the company, process, products, and how the internal transportation works at SSAB. Unstructured interviews help to narrow down the defined problem and give a better understanding of the current state and the factors that influence the internal transportation. In addition, semi-structured interviews are conducted in this study. Semi-structured interviews which are mostly used in qualitative research are open kind of interviews without having rigid and strict questions which lead to new ideas during the interview as a result of the discussions (Edwards, 2013). Interviews are done with responsible persons in each department and treatment station within different roles so that interviewees reflect their own opinions precisely and they talked about both interesting and important aspects from their side of view.

2.6.4 Observation

If the research objectives are in relation with what personnel does, observation is the clearest way to discover their performance while they are busy doing it. Observations include on-site observation, recording, defining, and analyzing the performance and behavior of personnel (Saunders et al., 2009). There are two types of observations; participant and structured observations. Participant observation is a qualitative form of observation and discovers the way that personnel are linked to their activities. In contrast, structured observation is a quantitative form of observation and it is connected to the frequency of those activities (Saunders et al., 2009). Creswell (2014) claims, a researcher can perform an observation either as a participant or as an observer. In both cases, the researcher almost making notes or record in the case
needed. The participant observer is involved in activities and processes, which cause the observer to be able to see what is exactly happening. Conducting an observation without participating provides information about what activities and how often they are happening instead of investigating why they are happening (Saunders et al., 2009).

During the study at SSAB, an observation is done from production lines to get an overall idea about how the production process is in this company. In addition, another initial observation is done around the SSAB site in order to become familiar with the layout and location of treatment stations and storage areas. Likewise, these observations lead to a better understanding of how the internal transportation system works. Furthermore, several observations are conducted from daily and weekly activities of drivers that are connected to the internal transportation. In addition, several observations are done from treatment stations to get information about how these stations are connected to the internal transportation. Meetings in groups and having discussions are classified as participant observations and these types of observations lead to a deeper information of the company's way of working (Creswell, 2014).

In order to minimize misunderstandings in the collected data, a researcher should check the provided questions for the observation; this activity also increases the reliability and validity (Saunders et al., 2009). In this study, collected data from observations was recorded, transcribed and sent to the responsible persons for confirmation.

2.6.5 Documents
The data for theoretical background and theoretical framework is collected from literature review to build the theory part. In order to describe the required theories in this study, different documents, scientific articles, and books are reviewed. In addition, it is important to be critical about reliability and validity of the collected data. Thus, scientific articles written by professionals and reviewed by several experts known as peer-reviewed articles beside books written by well-known authors are used. The literature review is done not only to reach the required background of the problem, but also to provide a theoretical framework.

In this study, the TRS system provides a data series for the year 2017 which shows the duration of waiting time for each specific cassette in each storage area. Additionally, there are several documents such as different types of delay reports that are exported from the TRS system. All documents and gathered data are verified with responsible personnel to become sure that the collected data are connected to reality.

2.7 Credibility
Credibility measures how efficient and effective are the interpretive study (Collis and Hussey, 2013). This part discusses and criticizes the used methods in order to represent credibility. Reliability and Validity are the two main tools that are used to explain the credibility.
2.7.1 Reliability
Before all else, reliability shows that how much the collected data is trustworthy, which means researcher trust in the source of collected data (Doody and Noonan, 2013). Moreover, reliability refers to reducing errors in mathematical calculations and measurements which can be improved by calculating and measuring more than once; and if it is possible tries to calculate and measure in different ways. A reliable study gives the opportunity to other researchers to have almost the same study and at the end come up with similar results (Doody and Noonan, 2013).

When the study is qualitative it is usually hard to know how the definition of reliability is going to be implemented. As Collis and Hussey (2013) argue, reliability is 'the absence of differences in the results if the research was repeated'. In order to increase the reliability of the study, all the interviews are done with the responsible persons who have significant experience in their positions. Moreover, all the gathered documents are explained by an involved person in documenting it. Reliability of this project can be argued if another person does the same project; the same result would be gained.

With respect to the reliability of the theoretical background and theoretical framework the gathered data is from scientific articles and books having a well-known author and as mentioned before all the articles are peer-reviewed. Additionally, theoretical background and theoretical framework are written based on different sources and used the comparison to strengthen the theory part (Saunders et al., 2009).

Regarding the reliability of the gathered data from observations and interviews, it is worth mentioning that all the gathered data has been checked with responsible personnel in order to minimize misunderstandings. Collected numerical data series has been checked with expert personnel to make sure the data is accurate.

2.7.2 Validity
Collis and Hussey (2013) explain validity as 'the extent to which the research findings accurately reflect the phenomena under study'. To be more precise, the validity in an interpretive study is usually high due to the fact that gathered data is directly in connection with involved individuals in the study. Some of the causes which lead to poor validity can be mentioned as inaccurate and wrong measurements, inappropriate samples, and faults which may occur in the procedure of doing the investigation.

The validity of this study can be considered as high. The reason for supporting high validity is conducting a combination of interviews and observations regards to all problem areas. In this study, semi-structured interviews are conducted with experienced personnel in order to understand the current state and discuss probable wastes more in-depth. It is debatable that semi-structured interviews are not highly valid because of the lack of fixed questions; however, observations are conducted in the same problem areas as interviews are done to increase the validity. Regards to the validity of quantitative data it should be mentioned that the data set is collected in the large population and is controlled with the expert personnel not to have faults in it.
2.8 Analysis Method

Analyzing logistics part of a company requires having a deep investigation in value adding activities, customers’ value, and total costs. Traditionally, logistics performance is measured based on companies’ budget and cost goals in different functions instead of cross-functional process (Harrison and Van Hoek, 2008). Kasilingam (1998) claims, logistics systems analysis are in four phases. The first phase is defining the problem and it includes definition of problem, focus areas, and purpose. The second phase is data gathering and it includes determining data sources, methodologies, identifying the accuracy of collected data etc. The third phase is related to the analyzing of the problem, this analyzing should be done with the help of gathered and estimated data. The final phase is user testing and implementing the logistics system (Kasilingam, 1998). Figure (8) presents this process.

![Figure 8: Analysis Method](image)

Analyzing part will be done in order to categorize the collected data to reach clear understandings. The analyzing method is completely related to research design, if the research is qualitative or quantitative (Saunders et al., 2009). Raw format of the quantitative data is not understandable for most people, so these data should be handled and analyzed. To make these data useful, the data should be processed and transformed into information. Graphs, charts, and statistics are the most common quantitative analysis techniques that help the researchers to present, describe, and investigate relationships in collected data (Saunders et al., 2009). Quantitative analysis techniques vary from simple graphs and tables showing the frequency of the data, to statistics showing comparison and statistical relationships with complex statistical modeling.
Qualitative data are the non-numeric data which varies from a list of short discussions to more in-depth transcripts of interviews or the whole literature review. These data should be analyzed in order to make them more understandable. Since qualitative research includes interviews, observations, and documents in the form of text, so qualitative analysis should have more concentration on the big picture of the collected data. Having a general overview of the collected data leads to a deeper understanding of the study area. (Saunders et al., 2009)

Gap analysis which stems from Good, Average and Poor is one of the famous tools in finding the differences between current state and potential state. Through gap analysis it can be determined if the requirements are met or not, and if they are not met, what should be done to meet them successfully. Here occurred gaps represent the space between where company is now (current state) and where it wants to be (potential state). The goal of gap analysis is to identify the most noticeable gaps of gather data, then fill the gaps with the help of existing resources (Gillbert, 2008).

To conduct a gap analysis, there should be a clear vision of the defined problem besides having a unique purpose based on this defined problem. The next step is to analyze the current state through comparing the gathered data with presented theories in the theoretical framework. Then a visual table can present the occurred gaps between current state and potential state. Finally, a comprehensive conclusion can be made based on the gaps and several recommendations will be given to fill these gaps.

According to Figure (8), first two phases are done and explained in advanced. The analysis part of research objective 1 and 2 will be done by comparing the findings with presented theories in the theoretical framework to find gaps which should be considered as wastes. Research objective 3 will be analyzed with the help of Minitab and Excel to reach the waiting time of cassettes in every storage area. Research objective 4 is highly connected to the theoretical framework and uses presented theories in order to provide recommendations for eliminating identified wastes and gaps. It should be mentioned that the way for reaching each research objective is explained more in detail in 2.1 Method Approach.

The quality of the analysis can be increased by dividing collected data into three different phases: data reduction, data presentation, and draw a conclusion (Miles and Huberman, 1994). As Miles and Huberman (1994) argue, data reduction means gathered data has to be simplified, shortened, and composed. In the study, all the conducted interviews are written down, so the information will not be lost. All the interviews are transcribed, and a reduction is made before sending them to the responsible interviewees for confirmation. Data reduction starts with selecting the related questions before interviews. After interviews, the collected data are limited to the purpose. In the following, several maps, pictures, and charts besides having various analytical activities will be used in order to represent the result of the collected data. Statistical analysis will be done with Excel and Minitab. This phase creates a general picture for the readers. Finally, a conclusion will be made based on the analysis part and recommendations will be given in order to answer the research objective 4. Figure (9) presents a perspective of the analysis method.
Figure 9: Analysis Method

Data Gathering

Research Objectives

Primary Data
- Interview
- Observation

Secondary Data
- Literature review
- Internal documents

Outcome

Lean and Logistics theories

Recommendations
3. Theoretical Framework

Regarding to the defined topic of the thesis which is improvements in the internal transportation of SSAB, at first general related literatures in logistics, transportation and Lean was reviewed. Reviewing these literatures and at the same time working on the defined problem make boundaries for theoretical framework. Literature reviews helped authors to find the correct type of data that can be supported and analyzed based on theories. Theories that will be used for both analysis and recommendation parts are presented in this chapter.

3.1 Logistics and Transportation

Logistics is a set of activities ensuring that right products are available to the right customers in the right quantity at the right time, as shown in table (1). At different stages of a products’ logistics life, various values are added to it. Manufacturing by adding form value transforms the raw material into components or finished products. Place value is created with transportation, here transportation means moving the product to/from where it is required. Time value is created with inventory control for making sure that the needed products are available on time. Finally, sales and marketing add possession to the product (Kasilingam, 1998).

<table>
<thead>
<tr>
<th>Right Place</th>
<th>Right Place</th>
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<tbody>
<tr>
<td>Wrong Time</td>
<td>Right Time</td>
</tr>
<tr>
<td>Christmas trees in USA</td>
<td>Christmas trees in USA</td>
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<tr>
<td>After Christmas</td>
<td>Nov. 25th to Dec. 24th</td>
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<td>Wrong Time</td>
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<tr>
<td>Christmas trees in Iraq</td>
<td>Christmas trees in Iraq</td>
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<tr>
<td>After Christmas</td>
<td>Nov. 25th to Dec. 24th</td>
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</table>

Table 1: Representation of Time and Place Values. (Wilson, 1996)

Logistics works as a connection between production and consumption; precisely it creates a bridge among production, storages, and suppliers which are separated by time and distance. The Council of Logistics Management gives a definition for logistics as process planning, inventory in-process, storage of raw material, finished goods, and complementary information from the start point to the point of consumption for the customers (Kasilingam, 1998).
Logistics represents the process of material flow, sorting, and moving material and information economically and efficiently. The main functions of logistics in this study include the location of production lines and treatment stations, select the type of transportation, and inventory controls. Some of these functions are performed by in-house personnel, while other parts can be done by out-sourcing. Regardless of who may carry out the functions, a system should be designed in order to reach the objectives (Ballou, 1992).

While operational and planning decisions are made in one part, they have effects on the other parts; logistics decisions are mostly made based on total cost approach. For having a clear vision, decisions for inventory and transportation are highly closed to each other. If a faster transportation model is in use, a lower inventory level may be reached. On the other hand, a higher level of inventory may be maintained if a slower transportation is used. Therefore, in order to investigate the optimal inventory level, a trade-off is needed. Figure (10) represents the relationship between transportation costs and inventory costs (Kasilingam, 1998).

![Figure 10: Inventory Cost versus Transportation Cost](image)

### 3.1.1 The Role of Transportation in Logistics

With respect to global business trends, transportation plays a key role as being a support for whole logistics. If transportation is enough successful and efficient then it leads to an efficient and successful logistics operations. Logistics management as one of the vital elements is defined as 'that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, service and related
information between the point of origin and the point of consumption in order to meet customers' requirements' (CSCMP, 2012).

Transportation is defined as a connection among production, storage, and consumption which adds place value. Optimal cost, on-time delivery, reduced work-in-process (WIP) time, minimum delay time, and availability of the transportation service are the requirements for a transportation system in order to support logistics. Essential parts of a transportation system are people, facilities, and equipment. Human resources include operative team, maintenance, administrative, support team, loading and unloading team. Tracks, terminals, road line and water ways, tunnels and terminals are facilities. Equipment contains cars, aircrafts, trailers, and containers. Transportation includes both inbound and outbound movements. Inbound movements are those sent from the raw material parts to warehouses or storages and outbound movements are finished products or components sent to customers (Kasilingam, 1998).

Moving units, goods, or finished products among different points from origin point to the consumption point contains different types of activities such as transportation, material handling, warehousing, storage, and serval other processes. All these activities should be optimized separately and then integrated in the logistics. Therefore, performance of these functions is completely dependent on each other; decision toward one function highly affects the other functions (Rushton and Saw, 1992). Transportation needs to be flexible, so it can response and support logistics. It is worth mentioning that, 75% of the logistics cost is related to transportation, therefore the more effective and efficient the transportation is, the more value is adding in whole supply chain (Rushton and Saw, 1992).

3.2 Facility and Intrafacility Planning

Facility planning refers to main parts of logistics which are facility location and facility layout. Facility location considers the best locations for setting up the facilities. At the macro level, facilities include plants, warehouses, terminals, stores, and customer sites. Facilities at micro level include smaller parts of a large facility such as painting station, welding station, etc. Facility layout refers to the optimal layout of smaller facilities in a large facility, so material handling and related costs will be minimized. The location and layout of the facilities play a key role in minimizing the total cost of logistics (Kasilingam, 1998).

Facility layout and facility location are essential decisions which have direct effects on the performance of an organization for a long period. The suitable and right layout and location for an organization does not guaranty success; however, the wrong layout and location lead to a failure. In the case that an organization choose a wrong layout and location and has its own facilities after a significant investment it cannot easily change the layout and location and move to a better place. Furthermore, working in the wrong location leads to poor performance and other difficulties. The only solution for not facing these problems certainly is to have the right location in the first place (Waters, 2003).
The area where facilities are located has a considerable impact on both construction and land costs, labor costs, and transportation costs to or from other facilities. Moreover, the layout of a facility has a significant effect on interafacility logistics costs which material handling costs can be mentioned as an example. Most of the previous historical investigation on facilities location was based on transportation costs (Waters, 2003).

The main purpose of identifying the best location for the facilities is to minimize the total cost of production. Additionally, transportation costs, operations costs, and costs of locating and relocating are considered as the key elements. Transportation costs are mostly based on distance and most models use linear transportation costs. Operation costs include labor, equipment, and additional overheads. Cost of locating includes the costs of land and building. Cost of relocating includes cost of closing the facility at the previous location, and cost of transferring equipment to the new location (Kasilingam, 1998).

Intrafacility logistics is an important area connected to the overall field of logistics. Intrafacility logistics is mainly related to the material handling in a large facility such as a warehouse or a plant. The aim of material handling is to move work-in-process (WIP), raw materials, tools, and finished products from one destination to another in order to clear the way for production. (Kasilingam, 1998).

Intrafacility logistics costs are affected by material handling, layout, stock locations, and storages. Material handling is one of the important aspects of manufacturing operation and it should be performed in an accurate, safe, and efficient manner. The time and cost in which products or components in a facility are moved or stored during the manufacturing process are considerable compared with total manufacturing cost and time (Kasilingam, 1998).

### 3.3 Lead-Time
Towards reaching the goal of lowering costs and having better customer satisfaction, time is used as an essential tool. To remain in today’s competitive market, considering time becomes more important. Time is appropriate measurement since it is understandable for both people within an organization and customers; also it is easy to measure (Rushton et al., 2014). Without having a time efficient system, it is impossible to have an efficient logistics system (Christopher, 2005).

Rushton et al. (2014) discuss three types of performance indicators refer to time; inventory turnover rate, customer order lead-time, and lead-time. Inventory turnover rate shows that in a period of one year how many times inventory is restored. Customer order lead-time is the period of time from when an order is made until it is delivered to customers. Order cycle time is another name to the customer order lead-time which is given by Christopher (2005). Lambert and Stock (1993) argue that it is important to investigate each single parts of the order cycle time to find the problems and make the order cycle time as short as possible. Figure (11) shows the concept of order cycle time.
Lead-time can be defined from different points of view. From the customer point of view, it is the customer lead-time. From the supplier point of view, it is the time from order placement into cash (Christopher, 2005). Besides Rushton et al. (2014) emphasize that lead-time is the required time for a product as a good or a service to go through all parts of a process in the complete flow. Short lead-time is desirable since it decreases the capital tied up and increases the flexibility (Christopher, 2005).

3.4 Lean

Lean can be defined as a concept also as a commitment. Considering Lean as a concept means to investigate and implement Lean in different levels. Lean as a commitment includes a process of improvements that has important effects within an organization and its competitiveness. Lean is a powerful approach that can resolve serious problems within an organization, also it can change the typical way of working that is run in a company (Atkinson, 2004). A set of tools, methodologies, techniques, and different processes are involved in the concept of Lean, and the logic behind all of them provides effective resource allocation. Lean is a major strategic plan, concentrates either on top of a business such as cost efficiencies or involves smaller parts lowering down in an organization (Atkinson, 2004). Despite whatever Lean means, it can be a long-term solution for most of the companies in different areas. Although Lean can reduce unnecessary costs in an organization, in the case that this is the main purpose of the organization, Lean will not work as a preventive methodology.

Toyota Production System (TPS) is the main root of the concept of Lean. Generally, Lean refers to eliminating wastes in all processes and increasing speed and flow. Additionally, there is a simple definition of Lean that is doing more with less (Bicheno and Holweg, 2009). This definition considered being in line with a definition of productivity which is doing good with having fewer materials, energy, pollution, and resources in general term (Bicheno and Holweg, 2009).
TPS and Lean Production are the names that influenced most of the early users of these theories to focus on production parts of their enterprises. In the following years, many companies have followed the original practices of Toyota and applied them to their supply chains. Companies are using TPS and Lean Production to connect several warehouses, manufacturing processes, logistical operations, and distribution centers. Recently, progressive companies in Lean use Lean thinking across their whole business with having the goal of eliminating wastes in business processes. It is claimed that reaching this goal needs a redefinition of the main purpose of the process and consider customer values in the business enterprise. Moreover, there are companies implementing Lean in their engineering performance in order to create better plants. Features of a better plant can be considered as a plant with a smooth flow, fewer wastes in processes, and short lead-times (King, 2009).

There are different perspectives regarding Lean (Chiarini, 2012):

- Lean is about cost reduction
- Lean is a concept for business improvement
- Lean is about waste reduction with continuous improvements
- Lean is a set of tools
- Lean is reducing setup times
- Lean is about cleaning
- Etc.

### 3.5 Why Lean?

Nowadays in the global arena, customers’ demands are increasing and competitions for customers’ satisfaction get stronger. As Chiarini (2012) claims, this situation makes customer demand a highly important issue for companies. Based on the importance of customer demand and its satisfaction, suppliers have to find a condition that is profitable for both customers and suppliers. In this condition, the performance of Lean should be considered since Lean is a powerful concept that positively affects companies’ competitiveness in different areas such as delivery time, delivery dependency, flexibility, quality, and cost. (Goldsby and Martichenko, 2005).

### 3.6 Lean Transportation

Literature review about Lean transportation has very few results, as this area of interest has not that much investigated to find some Lean in transportation. Transportation is one of the important parts of logistics and because of that in most cases Lean logistics is used to eliminate transportation waste.

Trent (2008) defines, 'Lean transportation encompasses all the characteristics, decisions and tools related to the activity of moving goods between different points in a supply chain, where the carrier/s -internal or external- and the shipper act partially or totally in a Lean environment.
That is an environment where the main interests of carriers as well as shippers are conform with the Lean principles of: customer-oriented value definition, continuous improvements, waste elimination and flow of pulled processes.

Lean transportation plays a crucial role to generally support Lean objectives. This support to reach Lean objectives refers to "smaller, more frequent and predictable deliveries" to stated destinations. Although mass production reduces transportation cost and is used to control transportation, it is in contrast with pull system. While implementing Lean in transportation it is vital not to concentrate on reducing costs, since transportation cost will increase because of having raise in the number of deliveries. This increase in transportation cost is acceptable when the inventory related costs are significantly decreased. (Trent, 2008)

Although there is a fine line between Lean production and Lean transportation, it is crucial to study the connection between Lean production and Lean transportation. As Womack et al. (1990) claim, Lean is applicable to any industry which means that Lean can be appropriate and relevant to many industries. When it is time to consider transportation as an important logistics function, a robust connection may link Lean from one side and transportation on the other side.

With respect to Toyota House (Lean House) and its main parts, there is a connection between just-in-time (JIT) and transportation. To summaries and have an overview of the TPS system, the Lean house known as Toyota house is presented in figure (12). The linkage between transportation and just-in-time (JIT) originates from two functions. First is the undeniable role of transportation in logistics, as it is the only way of transferring products between two destinations. Second, JIT system requires time, flow, and delivery to be successful, so JIT system is highly dependent on the transportation which provides both flow and delivery just in time. This indicates that transportation managers might have to align the second function to the JIT logic, instead of optimizing them individually. With respect to this alignment, it is worth mentioning that continuous flow of products, and a balance between customer demand and transportation capacity lead to reach this alignment.

On the other hand, the importance of transportation which is supporting JIT system is proven through the fact that selection of carriers is completely influenced by applying JIT (Regan and Garrido, 2000). Comparing to the JIT system in which transportation is in the center of concentration, in traditional system transportation is separated from both purchasing and inventory processes. Therefore, to have a more reliable, proper, dependable, and efficient transportation for JIT system, transportation should be more under control (Perry, 1988).
3.6.1 Quality in Lean Transportation

One of the major objectives of Lean is quality assurance; quality assurance here refers to having right units and products in the flow of processes. For instance; delivery time is a quality dimension for transportation. To be more precise, delivery time shows that implementation of both JIT and Jidoka are successful or not (Monden, 2011). As a result, unmanaged transportation and poor transportation system that are corresponded from personnel, responsiveness, reliability, etc. can easily influence the quality which is built from Lean implementation.

Transportation is responsible to support quality assurance and waste elimination at the same time, as Lean transportation is a link between inside and outside of the company. As Womack et al. (1990) believe Lean must be extended to the whole logistics within a company to add value from transforming raw materials point to delivering finished products to the customers in all processes. This added value makes sure that all processes have the same level of quality in manufacturing, loading, unloading, and transportation.
3.6.2 Waste Elimination in Lean Transportation
Transportation is grouped among one of the production's wastes and it should be eliminated, as the Lean Production School marked it as one of the most important type of production's waste out of seven others. Transportation waste is mainly related to internal transportation between different processes rather than broader transpiration. Likewise, it could not be stated that there is no waste in broader transportation just because they link suppliers to customers, moreover it is needed to investigate and analysis to detect waste in transportation.

The most important part here is to concentrate on waste elimination in transportation rather than eliminating the transportation cost. In order to identify waste in transportation, transportation processes should be classified in three groups: value adding, non-value adding, and non-value adding but necessary activities. These classifications and detecting wastes will lead to eliminating wastes which is more efficient than reducing transportation cost (Hines and Rich, 1997).

Transportation has direct effects on product delivery, service quality, lead-time, and it is also one of the biggest costs in logistics, so it is important to recognize wastes in transportation and try to eliminate them (Levinson and Rerick, 2002). Lean transportation is about non-stop working with carriers to have continuous improvements in transportation with both eliminating waste and reducing cost as Toyota always does.

3.7 Lean Tools
TPS model as one of the most useful systems has been used in different studies (Stenzel, 2007). Since eliminating or reducing waste is the main concern of TPS, it is required to have a logical system refers to Lean logistics (Liker, 2004). The main concern of Lean is to eliminate waste with time shortening (Ohno, 1978). “A system is designed to provide the tools for people to continually improve their work” (Liker, 2004). Lean includes a various collection of tools and understanding what these tools are and how they work is the best way to get use of them.

FujioCho, Chair of the Board, Toyota mentioned, ‘Many good companies try to practice and use various TPS tools. But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner in a concrete way on the shop floor’. Below, Lean tools in relation with the defined problem are going to be explained.

3.7.1 Gemba
Gemba is a Japanese term that means where the action takes place. From business perspective Gemba can be defined as areas where value adding activities are done in order to satisfy customers (Imai, 2007). In service industries, Gemba can be defined as the area that customer is in contact with offered service (Imai, 2007). There are three main segments that are involved in manufacturing industries: development, production, and sales. Thus, it can be mentioned that Gemba is the position of these three main segments. In mentioned positions, Gemba encourage managers and engineers to go to shop floor and see the problem and its impacts from closer view.
3.7.2 5S

5S is related to cleanliness and ordered workplace and it is linked to maintenance and having a certain order besides implementation. Logic behind this tool is to create a workplace which is more understandable and clearer for all personnel, so all can effectively work in this place. 5S stems from five Japanese words and below are the words with their English equivalent (Al-Aomar, 2011 and Chapman, 2005):

- Seiri (Sort)
- Seiton (Set)
- Seiso (Shine)
- Seiketsu (Standardize)
- Shituske (Sustain)

Sort
- Eliminate whatever is not required and just keep those that are necessary for the process
- Classify and group materials and tools based on the frequency of use
- Ask personnel to tag items which are not required, so all are aware of what is needed
- Have a holding area for those tools and materials which are hard to be grouped and classified

Set
- Everything should be in its own place
- Every place should be named and labeled based on the related materials and tools
- Set materials and tools based on frequency of use to have efficient work flow
- Keep materials and tools close to where they are needed

Shine
- Workplace should be organized and tidy
- Clean the workplace daily
- Root cause analyze dirtiness and correct it
- Clean the tools and materials which are used

Standardize
- Make normal and abnormal situations noticeable for everyone
- Keep workplace consistent
- Educate personnel how to maintain standards
- Make abnormal situations visible to the management
- Personnel easily move to different areas by having standards
Sustain

- Continuously improve the standards
- Root cause analyze the occurred problems
- Have regular audits
- Make the rules as a habit and stick to them
- Maintain the given responsibilities
- Innovate good habits

3.7.3 Jidoka

According to Ohno (1978), Jidoka is an automated system that gives machines and personnel the ability to stop the process as soon as they observe a problem or defect. Sometimes Jidoka and automation is used interchangeably, here automation refers to have automation with human intelligence. Jidoka increases the quality since it separates machines and men in order to reach more efficient work. Jidoka is known as one of the two important pillars of TPS beside just-in-time (JIT). Jidoka gives a machine the ability to determine normal parts from abnormal and defected parts without being controlled by any operators.

Automating the human activities (Jidoka) almost refers to defects and waiting waste out of the seven wastes. Using human intelligence as an automation system not only includes stopping the process when defects occur in the process, but also in this case personnel are more involved in mistake proofing when the process is stopped. It is not an effective way of working if personnel are idle and observing machines only to report an abnormality, so Jidoka will eliminate this waiting time. In addition, personnel can run more than one machine, and this leads to reduce the number of personnel. On the other hand, "force awareness" is related to the time when personnel observe the occurred problem and try to solve it immediately by teamwork, so it will not happen again later on (Ohno, 1978).

3.7.4 Just In Time

Just-in-time (JIT) is a concept found by Taiichi Ohno of Toyota. JIT originates after Second World War when sources for raw materials became rare and limited, so producing products which customers do not need them precisely at that time was not a useful idea. JIT, as it can be assumed from its name, is a management philosophy refers to having the products without delay at warehouses (Chiarini, 2012).

Just-in-time (JIT) stems from the concept of only producing what is needed, when it is needed, and how many quantities are needed. The principles of JIT are closely connected with Lean manufacturing, as JIT is a concept about managing efforts to reduce wastes and eliminate their sources through producing the right amount, at the right time and in the right place (Nahmias, 1997).

There are two typical classifications for material flow system: push system also known as traditional one, and pull system known as just-in-time. Both pull and push systems are driven by customer demand. The way that each system satisfies the customer demand is the main difference between these two systems. Donald Waters (2003) argues, although organizing
activities at the exact needed time is important for implementing just-in-time, definition of how to achieve JIT plays a key role in its success. He claims best definition for how JIT works is "pulling material through the process". Traditionally, every operation uses a timetable for finishing the work in a specified time. Then completed items will be pushed toward next operation and this will make a stock of WIPs. The problem with this system is ignorance of the actual activities of the next operation; probably it is working on a different task or waiting for other parts to be delivered. In the ideal condition, the second operation has to complete its current tasks before start working on the new parts which are newly arrived. So, this will result in delays and increases in the stock of WIPs. As it mentioned before (JIT) uses pull system to work across the processes. When an operation completes its task in a station, it sends a message to the previous operation to inform them that it is ready to work on a new unit. In this way, materials will be sent exactly when the proceeding operation receives the message. It should be mentioned that the lead-time that is generated inevitably in this way of working will be eliminated in the real just-in-time system, since message should be sent before the operation actually needs new units. Moreover, the batches of material will be sent as small as possible to keep the stock optimized. It is fairer to mention that JIT minimizes inventory instead of eliminating them (Waters, 2003).

Monden (1998) claims JIT has a direct effect on the internal processes of the company, which is related to the adaption of changes in demand by producing the right product in the right quantity at the right time. Furthermore, this critical tool controls purchasing and distribution as the external activities of a company.

In JIT system personnel know what is going to be produced next, just through having a look to what should be taken in the next process. This JIT system prevents wasting time and resource since personnel know what to do in the next process. In addition, this system provides information with regards to work pace, so personnel see if they are working either too fast or too early. When personnel are aware of their work pace, they can adjust accordingly and avoid wasting time (Shingo and Dillon, 1989).

Nahmias (1997) mentioned the benefits of JIT as below:

- Having a reduction of inventory costs by eliminating/reducing not required work-in-processes
- Having high-quality products and quality related issues are detected early because products are produced based on need and order
- Having a reduction in the waste of storage space, because the inventory level is reduced
- Preventing overproduction can reveal invisible problems

3.7.5 Kaizen

Kaizen is a Japanese phrase that became well-known in 1986 with Masaali Imai’s book “Kaizen: The Key to Japan's Competitive Success”. Kaizen is developed based on an attitude that believes employees should be responsible for having continual improvements in their tasks. General effects of following this approach can be cost-effectiveness and practical improvements. Accordingly, Kaizen is a tool for enterprise and process management that
identifies how important are employees’ interests and creativity in continuous improvement. Toyota production system is a good example for Kaizen when new suggestions for improvements are rewarded and encouraged (Monden, 1998).

3.7.6 Poka-Yoke
A quality improvement tool known as Poka-Yoke or mistake proofing developed in the early 1960s by Shigeo Shingo. This tool minimizes and reduces the negative effects through preventing mistakes from happening. Shingo and Dillon (1989) claim if there is a focus on errors to identify and eliminate them, as a result, defects will be avoidable.

Poka-Yoke uses an automatic system or device in order to recognize errors and problems before defects happen according to Shimbun (1989). Sometimes problems occur just because of misunderstandings or lack of knowledge about the procedure of the production processes. Poka-Yoke is developed from Jidoka out of TPS; it is the most simple and cheap way to detect the defects, so they will not flow to the next step of the production processes.

Although inspection is known as the least effective method for controlling the quality, Poka-Yoke is well-known to prevent defects from happening. Inspection is done by personnel and it relies on personnel's opinion during long working hours and almost repetitive work. However, Poka-Yoke uses an automatic way of control for detecting the defects. Applying Poka-Yoke as a Lean tool leads to (Shingo and Dillon, 1989):

- Not producing a defect
- Not having a defect within a process
- Not allowing a defect to flow to the next production process

Poka-Yoke reaches these three objectives through:

- Warning: when a mistake or an error has happened, an alarm will light up or sound
- Controlling: personnel do physical activities to prevent a defect from happening

3.7.7 Root Cause Analysis
Root Cause Analysis (RCA) investigates and classifies the root causes of occurred events in every process. There are considerable debates regarding the definition of root cause analysis, however Rooney and Heuvel (2004) used the following definitions as the main ones: ‘Root causes are specific underlying causes-Root causes are those that can reasonably be identified-Root causes are those management has control to fix it-Root causes are those for which effective recommendations for preventing recurrences can be generated’.

Root causes are underlying causes: the objective is to determine the specific hidden causes. The more deeply a researcher investigates about the reason why an event happened, the easier he/she will suggest preventive recommendations.

Root causes are those that can reasonably be identified: root cause analysis is not only cost beneficial, but also helps the researcher to gain more out of the time when he/she invests.
Root causes are those for which effective recommendations for preventing reoccurrences can be generated: this definition points that root causes that are recognized from investigations should be addressed directly by recommendations.

### 3.7.8 Value Stream Mapping

A value stream includes all activities in the form of both value-added and non-value added which are necessary to transform raw materials into needed products and deliver them to the final customers (Rother and Shook, 1999). These activities involved both information and material flow during the all processes. In the other words, value stream mapping (VSM) is one of the visual forms of Lean tools representing the flow of both information and material. As Rother and Shook (1999) argue, VSM is to identify different types of wastes and take action to eliminate them. With respect to mapping value stream, this tool is working on the big picture of a whole process and it does not consider individual parts of a process. Moreover, it improves the whole process instead of optimizing one piece of the process. Value stream mapping provides a common language which is understandable for the production processes and as a result more useful decisions can be made to have improvements. It involves all responsible personnel in the way that their process works from VSM perspective, so they can identify the wastes more clearly (McDonald et al., 2002).

To identify wastes within a process, it is useful to get help of value stream mapping (VSM). In VSM different activities and responsibilities are done to create value for customers. In addition, a VSM starts with a customer order either for a product or a service and ends with delivering the order to the customer and creates value (Rother and Shook, 1999). In VSM it is possible to represent the flow of both materials and information either as a product or a service in a process. A VSM clarify questions such as What does the schematic of the process look like? – How is value created in a process? – Which steps are value adding and which ones are not in a process? – Which areas in a process need more improvements? And waiting time, uptime and quality rate are three important terms of VSM. Waiting time is when either machines or people are idle both within the stations and between the stations. Uptime is the time when the process is available for manufacturing or producing, and the opposite of it, is downtime. Quality rate involves the ratio of defective products.

VSM makes it easy to find wastes, every organization has wastes and eliminating of these wastes is an excellent opportunity. The focus of VSM is on reducing or eliminating non-value adding activities. Non-value adding activities are needed and necessary activities based on the current state of the process and cannot be eliminated. On the other hand, there are several activities that are not needed but still occur, these activities use resources and do not create value (McDonald et al., 2002). Value adding activities include activities that transform or change materials and information to a finished product (McDonald et al., 2002). In addition, value adding activities are those that customers are willing to pay for them.

In order to define the future state map, it is vital to develop the current state map. Current state map in the form of VSM represents the inventories, production lead time, and value-added time. As before mentioned, the aim of Lean manufacturing is to increase customers satisfaction level through meeting their demands properly. Regarding VSM, inventory and lead-time are
two equivalent factors and trying to decrease them leads to reach ideal current state map. Basically, more inventory causes more waiting times for items to be processed (Chiarini, 2012).

3.7.9 Total Productive Maintenance
Machine breakdown can be mentioned as one of the important problems completely refers to the personnel on the shop floor (Abdullah, 2003). The importance of this problem is because of the fact that if one machine breaks down the all production line should stop. The most useful tool that plays a key role in unexpected machine breakdowns is total productive maintenance (TPM). Almost in every environment that Lean thinking is applied, total productive maintenance is one of the most important used tools (Abdullah, 2003).

Preventive maintenance, maintenance prevention, and corrective maintenance are the three main different elements for TPM. Preventive maintenance is related to scheduled and planned maintenance which is done regularly for all equipment instead of randomly checking the equipment without a regular plan. Maintenance personnel should do the preventive maintenance to observe any abnormalities in each equipment as they occur. This type of TPM reduces the unexpected machine breakdown and increases the throughput of machines.

Maintenance prevention refers to have the right machine at first. Right machines should be bought; otherwise, it would be hard to maintain it. To be more precise, if it is hard to lubricate a machine or it is hard to tighten the bolts then personnel will be unwilling to maintain that machine (Abdullah, 2003). As a result, a large amount of invested money will be lost besides facing a breakdown in that machine. Corrective maintenance is related to decide between buying a new machine and fixing the down one. In the case that one machine or its parts usually breaks down it is better to replace it with new one (Abdullah, 2003).

3.7.10 Standardized Work
One of the most crucial principles to eliminate waste is to standardize the activities of workers. Standardized work means that each specific activity is organized and is performed in an effective way. Furthermore, it does not matter who is running the activities, the level of desired quality should be achieved (Abdullah, 2003).

At Toyota, every personnel follow the same steps in a process for each specific activity. This contains the required time for an activity to be finished, and the order of steps in a process that should be followed for each activity (Abdullah, 2003). While personnel is doing their responsibilities based on standardized work, unnecessary WIPs will be minimized, non-value added activities will be reduced, and a balancing line will be achieved.

Standardized work eliminates variation and makes sure that results are repeatable and predictable. It represents useful practices and works efficiently without having motion wastes. ‘If a process is not standardized, and improvements were made, What was improved? Did you improve the randomness? Or did you just add one more version of how the work can be done to further increase chaos?’ (Liker and Meier, 2006). Since the important concerns of the standardized work are ergonomics and safety, visual instructions should be written from the
personnel and operators’ point of view. This perspective of them includes critical methods, tools, and quality characteristics for specific responsibility.

3.8 Waste
Regarding the high importance of waste identification in this study, here are the main definitions for waste from Lean perspective and transportation point of view.

3.8.1 Wastes from Lean Perspective
Womack and Jones (2003) mentioned activities that have not any influence on value should be considered as wastes, either temporary wastes or total. To be clearer, for understanding what waste is, it is needed to concentrate on the concept of value adding activities. Additionally, it is claimed that customers are who define the value, so asking a question such as what customers want from a process can be a starting point to identify values and eliminate wastes.

Lean is implemented in order to identify and eliminate wastes in all different processes: "from marketing to production processes, and from administrative to strategic processes" (Chiarini, 2012). Regards to traditional manufacturing, waste always is considered to be in production processes; however, there are several wastes in other processes which cause having waste in production. Sometimes, manufacturing is affected by unnecessary operations such as design, or uncontrolled inventories.

Within a Lean based organization value adding activities are those that, "at the lowest possible cost, maximize the value that customers recognize for particular outputs" (Chiarini, 2012). Chiarini (2012) mentioned, waste can be defined as "every activity that adds costs but non-value added for the customer". There are different classifications for wastes based on cultural and historical approaches. Below are three different classifications for different types of wastes (Chiarini, 2012):

- 3MU (Muda, Mura, Muri)
- 4M
- Seven types of wastes according TPS

3.8.1.1 3MU
Three terms of Muda, Mura, and Muri are almost used together to explain wasteful activities which should be eliminated in TPS system (Chiarini, 2012).

Muda:

Muda in Japanese means waste, and it refers to any type of activities in any processes which uses resources but does not create value. Muda is a general category of waste includes two types: type one includes some activities which are not possible to be eliminated, and type two includes several activities which can quickly be eliminated with the help of Kaizen. Meanwhile, Muda, Mura, and Muri are highly connected and dependent to each other, so eliminating one of them will also eliminate/reduce the others.
Mura:

This is completely related to unevenness. For instance, some unevenness may cause personnel to be in a hurry for a while and then wait. This type of waste is not steady, and it can be eliminated by focusing on the pace of work.

Muri:

Muri is a Japanese term and it means unreasonable or overburden. It is the third type of 3MU wastes and plays a key role in the Toyota Production System. Expect more workload from both machines and personnel than capacity. So, they have to work in a high pace environment with more effort than needed in a very long period rather than it is supposed to be. In other words, Muri is created when employees are under stress by demanding unnecessary or unreasonable work that exceeds their capacity. Work force should divide reasonably through the flow of material to avoid Muri.

3.8.1.2 4M

Ishikawa has invented fishbone diagram which is related to causes and effects. The 4M refers to fishbone diagram, and different types of wastes here are Material, Machine, Man, and Method Figure (13). The 4M diagram can sometimes change to 5M, while fifth M is called Mother Nature and it is related to temperature, humidity etc. (Chiarini, 2012).

Figure 13: Lean Waste and the 4M
3.8.1.3 Seven types of waste based on TPS

This is the most helpful and famous category of wastes as it is directly defined by Toyota. Actually, this helps personnel to identify probable wastes and root causes of them in the flow of processes. Seven types of wastes are (Liker and Meier, 2006):

- Defectiveness
- Motion
- Transportation
- Inventory
- Overproduction
- Overprocessing
- Waiting

Defectiveness:

While any of the ordered products or services does not meet the requirements, which is stated and specified by the customers, they are sent to a hidden factory. Hidden factory is a well-known factory in each factory where personnel work to repair products or redo activities. This type of waste is related to cost of poor quality (COPQ). COPQ in some cases is internally and in some others is externally. Comparing this cost to the exactly right cost of reworking is the same as seeing an iceberg as a small fraction which is visible above the water. COPQ includes costs for materials, rework, problem solving, transportation, setup times, and increased lead-time for customer delivery (Chiarini, 2012).

Motion:

As Chiarini (2012) mentioned, this type of waste is related to unnecessary movements of personnel that are wasting time. For instance, personnel searching for a tool in a work shop they are moving around to stand for another person's place, and so on. Some of the several causes for this type of waste are mentioned below:

- Not qualified personnel
- Personnel with poor training
- Lack of cleanliness and order
- Weak layout design
- Long working hours
- Working in isolated areas

To reduce unnecessary movements of personnel some changes are needed:

- Train personnel to increase their skills
- Use 5S to set workplaces in order
- Everyone should be aware of his movements
- Establish procedures and instructions for every process
Transportation:

In manufacturing companies, transportation is related to transferring units, goods, and products from one point of a warehouse to another, or from a step of a process to a warehouse. Usually transportation is either between two points of a warehouse, or one from warehouse and one in production process. Excessive inventories are highly connected to transportation and cause an increase in transportation activities. Some of the several causes for this type of waste are:

- Personnel with limited skills
- Weak layout design
- Finding that transportation is an unavoidably part of a process

The most useful way to reduce transportation is to change and redesign the layout, but it is not that much possible in big companies. Some Len tools which can help to reduce transportation waste are:

- Value stream mapping
- Multi-skilled personnel
- Just-in-time

Inventory:

Inventory is one of the known wastes in manufacturing processes which is highly connected to overproducing. 'Inventory is any product or raw material that has been stored within or outside the organization for a certain period of time' (Chiarini, 2012).

All type of raw materials, semi-finished products, and finished products can be stocked in a storage area. When partially-completed units are stocked in storage and are waiting for a production process, the type of inventory is called WIP (work-in-process). To recognize inventory as a waste, the easiest way is to find out where units are piled up. Then ask for the reason of why they are piling up in a specific storage. Below are several causes for inventory waste (Chiarini, 2012):

- Production process is quicker at the beginning rather than at the end
- Inefficient or defect parts in production process
- Immediate delivery to customers is not possible
- Bottlenecks in the production flow
- Long changeover times

It is important that all personnel should realize the fact that "excessive inventory hides problems, it does not solve them", also they should know that excessive inventory must be eliminated. Below are some traditional Lean tools to reduce excess inventory:

- Quick changeover operations
- Pull production
- Balancing the activities
Overproduction:

Manufacturing industries have to tackle with overproduction as the most important problem they face. Overproduction is producing more than demand because producing exceeds actual demand too soon or too fast (Shingo and Dillon, 1989). Chiarini (2012) mentioned "overproducing means producing when there is no customer order."

Overproducing causes to have products stocked in storages and warehouses, and they are waiting to be bought as forecasted in advanced. Below are some of the negative sides of overproducing (Chiarini, 2012 and Shingo et al., 1989):

- Slowing down the production process
- Increase in inventories
- Affects flexibility in planning
- Increase additional costs such as transportation, maintenance, and so on.

Main reasons that cause overproduction are mentioned below:

- Having more and faster machines than needed
- Producing before ordered demand
- Producing after ordered demand
- Unnecessary personnel in a process

This type of waste can be eliminated through having a balance in capacity and workload.

Overprocessing:

Overprocessing refers to unnecessary activities during the production process which are not considered as value added activities. There is a fine line between overproduction and overprocessing, since overproduction includes necessary and required activities which produce more than demand. Having accurate procedure for production process can eliminate overprocessing waste. Major reasons that lead to overprocessing are as below:

- Insufficient analysis of activities
- Insufficient design of production process
- Insufficient machines and tools
- Lack of high quality materials for production process
- Lack of standardized work

Chiarini (2012) mentioned several recommendations to eliminate this type of waste:

- Automating possible activities
- Re-evaluate procedures of production planning
- Value analysis in all processes
- Redesign production process
- Revise activities within a process
Waiting:

Waiting time considers both personnel's activities and machines' operations (Rother and Shook, 1999). Waiting time is one of the most acceptable types of waste; for instance, sometimes operators should wait for a machine to do its operation and there is not any other choice. When an operator is waiting in front of a machine as a supervisor of that machine maybe he can do another activity at the same time. Some causes of waiting are (Chiarini, 2012):

- Lack of cleanliness and order
- Not having balance between activities
- Lack of procedures and instructions for a process
- Producing in big lots
- Weak preventive maintenance
- Weak layout design

Following can help to remove these causes:

- Production leveling
- Total productive maintenance
- Use 5S to set workplaces in order
- Poka-Yoke which is a mistake proofing system
- Improve layout
- Fast changeovers

3.8.2 Waste from Transportation Perspective

It is claimed that in the ideal perspective, all movements of materials should be considered as waste (Bicheno and Holweg, 2009). Waste in transportation known as a type of waste that cannot be completely eliminated, so this type of waste should continuously be reduced over time. The number of operations in material handling and transportation is connected to the probability of deterioration and damage. According to Bicheno and Holweg (2009), transportation is a type of service and there are four types of wastes involved in this service:

1. Delay: from a customer point of view delay can be defined as waiting time for a service or a response, waiting for a delivery, not arriving at the scheduled time, and waiting in queues. Although suppliers think that customers’ time is free, a problem starts when the customer has to supply others.
2. Unnecessary Movements: one of the significant unnecessary movements is queueing several times, and weak dependency and ergonomics within the service.
3. Double Handling: double handling means re-doing and it should be considered as a pure waste that has negative impacts on production and quality.
4. Unclear Communication: this type of waste is defined as seeking clarification and being confused about how service works. Also, wasting time in order to find a place can lead to double handling or misuse.
Bicheno and Holweg (2009) believe, inventory can be mentioned as an enemy for productivity and quality. This situation is because of a trend of inventory to increase lead-time, prevent fast recognition of a problem, and reduce communications by increasing gap between two points. As mentioned before, inventory always knowns as one of the most important wastes specially in Lean thinking. Having no inventory is an ideal goal that in most cases is impossible to reach.
4. Current State
This chapter presents the company background and empirical findings from gathered data through interviews, observations, and documents. Company background gives a general information about SSAB and its products. In addition, empirical findings from interviews, observations, and documents are about performance of drivers, visiting treatment stations and statistical data series.

4.1 Company Background
SSAB stands for Svenskt Stål AB formed in 1978 and is well-known because of its special steel products. This company produces steel products for both standard and special orders and uses. SSAB is a highly specialized global steel company that has close relationship with customers. SSAB produces high-strength steels and provides services in order to have better performance and sustainability. SSAB’s vision is a stronger, lighter, and more sustainable world. The company believes that together with their customers, they will go further in reaching the full potential of lighter, stronger, and more durable products in the steel industry. SSAB has a flexible production and a cost-efficient system.

The production plants of SSAB are located in Sweden, Finland, and the US that have a total production capacity of approximately 8.8 million tons per year. Meanwhile, the company can process and finish different types of steel products in Brazil, China, and many other countries. In Finland and Sweden, blast furnaces are used for the production processes, however; in the US electric arc furnaces are used.

SSAB in Oxelösund has different product types known as Hardox, Strenx, Armox, Special Mild Steel, and Toolox. Hardox and Strenx are the two power brands of SSAB and both of them have a unique position in the global market. Hardox is known as a global leading brand of wear steels that is designed to have a longer service life and maximum payload. Strenx is a brand covering structural steel products and it leads to lightweight and sustainable solutions.

There are several features that make SSAB unique such as globally recognized brands, long-term customer relationships, innovative services and applications, strong end-user focuses, global leadership in value-added, high strength steels, and home market leadership in Nordic and the US.

This report is done at SSAB Oxelösund branch. SSAB Oxelösund is known as a special production site and it produces special steels based on customers’ order. This branch has about 2000 employees and Figure (14) shows the big picture of the company. As it is shown in Figure (14), SSAB Oxelösund is located next to the sea and has its own harbor. Also this figure indicates how big the production site is.
Required raw materials and semi-finished products are provided from external suppliers and most of them are delivered to the company by ships. SSAB Oxelösund has a harbor in the site where raw materials coming by ships are unloaded there. SSAB Oxelösund converts outsourced raw materials to the finished products through different production processes. In addition, it receives semi-finished products mostly by ship from other branches of SSAB and completes the production processes to make them as finished products.

4.2 Internal Transportation
Several unstructured and semi-structured interviews are conducted to find the required data regarding the internal transportation and how it works currently. Here the interviews are done with three responsible persons whom two of them are technicians of drivers with having experience of working as a driver at the SSAB internal transportation. The third interviewee is an area manager. So, not only they have a good understanding of drivers’ working condition based on their previous experiences, but also they are responsible for daily monitoring of the internal transportation. The interviews are conducted both individually and in a group with mentioned persons. Since the internal transportation of SSAB is wide, having interviews with all three responsible persons improved the accuracy of answers and led to strong discussions. These discussions helped to understand the topic more in depth and raised the hidden parts of the defined problem. In addition, these discussions provided some boundaries for the topic to narrow it down, since the related scope is so wide. It should be mentioned that authors had the
opportunity to choose interviewees themselves and mentioned persons were not chosen by the company.

The aims of conducting interviews with responsible persons of the internal transportation were understanding the current situation, deep understanding of how they monitor drivers’ performance, collect useful documents for controlling drivers’ performance, and generally gather required information for analysing RO1.

According to the interviews, SSAB has 60 drivers and they are working in three shifts per day and seven days a week for the whole year. SSAB has different types of trucks besides having seven carriers in its internal transportation, in each shift there are 12 persons who work as a driver in the internal transportation. In each shift seven drivers are driving carriers for movements of the cassettes which is the main focus of this study. It should be considered that the roles of all 60 drivers are rotating among different types of vehicles, so there are not always the same persons who drive the carriers. During the day shift, one of the seven carriers is only responsible for missions from the harbor of the company and in evening and night shifts it works in the same area as others since the harbor is closed.

With respect to the company’s database, the numbers of missions are different on each shift. For having an overall perspective, it can be mentioned that, on average 5000 missions have to be done by the seven carriers per week. Information related to the performance of all seven carriers together on each shift can be collected from TRS. Accordingly, interviewees claimed, it is undeniable that there are some drivers who work more efficient and effective compared with others. TRS only shows general information about the performance of the all seven drivers in a team. Also, there is not any bonus for drivers whose performance is better than the others or any penalty for those who work less efficient.

The carriers are owned by another company and that company is responsible for service, maintenance, and providing seven carriers on each shift for SSAB. Based on the interviewees’ discussions and exported data from TRS, it is clear that in some shifts the number of available carriers is less than seven. The technician of drivers is responsible for having contact with the responsible company to make sure that they can provide seven carriers on each shift. In the case that they provided carriers less than needed, he is responsible to ask for the reason. Mechanical problems are the main reason for having less than required carriers.

All interviewees agreed that, although there are some rules to limit the way that drivers should work such as doing the missions based on priorities, most of the drivers do not limit themselves completely to these rules and almost everyone has his/her own way of working. Sometimes drivers in a group of six or seven people in a shift choose a specific way of working in which they set a goal for themselves and try to reach it. On the other hand, in some shifts drivers do not work as efficient as others. Some of the drivers prefer to do the missions that are close to them based on the location that they are instead of doing the missions based on priorities. Interviewees mentioned that there are not any pre-scheduled trainings or meetings for drivers except the first information that drivers got at the beginning of their job at SSAB. While, the drivers’ technicians are available on the morning shifts to answer the drivers’ questions or give
them the necessary information. It should be mentioned that author could not reach a specific written procedure for the way that drivers should work.

As it is mentioned in the problem description, delay reports are used to provide information about the delays in the internal transportation. Delay reports are sent from the operators in the treatment stations to the technicians of the drivers to present the information about the duration that at least one of the operators and/or production lines and/or machines are idle because of a delay in the internal transportation. In addition, when drivers are done with a mission, they enter a done code to TRS and system automatically record the time when mission is done. Interviewees claimed that, there are differences between the presented delay times from treatment stations with actual times that system has recorded automatically. Therefore, responsible persons in the treatment stations send delay reports to technicians of drivers while technicians do not consider them as valid reports. After conducting interviews with different persons in treatment stations, all the interviewees agreed that delay report that are sent to transportation department are not accurate. Since the time that a carrier delivers a cassette is not the same as when machine starts working. Currently, neither personnel in the transportation department nor in the treatment stations accept the delay reports as valid reports, so they do not use them.

4.3 Drivers’ Way of Working

The way that drivers work is studied by going with different carriers on different shifts to observe the way that drivers work. There is a screen in each carrier that shows the required information to drivers as it is shown in Figure (15).

![Figure 15: Screen of the Carriers](image-url)
The first column shows the priority of each mission in which yellow and red colors mean late and very late respectively. Based on the priority system, priority number 1 should be done in 15 minutes, priority number 2 should be done in 30 minutes, and priority number 3, 4 and 5 should be done in 60, 100 and 120 minutes respectively. Each cassette has a specific identification number; the identification number of the cassette that should be moved is shown in the screen in Lastht column. Also, the locations that cassette should be moved are presented as From/To. The time that mission is announced in the system is also presented in Btid column. Drivers have opportunity to sort the missions on the screen based on several factors such as priority, location, or announced time.

Drivers choose one of the missions shown on the screen, and then they take the cassette and deliver it to the announced destination and choose another mission. When they choose a mission, system shows that which driver has chosen the mission and when they deliver the cassette to the destination they enter the information to the system about exact time and location. According to observations, drivers prefer to do the missions based on their locations instead of the priorities. So, usually they do the missions that are closer to them. Moreover, when drivers need to deliver an empty cassette to a treatment station or production line, they cannot find the information on the screen about where the empty cassettes are located. Therefore, they should check all middle storages to find an empty cassette. Figure (16) presents the layout and locations of production lines, treatment stations, and middle storages. Table (2) presents the name and main activity of all the treatment stations at SSAB. However, some of the stations are not visited in this project, since both time and scope for this project were limited. Based on the gathered data, treatment stations which are more connected to the internal transportation are visited.
<table>
<thead>
<tr>
<th>Station</th>
<th>Main Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H2</td>
</tr>
<tr>
<td>2</td>
<td>Hall 9</td>
</tr>
<tr>
<td>3</td>
<td>Hall 10</td>
</tr>
<tr>
<td>4</td>
<td>Hall 11</td>
</tr>
<tr>
<td>5</td>
<td>H 5 (BLM)</td>
</tr>
<tr>
<td>6</td>
<td>H 4</td>
</tr>
<tr>
<td>7</td>
<td>MTB</td>
</tr>
<tr>
<td>8</td>
<td>Småplåten</td>
</tr>
<tr>
<td>9</td>
<td>Sortering</td>
</tr>
<tr>
<td>10</td>
<td>Hardox</td>
</tr>
<tr>
<td>11</td>
<td>Strenx</td>
</tr>
<tr>
<td>12</td>
<td>Saxträckan</td>
</tr>
<tr>
<td>13</td>
<td>Valsverk</td>
</tr>
<tr>
<td>14</td>
<td>Proplate</td>
</tr>
<tr>
<td>15</td>
<td>Harsco</td>
</tr>
<tr>
<td>16</td>
<td>Trasiga Kassetter</td>
</tr>
<tr>
<td>17</td>
<td>Okänd Plats</td>
</tr>
<tr>
<td>18</td>
<td>Sjoklagret</td>
</tr>
<tr>
<td>19</td>
<td>Central Lager</td>
</tr>
<tr>
<td>20</td>
<td>Centralverkstan</td>
</tr>
<tr>
<td>21</td>
<td>Låt Stå</td>
</tr>
<tr>
<td>22</td>
<td>Fiskbenet</td>
</tr>
<tr>
<td>23</td>
<td>Delivery</td>
</tr>
<tr>
<td>24</td>
<td>Harbor</td>
</tr>
</tbody>
</table>

*Table 2: Treatment Stations and Their Activities*
Figure 16: Layout of SSAB
4.4 Hall 10 and Hall 11

The main activity of these two treatment stations is cutting. Hall 10 and Hall 11 receive plates from different stations and production lines. As there is limited space for cassettes in Hall 10 and Hall 11, when the stations do not have space for new cassettes the carriers have to leave the cassettes in middle storages (Mellan Lager Plats). Since the information about cassettes and plates are shared in the system, the operators can check the information about types of plates that are waiting in Mellan Lager Plats (MLP). Then the operators in the station can decide which cassettes should be ordered to bring in based on the priorities. When they receive a loaded cassette, in most cases the plates on the cassette are not sorted for the next destination after Hall 10 and Hall 11. Although system shows the information regarding five next destinations of a plate, the stations or production lines that send a cassette to Hall 10 and Hall 11 do not sort the plates based on next two destinations and they only load the cassette with plates that should be cut. After receiving the cassettes, the operators in these two Halls unload the plates on the floor for cutting.

After cutting the plates, they sort them based on the next destination on different cassettes. For instance, when they receive a cassette with 30 plates on it, after cutting the 30 plates should be divide on 2 different cassettes since some of plates should be sent to painting station and some of them should be sent to Fiskbent. Hall 10 and Hall 11 have limited space compared with production lines as the main suppliers of these two Halls. During the loading of the cut plates on an empty cassette, operators order a mission in the internal transportation system when the cassette is around seventy percent full. As interviewee mentioned the most time-consuming activities in Hall 10 and Hall 11 are waiting for a free cassette to load the cut plates on it and sorting the plates after cutting. During the visit of Hall 11, the working process was stopped, since they were waiting for an empty cassette. The interviewee mentioned that, they have cut the plates and they are waiting for empty cassettes about six hours to send the plates out.

The interviewee explained that when the cutting machine does not work for more than six minutes, the operators should enter a code to be able to use the machine again. The code presents the reason for down time and each code presents a specific reason. The operators enter the code that presents the internal transportation if the delay is because of the late delivery of cassettes. It should be mentioned that the procedure for reporting delay times is same in all treatment stations and production lines.

4.5 H4, H5, Småplåten

The main activities in H5 are painting and blasting. H4 and Småplåten are stations that sort plates based on the type of delivery; ship, train or truck. These stations can be considered as the final treatment stations before delivering to customers. The process starts with receiving loaded cassettes in H5. Then a crane unloads the cassettes and before entering plates to painting process they will be sorted based on the length of plates if they are less than six meters or more. Since H5 does not have required area for sorting plates, when the painting and blasting is done, the plates will be loaded on cassettes and send to Småplåten or H4. Plates that are less than six
meters should be sent to Småplåten and the plates that are more than six meters should be sent to H4 for sorting based on delivery types.

As it is presented in Figure (16), Småplåten is located in a separated area and far from H5. While, H4 and H5 are in a same building and there is only a wall that separates them. Since there is a wall located between H5 and H4 the crane cannot reach H4 and that is why they have to send plates from H5 to H4 by carriers. It should be considered that, when H4 or Småplåten are full and cannot accept cassettes for sorting, the operators in H5 have to send the cassettes to Mellan Lager Plats and when H4 or Småplåten have available space they can order missions to receive cassettes from MLP. This happens a lot since the painting speed in H5 is faster than sorting cassettes in H4. When the cassettes arrive to H4 the operators should unload the plates on the floor, sort them based on delivery type, and load them on the empty cassettes. The process of working in Småplåten is the same as H4. The interviewee in H5 claimed that sometimes they receive a plate with defects and they have to send it to other treatment stations for repair before painting, which means extra missions for the internal transportation. In H5 they always have an empty cassette on which they load plates with defects. When the cassette with defected plates is full they send it to the required treatment stations for repair and usually it takes two or three days to fix the defects.

4.6 H2

H2 is a quenching and hardening station that receives plates from different treatment stations of SSAB. Also, H2 has suppliers from the US, Finland, and Borlänge. These suppliers send semi-finished plates to H2 for hardening which is a time-consuming process. After the treatment, plates are loaded on cassettes to send to other stations. Since hardening is a time-consuming process, the operators prefer not to load the cassettes fully. This is because of keeping the flow of material continuous. Same as H5, H2 always has an empty cassette at the end of treatment line for damaged products that do not fulfil the quality control. Treatment of these products mostly should be done in H2, while this station cannot send them internally and has to load the damaged plates on a cassette and send it to the beginning of the line by carriers. As the starting point of H2 is usually full, the cassette should be sent to a middle storage and wait there before delivering to H2 to repair. The delay times are reported same as other stations and the interviewee believes that, the delay reports that are sent to TRS are not accurate. The interviewee mentioned that, the operators in H2 sort the cassettes based on the next destination and not to the next two destinations.

4.7 Middle Storages

Middle storages (MLP) play key role in the internal transportation of the company. These storages areas are important factors for providing a continuous material flow through production process at SSAB. Since the production process involves several production lines and treatment stations with different speeds and lead times, middle storages are designed to make sure that material flow is continuous. So, when it is not possible to send the cassettes gate to gate, the cassettes can wait in the middle storages.
With respect to third research objective which is defined to study the waiting times of the cassettes in different storage areas, company’s database provides data series for the year 2017. These data series are a big data in the form of excel sheet which include all the movements to and from different middle storages and stations. In addition, this big data shows cassette number, priority, time that a mission is created and done, and locations. Since it is a big data, a sample of the excel sheet is presented in Table (3).

<table>
<thead>
<tr>
<th>Prio</th>
<th>Lastenhet</th>
<th>Från</th>
<th>Till</th>
<th>Reserverad tid</th>
<th>Skapad</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>6921</td>
<td>864</td>
<td>01Jan2017 14:17:29</td>
<td>01Jan2017 12:23:06</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>6846</td>
<td>182</td>
<td>01Jan2017 14:32:56</td>
<td>01Jan2017 13:01:12</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>7721</td>
<td>4</td>
<td>01Jan2017 14:32:56</td>
<td>01Jan2017 14:29:20</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>7604</td>
<td>4</td>
<td>01Jan2017 14:36:13</td>
<td>01Jan2017 14:29:50</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>7520</td>
<td>4</td>
<td>01Jan2017 14:38:33</td>
<td>01Jan2017 14:29:50</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>7547</td>
<td>4</td>
<td>01Jan2017 14:41:07</td>
<td>01Jan2017 14:36:50</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>6217</td>
<td>4</td>
<td>01Jan2017 15:01:54</td>
<td>01Jan2017 14:55:22</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>7082</td>
<td>5567</td>
<td>01Jan2017 15:06:29</td>
<td>01Jan2017 15:01:51</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>7720</td>
<td>4</td>
<td>01Jan2017 15:14:13</td>
<td>01Jan2017 15:11:54</td>
</tr>
</tbody>
</table>

Table 3: Exported Data

Regarding this table, Prio refers to prioritization and it varies from 1 to 5. Lastenhet shows the specific number of each cassette. Från/Till show the location of each storage area. Skapad shows the time when a mission is created in the TRS and Reserverad tid shows the time when a mission is done.
5. Analysis

This chapter represents the analysis of the collected data. In chapter 4, current state and how the internal transportation works today are explained. Chapter 5 includes in-detail discussions and analysis for each research objective beside presenting the related tables and graphs.

5.1 Research Objective 1

As mentioned before research objective 1 is related to study the performance of carriers and drivers. With respect to the gathered data for this research objective, several problem areas are identified which have both direct and indirect influences on the performance of drivers and the way they work. In the following, each problem area and its related theories are discussed.

5.1.1 Priority System and Way of Working

According to the conducted interviews and observations, it is found that drivers have different ways of working and there are several drivers who work more efficient and effective. Although the priority system is one of the main rules to state how a driver should work, some of the drivers do not pay attention to these rules and this leads to having different ways of working. The reason for having the priority system is to inform drivers about the importance of each mission, so they can decide to do which mission first. The priority system is made to help drivers have a standard way of working. Accordingly, calculations are done to evaluate the performance of drivers in relation to the priority system. It should be mentioned that, some of drivers do not know the importance of priority system and they think following the priority system is not the most efficient way of working for them.

By exporting the required data from TRS, the waiting time of a cassette for a carrier is calculated for approximately 245000 missions for the whole year 2017. As it is presented in Figure (17), 47% of missions are done with priority number 3 and the number of missions with priority 4 and 5 are almost the same. Priority 2 has the least number of missions in this chart and priority number 1 is not considered in this chart because it contains less than 1% of all the missions.

![Figure 17: Variation of Priorities](image-url)
Table (4) is provided to give a clearer vision of the calculations for the priority system. The first column shows the priorities which are from 1 to 5 and priority number 1 refers to the most important mission and priority number 5 refers the least important one. The next column presents the goals that are set by the company for doing the missions with specific priorities. Third and fourth columns show how many percentages of the missions reached and did not reach the goals respectively. The last column presents the average times of doing each priority.

<table>
<thead>
<tr>
<th></th>
<th>Goal (Min)</th>
<th>Reach goal (%)</th>
<th>Did not reach (%)</th>
<th>Average time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prio 1</td>
<td>15 Min</td>
<td>48%</td>
<td>52%</td>
<td>38 Min</td>
</tr>
<tr>
<td>Prio 2</td>
<td>30 Min</td>
<td>64%</td>
<td>36%</td>
<td>37 Min</td>
</tr>
<tr>
<td>Prio 3</td>
<td>60 Min</td>
<td>66%</td>
<td>34%</td>
<td>63 Min</td>
</tr>
<tr>
<td>Prio 4</td>
<td>100 Min</td>
<td>84%</td>
<td>16%</td>
<td>52 Min</td>
</tr>
<tr>
<td>Prio 5</td>
<td>120 Min</td>
<td>93%</td>
<td>7%</td>
<td>29 Min</td>
</tr>
</tbody>
</table>

**Table 4**: Evaluation of Priority System

Figure (18) is accorded to make a comparison among different priorities in terms of how fast they were done. This figure shows that missions with priority 5 are done faster than the others. In addition, missions with the priority 4 are done faster that missions with priority 3. As it is clear from both Table (4) and Figure (18), priorities did not reach the defined goal. Moreover, it should be mentioned that priority 1 refers to the most important missions that should be done immediately and these 23 minutes (38-15=23) is a considerable waiting time for a carrier. These calculations and figures show that drivers do not follow the priority system properly.

**Figure 18**: Average Time of Each Priority
Chiarini (2012) defines waste as activities that use resources but do not add any values. Currently, several people in the both production planning and transportation departments are involved with the priority system. They are working continually on the priority system by changing the priorities of stations and production lines regularly to inform drivers about the importance of each mission. However, the collected data and calculations show that drivers do not follow this information and priority system does not work properly based on its defined goals. A comparison between the current condition with the presented definition of the waste leads to a conclusion by considering the priority system as a waste. With respect to the different types of the wastes that are presented in the theoretical framework, it can claim that Muda from 3MU, overprocessing, unnecessary activities, and unclear communication are types of the wastes that exist in priority system.

Standardize the activities of the employees should be considered as one of the most crucial principles to eliminate waste. Standardized work is defined as performing each activity in an effective way. In a standardized working process, the level of desired quality will be achieved, no matter who is running the process (Abdullah, 2003). Toyota production is a reliable example for standardization when all personnel follows the same steps in a process for each specific activity. When personnel is doing their responsibilities based on standardized work, unnecessary WIPs will be minimized, non-value added activities will be reduced, and a balancing line will be achieved (Liker and Meier, 2006).

Standardized work is a useful tool for eliminating variation and making sure that results are repeatable and predictable. Having standardized work by eliminating waste of motion, will lead to more efficient and effective way of working. After providing a standard way of working that is followable for all employees, it is necessary to sustain it by considering the 5S theory. Discussions show a gap between current state and ideal state suggested by theories.

5.1.2 Availability of Carriers
Another company provides all the carriers for the internal transportation of SSAB. Collected data shows that in some shifts the number of carriers is less than required and the responsible company cannot provide the required number of carriers in each and every shift. However, the drivers are SSAB’s employees and they cannot work when the number of carriers is less than required.

Mura from 3MU is defined as unevenness which is one of the principals in Toyota Production System. Waste of unevenness has direct and indirect effects on both machines and personnel. Specifically, in this project, having fewer carriers puts pressure and stress on drivers because they have to do the same amount of work with fewer resources. Having less than needed carriers can lead to other wastes such as machine failure and safety problems because drivers must work faster, or they can be tired because of working under pressure. Moreover, one of the main wastes in 4M is a waste of human resources which is considerable. Having employees that cannot add values should be considered as a pure waste. In this case that there are fewer carriers than needed, some drivers are idle which is a pure waste.
5.1.3 Pre-scheduled Meetings
Currently, there are not any pre-scheduled training or information meetings for drivers. There are approximately 60 drivers working in the internal transportation and they have different levels of experiences. As mentioned in the theoretical framework, unclear communication among personnel can lead to different types of wastes in their ways of working.

Informing personnel about the importance of their work and giving them updated information about the working condition is the first step to eliminate waste with the help of Kaizen for having a continuous improvement. Kaizen can be defined as providing the employees with the required information about their working process and giving them the opportunity of presenting their suggestions about improvement in their tasks. Also, this way of working encourages them to be more creative in their tasks and responsibilities for having continual improvements. For instance, pre-scheduled meetings can help drivers to have continuous improvements and reach a standard way of working. These meetings can help them to share their experiences by discussing the way that they should work to reach the goals. Also, drivers' technicians can evaluate their performances regarding the defined standards and the priority system. Moreover, he can give them suggestions and lead them to reach the goals based on his evaluations.

5.1.4 Delay Reports
Based on the collected data, delay reports that are sent from treatment stations to the transportation department are not valid. However, delay reports can be very helpful for responsible persons in the transportation department to evaluate the performance of drivers in different shifts. Operators in treatment stations and production lines spend time to register the waiting times and export reports on daily and weekly basis. Then they send these reports to the transportation department to inform them about the time that operators or machines were idle because of the delay in the internal transportation. All these activities are considered as waste because the transportation department does not consider these reports as valid ones and they ignore them. Therefore, there are not any added values regarding all the activities to provide these reports and send them to the transportation department.

5.1.5 Specific Locations for Empty Cassettes
Currently, there are not any allocated locations with specific codes as storages areas for empty cassettes. Therefore, drivers cannot see the location of empty cassettes on the screen of their carriers and they have to search all the area for a specific type of cassette that they need. This leads to unnecessary movements for carriers and delay for the customers. When it is not easy to find the required type of cassette for the customer, drivers prefer to do other missions and it means more waiting time for customers. Additionally, this way of working is not acceptable from a sustainability perspective, since it leads to higher fuel consumption, air pollution, and machine failure. Having the information about the storage of empty cassettes is important for analyzing the usage of cassettes.

Waste of motion is defined as unnecessary movements of personnel in working area. As Chiarini (2012) mentioned, one of the main reasons for the waste of motion is the lack of order in working place. In the ideal world, all movements of materials should be considered as a waste (Bicheno and Holweg, 2009). Transportation is known as a type of waste that cannot be
completely eliminated, so it should be reduced continually. Moreover, the number of operations in material handling and transportation is connected to the probability of deterioration and damage. Although waiting time is one of the most acceptable types of waste it should be reduced by continues improvements (Rother and Shook, 1999).

5S is a tool that can make the workplace organized and clear for all personnel, so they can reach every item that they need immediately to work as efficient as possible. The main principles of this tool are classifying the group of the frequently used material and organizing them in a specific location in a way that everyone can find them easily.

Table (5) presents the problem areas in RO1 and identifies the gaps between current state and theory recommendations. Types of wastes and required Lean tools to eliminate these wastes are presented as well, so it gives an overall information about Chapter 3, 4, and 5 at a glance.

<table>
<thead>
<tr>
<th>Current State</th>
<th>Theory Recommendation</th>
<th>Gap/Match</th>
<th>Type of Waste</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some drivers work more efficient and effective compare with others.</td>
<td>In a standard system, it does not matter who is running the activity, the level of desired quality should be achieved.</td>
<td>Gap</td>
<td>-3MU</td>
<td>-5S (Standardize and Sustain) -Kaizen</td>
</tr>
<tr>
<td>Number of available carriers is less than required in some shifts.</td>
<td>Achieving standardization requires evenness in human resources and equipment.</td>
<td>Gap</td>
<td>-3MU</td>
<td>-5S (Standardize and Sustain) -Kaizen</td>
</tr>
<tr>
<td>Drivers do not limit themselves to follow the priority system and they have individual ways of working.</td>
<td>TPS recommends every personnel should follow the same steps in a process for each specific activity.</td>
<td>Gap</td>
<td>-3MU</td>
<td>-5S (Standardize and Sustain) -Kaizen</td>
</tr>
<tr>
<td>Company does not have any prescheduled training courses or information meetings.</td>
<td>Educate personnel how to maintain the standards. Inform them about the importance of their role in the process. By communication motivate them to have continues improvement</td>
<td>Gap</td>
<td>-3MU</td>
<td>-5S -Kaizen</td>
</tr>
</tbody>
</table>
Delay times of the transportation system are reported manually by operators and this information is not valid. Automation of human activities specially in term of waiting times and defects can improve the accuracy and speed of the activities.

Drivers cannot see the information about the empty cassettes on their screen, so they have to check the area for finding the empty cassettes. Work place should be organized so personnel can easily find the tools that they need.

<table>
<thead>
<tr>
<th>Gap</th>
<th>-3MU</th>
<th>-4M</th>
<th>-Unclear Communication</th>
<th>-Jidoka</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap</td>
<td>-3MU</td>
<td>-4M</td>
<td>-Unnecessary movements</td>
<td>-5S</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Delay</td>
<td>-Jidoka</td>
</tr>
</tbody>
</table>

Table 5: GAP Analysis in RO1

5.2 Research Objective 2
Research objective 2 is related to study the treatment stations and identify the wastes that are connected to the internal transportation. According to the collected data, several problem areas are identified and explained in the following.

5.2.1 Pre-sorting the Plates
As mentioned in the previous chapter, Hall 10 and Hall 11 are cutting stations and they receive plates for cutting operation from almost all production lines. Although these two stations are receiving significant tons of plates every day, they have limited space inside the station and the process of unloading, cutting, sorting, and loading plates on different empty cassettes is time-consuming. Managing this process is more difficult with respect to limited space inside stations specially in Hall 10. This causes slower flow in these two stations and eventually slower material flow for the whole production process.

On the other hand, some of the production lines that send plates to Hall 10 and Hall 11 have more space for sorting the plates based on the next two destinations instead of next destination. In the case that they can do the pre-sorting, cutting stations receive loaded cassette that all the plates on it have the same destination, so they can cut the plates and load them on one empty cassette and send them out. Sorting the plates based on the next two destinations specially when the first destination is cutting stations would help Hall 10 and Hall 11 to have a much faster and smoother flow.

In this case, 3MU can be considered since there is unevenness among the working process and layout design or lack of balance between the capacity of layout and processes. The term Mura from 3MU is completely related to unevenness and it causes personnel to be in a hurry, this
type of waste is not steady, and it can be eliminated by focusing on the pace of work. Muri from 3MU means expect more workload from both machines and personnel than capacity. So, they have to work in a high pace environment with more effort than needed. Implementing the pre-sorting process in production lines can divide the work force more reasonably through the material flow and eliminate these wastes.

Investigating and classifying the root causes of an occurred problem in every process known as Root Cause Analysis (RCA) which is a powerful tool. As Rooney and Heuvel (2004) mentioned, root causes are underlying causes and the objectives should be determining the specific hidden causes. In this case, root cause analysis can identify the hidden parts of this problem to find out clearly why this situation is happened. Giving solutions and recommendations are easier when a deep investigation for finding the reason of the occurred problem is done. Recommendations that are given based on the root cause analysis are more reliable since all hidden parts of the problem are analyzed.

Gemba is a lean tool that encourages managers and engineers to go and visit the occurred problems from the closest point of view to have a better understanding of its impacts. Gemba can be very helpful in this case because visiting the stations and production lines will give the responsible persons better understanding of the problem and new ideas for solving it. Specifically, in this case, Gemba will help managers and responsible persons to understand the situation and its related wastes in depth.

Currently, treatment stations do not use value stream mapping for identifying wastes within their process or evaluating new implementations; however, this tool can be very helpful for them specially for continuous improvements. Value stream mapping (VSM) is an important tool for identifying wastes within a process. VSM can answer the questions such as How is value created in a process? – Which steps are value-adding and which ones are not? – Which areas in a process need more improvements? Every process and organization have wastes and eliminating these wastes is an excellent opportunity. The focus of VSM is on reducing or eliminating non-value adding activities. Non-value adding activities are needed and necessary activities based on the current state of the process and cannot be eliminated. On the other hand, there are several activities that are not needed but still occur, these activities use resources and do not create value (McDonald et al., 2002). VSM gives useful information about the current state to the employees and lets them be involved in understanding the wastes. In addition, Value stream mapping can provide a common language that is understandable for the production processes and as a result more useful decisions can be made to have improvements. Thus, with the help of VSM further improvements can be evaluated (McDonald et al., 2002).

5.2.2 Layout Design
H5 and H4 are painting and sorting stations which are located in a same building and because of a wall that separates them the material cannot move internally inside the building. So, they have to order a lot of missions in the internal transportation and use a significant number of cassettes for material movement between H5 and H4. As mentioned H5 as the painting station has a continuous working process, while the working process in H4 as a sorting station is a batch. These different ways of working prevent them from sending plates gate to gate and they
have to use MLP which means double the number of transportation missions and long cassettes occupation.

Waste of transportation is the clearest waste involved with the layout problem in H5 and H4. As mentioned by Bicheno and Holweg (2009), although all transportations and material movements should be considered as a waste in the ideal world, this type of waste cannot be completely eliminated. Thus, continuous improvement plays a key role in reducing this waste over time. It should be considered that the highest number of the material handling means the highest risk of damage and deterioration. Besides environmental wastes that are inevitable in the waste of transportation, there are other wastes involved with the waste of transportation such as delay for the customers, double handling, and waste of human resources.

In this case Gemba encourages the managers and engineers to go and visit the problem area closely to see the problem and its related wastes. Value stream mapping can proof the wastes and make them understandable for everyone. Additionally, Calculating the number of transportation missions that could be reduced after removing the wall can make the analysis and decision making easier. After removing the wall, VSM will be a useful tool for evaluating the results and presenting the advantages.

5.2.3 Quality Control
Gathered data shows that both H5 and H2 have a problem with a Quality control. The final quality control in H5 is done after painting process and when the operators find some defects on the plates they have to send them to other stations for repair and it means creating a mission in the internal transportation, using cassettes, and having delay in the painting process.

Likewise, quality control is done at the end of the treatment process in H2 and most of the damaged plates should be sent to the starting point of the line in H2 for the repair process. While based on the layout design in H2 it is not possible to send the plates for the repair process internally and they should be sent with the help of cassettes and carriers by the internal transportation.

Defectiveness is one of the seven types of wastes defined by TPS. It explains that, when ordered products or services do not meet the requirements, which is stated and specified by the customers, they are sent to a hidden factory. A hidden factory is a well-known factory in each factory where personnel works to repair products. This type of waste is related to the cost of poor quality (COPQ). COPQ can be both internally and externally. Comparing this cost to the exactly right cost of reworking is the same as seeing an iceberg as a small fraction which is visible above the water. COPQ includes costs for materials, rework, problem-solving, transportation, setup times, and increased lead-time for customer delivery (Chiarini, 2012).

As for the layout design, waste of transportation is the main waste involved with the quality problem. Also, there are other types of wastes related to unnecessary movements and quality control such as waste of human resources, overprocessing, unnecessary activities, and double handling.
Shigeo Shingo developed a quality improvement tool known as Poka-Yoke or mistake proofing. This tool minimizes and reduces the negative effects through preventing mistakes from happening. As this Poka-Yoke developed from Jidoka out of TPS, it recognizes errors with the help of an automatic system. The main advantage of implementing Poka-Yoke is preventing defects from entering the next steps of the production process and material flow. Although inspection is known as the least effective method for controlling the quality, Poka-Yoke is well-known to prevent defects from happening. As inspection is done by employees and it depends on their opinion during the long working hours and almost repetitive work. However, Poka-Yoke uses an automatic way of control for detecting the defects. Applying Poka-Yoke as a Lean tool leads to not producing a defect, not having a defect within a process, and not allowing a defect to flow to the next production process (Shingo and Dillon, 1989). Table (6) is provided to present the gaps between the current situation and theories in research objective 2. Types of wastes and required Lean tools to eliminate these wastes are presented as well, so it gives an overall information about chapter 3, 4, and 5 at a glance.

<table>
<thead>
<tr>
<th>Current State</th>
<th>Theory Recommendation</th>
<th>Gap/Match</th>
<th>Type of Waste</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>When Hall 10 and Hall 11 receive a loaded cassette, in most cases the plates on the cassette are not sorted for the next destinations. So sorting the plates for next destinations takes significant time from personnel in Hall 10 and Hall 11.</td>
<td>Unevenness in manufacturing process should be eliminated continually.</td>
<td>Gap</td>
<td>-3MU</td>
<td>-Root cause analysis -Gemba -Value stream mapping</td>
</tr>
<tr>
<td>H5 cannot send plates to H4 internally and they have to use cassettes and carries for this movement.</td>
<td>Overprocessing and unnecessary activities are non-value adding activities that should be eliminated from material handling process.</td>
<td>Gap</td>
<td>-3MU -4M</td>
<td>-Root cause analysis -Gemba -Value stream mapping</td>
</tr>
<tr>
<td>Sometimes H5 receives plates with defects on</td>
<td>Activities that have not any influence on</td>
<td>Gap</td>
<td>-4M</td>
<td>-Poka Yoke</td>
</tr>
</tbody>
</table>
them and they have to send it back for repair. 

value should be considered as wastes. Double handling is a pure waste that has negative impacts on production and quality.

-Transportation
-Unnecessary movements
-Overprocessing
-Double handling
-Defectiveness

-Root cause analysis
-Gemba
-Value stream mapping

H2 at the end of its line have to send the defected plates by carriers to another port of H2 for repair, since they cannot send plates internally or even gate to gate.

Overprocessing and unnecessary activities are non-value adding activities that should be eliminated from material handling process. Double handling is a pure waste that has negative impacts on production and quality.

Gap
-4M
-Transportation
-Unnecessary movements
-Overprocessing
-Double handling
-Defectiveness

-Poka Yoke
-Root cause analysis
-Gemba
-Value stream mapping

Table 6: GAP Analysis in RO2

5.3 Research Objective 3
This part presents the graphs and charts, which are gained from analyzing data series with Minitab and Excel. The graphs provide understandable information about the waiting time of cassettes in different storage areas. These graphs present that in which storages cassettes were waiting more. This information provides a useful and clear vision for the company about cassettes’ waiting times in different storage areas (MLP) and can be considered as useful information for future studies in this area.

With respect to RO3 which is aiming to find the waiting times in different storage areas, the gathered data which are in the form of excel sheets have been analyzed. The gathered data includes 330726 rows and 19 columns, and each row specifies one transportation mission in the year 2017. As shown in Figure (3), “Prio” refers to the prioritization system which differs from 1 to 5 in the system, “Lastenhet” shows cassette numbers, “Från and Till” show that a movement is done from where to where, “Reserverad tid” is the time when a carrier reserves a mission to do it, and “Skapad” is the time when a mission is created in the internal transportation system.
Different Locations including storage areas, treatment stations, and production lines are mentioned in Table (2). Different locations are grouped based on the similarities in their main activities. There are six different groups as shown in Table (7). To analyze, each group of data set is moved to Minitab, and with the help of Minitab different graphs are plotted. In the following, each graph is explained and the reasons for having these graphs with these boundaries and constraints are motivated.

<table>
<thead>
<tr>
<th>Group</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>H2, H4, H5, Hall9, Hall10, Hall11, MTB, Sortering, Småplåten</td>
</tr>
<tr>
<td>Group 2</td>
<td>Hardox, Strenx, Saxsträckan, Valsverk, Proplate</td>
</tr>
<tr>
<td>Group 3</td>
<td>Central Lager, Sjoklagret</td>
</tr>
<tr>
<td>Group 4</td>
<td>Centralverkstan</td>
</tr>
<tr>
<td>Group 5</td>
<td>Harsco, Trasiga Kassetter, Okänd Plats, Låt Stå</td>
</tr>
<tr>
<td>Group 6</td>
<td>Fiskbenet, Delivery, Harbor</td>
</tr>
</tbody>
</table>

Table 7: Locations in Groups

The aim of research objective 3 is to analyze the waiting times of cassettes in the whole year 2017 to find out if there is a considerable number of cassettes waiting for a significant duration, and in which locations these cassettes were stocked. Waiting time of a cassette in a specific location means how long a cassette stays in a location from the time it enters that location until the time when it goes out of that specific location. The importance of having an empty cassette available on the required time can be addressed when a treatment station stops working and both machines and operators are idle just waiting for one empty cassette. There are not any specific duration shows for how long a cassette can wait in different stations.

Following each group is studied, related graphs are exported from Minitab, and the results are explained and discussed more in detail.

5.3.1 Group 1
Group 1 contains 128756 transportation missions in which 111660 of cassettes were waiting under 1 day. To be more precise, almost 86% of the cassettes in the whole year 2017 were waiting under 1 day in mentioned locations of group 1 (Table 8). Meanwhile, the average waiting time in the investigated period is 0.7 day. As 86% of the missions were already done under 1 day, it is decided to investigate the missions that are waiting 3 times more than 1 day more in detail. Regards to the data series, 4262 number of transportation missions were waiting more than 3 days. And 541 cassettes were waiting in one of these locations for more than 10 days.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean</th>
<th>Sample Under 1day</th>
<th>More than 3days</th>
<th>More than 10days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group1 H2,H4,H5,Hall9,Hall10,Hall11,MTB,Sortering, Småplåten</td>
<td>0.7 day</td>
<td>128756</td>
<td>86%</td>
<td>4262</td>
</tr>
</tbody>
</table>

Table 8: Group 1
In order to present the results of the calculation for group 1, a boxplot is made for the cassettes that were waiting more than 3 days in a specific location. Figure (19) represents the variability for each location and make comparison among different locations. Moreover, whiskers (lines which are extended out of each end of a box) indicates how much each sample varies. As it is obvious from the boxplots, some of the data points are outliers. Outliers refer to the samples which do not seem to belong to the rest of the data. So, it can be mentioned that outliers can strongly influence the study area, and they should be identified and the causes for their unusual existence should be found.

The number of the investigated sample for each location, their means, and standard deviations, and the maximum and minimum of them are presented in Figure (20). Regards to the sample of each location, it should be mentioned that, each sample has at least 20 observations. Since, there should be at least 20 observations in each group of samples to represent the distribution of the examined data.

Figure 19: Boxplot Group 1
As for figure (19), H2, H4, H5, Hall 10, Hall 11, MTB, Småplåten, and Sortering have a variable range of outliers. So, these 8 locations from group number 1 need more studies to find the causes of each outlier point. In addition, with respect to figure (19), there were not considerable number of cassettes stocked in Hall 9 for a significant time. Meanwhile, to make it more understandable a bar chart is provided to show how many cassettes were waiting in each location of group 1 for more than 3 days (Figure 21). So, it would be much easier to compare different locations and decide which location should be root cause analyzed first. As it is depicted in Figure (21), there were 955 and 883 cassettes waiting in H2 and H5 for more than 3 days respectively. So, it is worth to find the reason why these high number of cassettes were waiting in these two locations. In addition, there were 623 cassettes waiting in Hall 11 and 500 cassettes waiting in MTB in the investigated duration. Meanwhile, there were only 79 cassettes waiting in Hall 9 which shows a continuous flow in this treatment station.

![Boxplot Waiting time by Location](image)

**Figure 20:** Boxplot Group 1

As for figure (19), H2, H4, H5, Hall 10, Hall 11, MTB, Småplåten, and Sortering have a variable range of outliers. So, these 8 locations from group number 1 need more studies to find the causes of each outlier point. In addition, with respect to figure (19), there were not considerable number of cassettes stocked in Hall 9 for a significant time. Meanwhile, to make it more understandable a bar chart is provided to show how many cassettes were waiting in each location of group 1 for more than 3 days (Figure 21). So, it would be much easier to compare different locations and decide which location should be root cause analyzed first. As it is depicted in Figure (21), there were 955 and 883 cassettes waiting in H2 and H5 for more than 3 days respectively. So, it is worth to find the reason why these high number of cassettes were waiting in these two locations. In addition, there were 623 cassettes waiting in Hall 11 and 500 cassettes waiting in MTB in the investigated duration. Meanwhile, there were only 79 cassettes waiting in Hall 9 which shows a continuous flow in this treatment station.

(7.06+6.79+6.59+6+6.88+7.88+5.48+6.48+6.14)/9=6.58

As it is shown, there is one cassette which was waiting for 150.34 days in H2, however it is strongly important for treatment stations to have empty cassettes available on time.

Meanwhile, to make it more understandable a bar chart is provided to show how many cassettes were waiting in each location of group 1 for more than 3 days (Figure 21). So, it would be much easier to compare different locations and decide which location should be root cause analyzed first. As it is depicted in Figure (21), there were 955 and 883 cassettes waiting in H2 and H5 for more than 3 days respectively. So, it is worth to find the reason why these high number of cassettes were waiting in these two locations. In addition, there were 623 cassettes waiting in Hall 11 and 500 cassettes waiting in MTB in the investigated duration. Meanwhile, there were only 79 cassettes waiting in Hall 9 which shows a continuous flow in this treatment station.
5.3.2 Group 2

Group 2 has 43913 transportation missions and 87% of this sample was waiting in one of Saxsträckan, Strenx, Hardox, Valsverk, or Proplate for less than 1 day (Table 9). There are 1616 cassettes in group 2 were waiting for more than 3 days, and 438 cassettes were waiting for more than 10 days. Since 87% of the cassettes had waiting time under 1 day, so the remaining 1616 cassettes are analyzed more in detail to find where they were waiting more.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean</th>
<th>Sample</th>
<th>Under 1day</th>
<th>More than 3days</th>
<th>More than 10days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group2</td>
<td>0.64 day</td>
<td>43913</td>
<td>87%</td>
<td>1616</td>
<td>438</td>
</tr>
</tbody>
</table>

Table 9: Group2

Figure (22) refers to the 5 different boxplots to make comparison among them in group 2. As it is depicted, in this group the maximum waiting time is related to a cassette that was waiting for 153.90 days in Valsverk. Regards to the spread of outliers and the number of outlier’s points, all five locations need to be studied more in depth to find the causes for these outliers.
As the statistics show for the group 2, the average waiting time of 1616 cassettes is 8.62 days. 
\[(8.6+11.7+6.4+5.3+11.1)/5=8.62\text{ days}\]

Hardox had a cassette with the maximum waiting time of 99.8 days and average waiting time of 8.6 days. Proplate had a highest waiting time with 70.3 days and the average waiting time in this location was 11.7 days. Saxsträckan had average and maximum waiting time of 6.4 days and 89.2 days respectively. Average waiting time in Strenx was 5.3 days and the maximum waiting time was 26.8 days in this location. Valsverk had 11.1 days and 153.9 days for average waiting time and maximum waiting time respectively.

Meanwhile, Figure (23) shows the frequency for the cassettes waiting for more than 3 days in each location of the group 2. As it is shown in the bar chart, in group 2, proplate can be prioritized to be studied more in detail first; as it had 710 cassettes waiting for more than 3 days. In addition, Strenx and Saxsträckan have almost the same number of cassettes (approximately 300 cassettes) waiting in these two locations. There were 171 cassettes waiting for more than 3 days in Hardox, also there were 122 cassettes waiting in valsverk.
5.3.3 Group 3  
Group 3 includes Central Lager and Sjoklagret with having 51065 transportation missions for the whole year 2017. Regards to the calculated waiting time, 75% of the cassettes were waiting under 1 day and 5957 cassettes were waiting in one of these two locations for more than 3 days; also, there were 1396 cassettes waiting for more than 10 days. Now the focus of this study is on those 5957 cassettes waiting more than 3 days.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean</th>
<th>Sample</th>
<th>Under 1day</th>
<th>More than 3days</th>
<th>More than 10days</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Lager, Sjoklagret</td>
<td>1.46 day</td>
<td>51065</td>
<td>75%</td>
<td>5957</td>
<td>1396</td>
</tr>
</tbody>
</table>

Table 10: Group 3

As for Figure (24), the frequency and variability of outliers are depicted. As mentioned before each outlier indicates one problem which strongly influences the result and needs to be studied more to find out the reason why it happens. With respect to this boxplot, the average waiting time in group 3 is 10.87 days for those cassettes that were waiting for more than 3 days.

\[
\frac{(8.14+13.60)}{2}=10.87 \text{ days}
\]

Likewise, the maximum waiting time in group 3 is related to Central Lager and it was 220.67 days, and the maximum waiting time in Sjoklagret was 136.58 days. Although both these two
locations should be studied more, Central Lager has priority to Sjoklagret; since it had a greater number of stocked cassettes.

![Boxplot of Waiting time by Location (Group3, waiting time more than 3 days)](image-url)

**Figure 24:** Boxplot Group 3

Provided bar chart makes it easier to see how many cassettes were waiting in these two locations for more than 3 days (Figure 25). As it is shown, there were 4883 cassettes waiting for more than 3 days in Central Lager which is really a considerable number of cassettes. Since one station cannot continue working just because of waiting for only one empty cassette. Moreover, there were 1074 cassettes waiting in Sjoklagret for more than 3 days.
5.3.4 Group 4

Group 4 includes Centralverkstan which is the central workshop and had 142 transportation mission for the whole year 2017 (Table 11). The average waiting time of each cassette in this location was 11.33 days, 66% of all cassettes were waiting under mean, and there were only 28% of the cassettes waiting under 1 day.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean</th>
<th>Sample</th>
<th>Under 1day</th>
<th>More than 10days</th>
<th>Under mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 4 Centralverkstan</td>
<td>11.33 day</td>
<td>142</td>
<td>28%</td>
<td>45</td>
<td>66%</td>
</tr>
</tbody>
</table>

Table 11: Group 4

Boxplot of waiting time of each cassette by location is depicted in Figure (26). As for this boxplot, there were 40 cassettes waiting more than 11 days and the maximum waiting time was 118.96 days. In addition, the frequency of the outliers in this boxplot is less compared with other groups.
There were 9690 transportation missions in group 5 from which 9000 missions were related to Harsco (Table 12). The average waiting time in group 5 is approximately 2 days and 86% of the cassettes were waiting less than 2 days. The average waiting time is increased 3 times and there were 451 cassettes waiting in one of these locations for more than 6 days, also there were 277 cassettes waiting for more than 10 days.

**Table 12: Group 5**

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean days</th>
<th>Sample</th>
<th>Under mean</th>
<th>More than 6 days</th>
<th>More than 10 days</th>
<th>Harsco</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group5</td>
<td>1.92</td>
<td>9690</td>
<td>86%</td>
<td>451</td>
<td>277</td>
<td>9000</td>
</tr>
</tbody>
</table>

The focus of the study is on those 451 cassettes waiting for more than 6 days and the related boxplot is presented in Figure (27). Likewise, the average waiting time for the cassettes waiting more than 6 days in group 5 was 30.45 days.
As it is depicted in the boxplot, Harsco, LåtStå, and TrasigaKassetter need to be investigated more in detail. In addition, Harsco and TrasigaKassetter had the cassettes with most waiting time of approximately 308 days. LåtStå had a cassette which were waiting for 90.88 days in the year 2017. Meanwhile, during the studied duration there were only 6 cassettes waiting in OkäandPlats for more than 6 days.

Figure (28) is a provided bar chart to show the number of waited cassettes for more than 6 days in each location of group 5. As it is depicted Harsco with having 209 cassettes, had the greatest number of cassettes waiting for more than 6 days which needs to be studied more. The next location for studying is TrasigaKassetter with having 162 cassettes waiting for more than 6 days.

<table>
<thead>
<tr>
<th>Location</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harsco</td>
<td>209</td>
<td>23,890</td>
<td>37,641</td>
<td>6,0076</td>
<td>308,23</td>
</tr>
<tr>
<td>LåtStå</td>
<td>74</td>
<td>25,013</td>
<td>31,391</td>
<td>6,1787</td>
<td>190,48</td>
</tr>
<tr>
<td>OkändPlats</td>
<td>6</td>
<td>43,317</td>
<td>36,921</td>
<td>7,8667</td>
<td>90,882</td>
</tr>
<tr>
<td>TrasigaKas</td>
<td>162</td>
<td>29,627</td>
<td>43,951</td>
<td>43,623</td>
<td>307,49</td>
</tr>
</tbody>
</table>

**Figure 27: Boxplot Group 5**
5.3.6 Group 6

Fiskbenet, Delivery, and Harbor are the three locations in Group 6 and there were 13947 transportation missions in this group for the whole year 2017 (Table 13). The average waiting time in group 6 was 1.64 days and 82% of all cassettes were waiting under 2 days. Thus, these 2 days is increased 3 times and it is found that there were 876 cassettes waiting for more than 6 days in one of these locations. Moreover, there were 155 cassettes waiting for more than 20 days in group 6.

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean</th>
<th>Sample</th>
<th>Under 2days</th>
<th>More than 6days</th>
<th>More than 20days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 6</td>
<td>Fiskbenet, Delivery, Harbor</td>
<td>1.64 days</td>
<td>13947</td>
<td>82%</td>
<td>876</td>
</tr>
</tbody>
</table>

Table 13: Group 6

Figure (29) is made to show a comparison among these three locations and as it is shown both Fiskbenet and Delivery had greater numbers of outliers. Maximum waiting time in this group was related to Fiskbenet with 210.27 days. In addition, maximum waiting time of a cassette in delivery was 107.03 days, and maximum waiting time in harbour was 124.95 days. The average waiting time of those cassettes waiting in group 6 for more than 6 days was approximately 17 days.

\[
(13.13+16.41+21.44)/3 = 16.99 \text{ days}
\]
Figure 29: Boxplot Group 6

Figure (30) is created based on the number of cassettes waiting more than 6 days in one of the locations of group 6. As for this bar chart, there were 513 cassettes in Fiskbenet and 341 cassettes in Delivery were waiting for more than 6 days. Both Fiskbenet and Delivery should be studied more in order to find the reason why there are these numbers of cassettes waiting for more than 6 days.
Figure 30: Bar Chart Group 6
6. Recommendations

This chapter includes suggested recommendations for eliminating the identified wastes, filling the existing GAPs, and some general recommendations. These recommendations are given based on all collected data and their analyses.

Research Objective 4

Research objective 4 is presented in this chapter since it is related to giving recommendations to eliminate discussed wastes. Recommendations are categorised based on the research objectives and they are given specifically for each problem area.

6.1 Recommendations for RO1

Priority System and Way of Working: Based on the discussions in the previous chapter, the priority system does not work properly, and drivers do not follow this system. However, several employees are spending a significant amount of time on this system, so the priority system should be studied and a root cause analysis should be done to find why drivers do not follow this system.

A written working procedure should be made to help all drivers with different levels of experiences. This procedure should explain the most effective and efficient way of working for drivers and it can be the first step through standardization. Also, it can be a basis for evaluating the performance of drivers and the results of this evaluation would be helpful for having continuous improvement. Providing a performance measurement system can help the transportation department to not only evaluate the current situation but also evaluate new implementations to check if they are working effectively or not.

Availability of Carriers: considering the waste of human resources and 3MU, it is highly recommended to have required numbers of carriers on each shift. The advantages involved with having all required carriers are to have no waste in human resources, normal working pressure for all drivers, and faster working process.

Pre-scheduled Meetings: with respect to the key role of discussions and information meetings in continuous improvement, it is recommended to set pre-scheduled meetings with drivers. These meetings provide drivers with opportunity of sharing their experiences and discussing about the new ideas. Additionally, the results of evaluating the performance of drivers can be discussed during these meetings.

Delay Reports: delay reports are important communications between treatment stations and transportation department and can be very useful for them. However, delay reports are not valid and are ignored by everyone. It is recommended to make delay reports valid by explaining for operators in treatment stations that why these reports are not valid and ask them to enter the codes at the right time. Also, this problem can be solved by connecting the delay reports to carriers’ system. Then, a system can automatically calculate the delay time, when a carrier delivers the requested cassette to a treatment station.
Specific Locations for Empty Cassettes: according to presented discussions about location of empty cassettes, it is recommended to have specific locations with specific codes as middle storages for empty cassettes. As a result, drivers can find the empty cassettes more easily and the usage of empty cassettes can be analyzed. To be more precise about this recommendation, it should be mentioned that, layout and locations need to be investigated in order to find a specific location for empty cassettes. This location should be easily accessible for drivers.

6.2 Recommendations for RO2

Pre-sorting the Plates: regarding the high number of suppliers and limited space in Hall 10 and Hall 11, it is recommended to pre-sort the plates for the next two destinations before sending them to Hall 10 and Hall 11. In this way, plates would be cut and sent to the next destinations faster than before since there is no need for sorting them in Hall 10 and 11. As mentioned in the discussions, Gemba and Root Cause Analysis are useful tools for solving this type of problem; since the reason of why plates are not pre-sorted should be found. Different cases for pre-sorting should be investigated, perhaps pre-sorting is not applicable for all stations or destinations, but it can be done for specific stations at least.

Layout Design: regarding the problem with layout design, it is required to have a detailed analysis that shows the advantages, disadvantages, and costs of removing the wall between H5 and H4. While the wastes that are existed in the current way of working are discussed in depth. There should be a calculation and evaluation to find how many cassettes is used between H4 and H5; so, how many cassettes will be free if the wall is destroyed.

Quality Control: as mentioned before, there are several wastes related to quality control in H5 and H2. Accordingly, it is recommended to use Lean tools such as Poka-Yoke and Root Cause Analysis to prevent a flow of defected materials through next steps in the processes.

VSM: it is recommended to use value stream mapping continually for all treatment stations. With the help of VSM, all stations can identify the probable wastes continually and VSM is the main step for continuous improvement. Moreover, changes in the way of working and new implementations can be evaluated with the help of value stream mapping.

6.3 Recommendations for RO3

With respect to the collected data for research objective 3 and related analyses, two types of recommendations are given.

Database: the first recommendation is based on the gathered data. As before mentioned, the required data series were collected from the TRS system. While during the analysis phase, it is found that there is another database in the company which is reporting the transportation missions. Likewise, both databases are studied and found that besides having similarities there are some codes which are different in two different databases. To make it more considerable and reliable it is recommended to combine these two systems to have one unique database.
This unique database will be understandable for all involved departments and these departments can easily communicate and discuss the terms. In addition, one unique database leads to more understandable analysis for responsible persons from different departments. Regarding the data base and reporting system, it is worth mentioning that, there are some inputs that are registered incorrect in the data base. These invalid inputs make quantitative analysis more complex and decrease its validity. It is recommended to use automated reporting system in internal transportations instead of entering the information manually by drivers and operators. For instance, when the location of a cassette is reported wrongly, that cassette will be lost because of the huge area and in some cases, it takes several weeks to find the cassette.

**Root Cause Analysis:** this recommendation is based on the analysis of RO3. As it is presented in tables, boxplots, and charts in the analysis there are many cassettes waiting in different locations for more than a specific duration. These cassettes can be unloaded and be involved in other transportation missions instead of staying in a queue for long period just waiting. In addition, with respect to the boxplots, there is a wide spread variation for outliers and as before mentioned each outlier indicates one problem which strongly influences the result. So, outliers regarding their importance of location and duration of waiting time should be root cause analyzed to find the reason why they happen. When the reasons are found, the next step is try to eliminate these reasons and as a result have more empty cassettes. Founded root causes can continually be controlled in order to make improvements and compare the current state with previous ones to see the improvements.
7. Conclusion
The conclusion of this study is presented in this chapter. Also, suggestions for further research in the studied area are given.

7.1 Conclusion of the Study
This thesis started with the purpose of having improvements in the internal transportation of SSAB Ozelosund. Improvements in this project are identifying the probable wastes in the internal transportation and providing recommendations based on theories to eliminate wastes. After understanding the way of working and defining the problem description, it was found that there are three different areas involved with the internal transportation of SSAB. The main resource in the internal transportation that strongly has influence in the transportation is known as cassettes. Three main areas that are in close relation with these cassettes are carriers, drivers, and treatment stations. Accordingly, four research objectives were designed to cover all problem areas and recommendations.

As this study was a combination of a quantitative and qualitative types of research, several interviews with responsible persons in different departments and observations from treatment stations were done for the qualitative part. Exporting data series from company’s database was done for the quantitative part. Simultaneously, the literature review was done in different areas specially Lean and logistics. In the theoretical framework, logistics theories, transportation, and all types of wastes and lean tools that are related to this project are presented.

Identified problems were presented in the fourth chapter with deep explanations about the problem area. In addition, discussions compared the current state with presented theories and explained that why the mentioned problems should be considered as wastes and what are the involved areas in that types of wastes. Required Lean tools for each identified waste were pointed out to provide the reader with an idea about the solution for solving the problem and eliminating the wastes.

Analyzing the research objectives showed that, one of the most important problems in research objective 1 was lack of standardization in the way that drivers are working, and this is happening because they cannot follow the priority system properly. So, it is recommended to study the priority system with the help of presented tools. The main problems in the second research objective were sending unsorted plates to Hall 10 and Hall 11, also layout design in H5 and H4.

Calculating the waiting times of cassettes in middle storages were done and provided plots with the help of Minitab were presented in the previous chapter. In these calculations, the focus was on the cassettes that waited more than 3 times of the average waiting time of each group. Accordingly, problems that were shown as outliers in the box plots should be analyzed with the help of root cause analysis.
7.2 Further Research

By following the defined research objective in this thesis, the first problem for further studies is priority system. There should be a study in this area to find out why the current system does not work properly and what the solutions for solving this problem are. Prioritization system uses many resources and directly has influences on the internal transportation and the way that drivers work; so, there should be a more in detail study. This study should be done for a few months back from the company’s current state to evaluate all different aspects of the prioritization system. The prioritization system can be more effective with a few changes and developments.

There should be a layout investigation for two different purposes. First layout investigation would lead to finding a suitable place as a storage for empty cassettes. As it is discussed, having specific location for empty cassettes would be a valuable step in improvements of internal transportation. Further researches can be done in finding the solutions for weak layout design in H5 and H4.

A study should be done to investigate the possibility of pre-sorting in all cutting stations’ suppliers. These investigations are individual since each of these suppliers have a specific layout design and individual way of working. The location and way of working in each supplier should be studied to find individual solutions for pre-sorting.

Regards to analyzing the waiting times of cassettes in middle storages, it is required to have pro-active way of working to be able to manage the cassettes’ usage in an optimized way. The ultimate aim of similar studies in the future besides this master thesis is to have an optimized internal transportation. In order to have an optimized model, there is a need for exact and accurate type of data. This kind of data should be reliable and unique within different departments. With help of such a data, the usage of cassettes for different stations can be calculated. Moreover, in the next step it is possible to predict the availability of cassettes for a specific location in a specific time. For instance, it is possible to forecast how many cassettes would be needed in 10 days in the cutting station.

Eventually, the role of performance indicators should not be forgotten in systems which want to have continuous improvements. As it mentioned before, performance indicators are required to evaluate the new implementations in both internal logistics and treatment stations.

7.3 Impact/Effort Matrix

With respect to the given recommendations and suggestions for further analysis, an impact/effort matrix is provided to show the relation between impact and required effort for analyzing and implementation. All the recommendations and suggestions for further research are mentioned in 14 individual items to present them clearer. The efforts are categorized in three segments as difficult, medium, and easy. Also, impacts are presented as high, medium and low respectively.
1- As the priority system does not work properly, there should be a root cause analysis for identifying why drivers do not follow the priority system.

2- Currently there is not a specific working procedure for drivers and they have different ways of working. A procedure should be prepared that shows the most effective and efficient way of working.

3- A performance measurement should be prepared based on the working procedure to evaluate the drivers’ performances continually.

4- Setting pre-scheduled information meetings with drivers for discussing continuous improvement.

5- Validating the delay reports.

6- Currently there are not any specific areas for storing empty cassettes, so some areas with specific codes should be allocated for storing empty cassettes.

7- Drivers cannot see the locations of empty cassettes, so they have to drive in the area to find a specific type of cassette that they need. Therefore, drivers should be able to see the information about the location of each cassette on the screen of their carriers.

8- Root cause analysis for pre-sorting the plates before sending them to Hall 10&11. (sorting based on next 2 destinations instead of next destination)

9- Analysis and investigation for changing the layout in H5 and H4

10- Root cause analysis for having more effective quality control especially before sending plates for painting in H5 in order to prevent Double Handling.

11- Setting performance indicators and defining the scope for having continuous performance measurements and being able to evaluate new implementations.

12- Making Value Stream Map for each treatment stations and control it continually, so personnel can identify the wastes in their stations and it can help them to evaluate new implementations.

13- Root causes analysis the outliers in presented boxplots.

14- Use (MRP) or (Resources Allocations) calculation for preparing a way to work proactive, analyze, control, and estimate the availability of the cassettes’ usage continually.

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**Figure 31:** Impact/Effort Matrix
8. References


Kahn, R.L. and Cannell, C.F., 1957. The dynamics of interviewing; theory, technique, and cases.


Appendix

Visiting Summary
During the visits from the treatment stations, there were several interviews with responsible persons and the summary from these conducted observations were confirmed by the responsible person. The following includes these summaries.

Hall 11 – 29. March.2018
Hall 11 is a cutting and welding station. During the visit, the whole station was stopped because of the failure in Magnetic Crain so we could not see the working processes. The station receives the cassettes while they are approximately fully loaded. Usually plates have five to eight different destinations after Hall 11. As a person who works in Hall 11, he supports the idea that it is much easier for them to receive the cassettes with one or two different destinations after cutting. After treatments, the plates are sorted on different cassettes and sent out to the next destination. In this station, it takes too much time to sort the plates after cutting and this is one of the considerable wastes. Delay time starts when the cutting machine does not work for six minutes and ends when the machine starts working again.

Hall 10 – 20. April.2018
Hall 10 receives plates from different stations. Before cassettes arrive, the operators in Hall 10 check the system that which type of plate is going to arrive. When they receive the loaded cassette usually it is not sorted for next destination after Hall 10. After receiving the cassettes, they unload the plates on the floor for cutting. The operators have the opportunity to check the next five destinations of each plate. However, after cutting the plates they cannot sort them based on next destinations, because they have neither time nor place. Johan supports the idea that it is much better to pre-sort the plates before arriving to Hall 10. In Hall 10, they send a mission to transportation system when the cassette is around seventy percent full. Regards to delay time, it could be mentioned that Delay time starts when the machine does not work for six minutes and ends when the machine starts working again. The most time-consuming activity is in the case that there is not available free cassette on time. Therefore, personnel at Hall 10 have to pile the plates on the floor since there is not any free cassette for them. Non-value adding activities in this station can be mentioned as waiting for cassettes and unnecessary movements because of the layout.

H2 – 24. April.2018
This station receives plates from different stations, also they have suppliers from the US, Finland, and Borlänge. The operators have access to the same system as Hall 10 and Hall 11 and they know the two next destinations after H2 but they sort the plates based on one next destination. After the treatment, plates on each cassette go to one specific destination but the
cassettes are not fully loaded. Since they do not want to breakdown the flow, the cassettes are not fully loaded. They send the mission to transportation system a few minutes before they have mostly load a cassette. In this station, they are connected to the same radio channel as carriers but Hall 10 and Hall 11 are not connected to this channel. Therefore, operators in this station have better understanding of the day-to-day situation of carriers. With respect to the delay times, it could be mentioned that delay time starts when the machine does not work for six minutes and ends when the machine starts working again. Same as Hall 10 and Hall 11 machine asks the reason for the delay after six minutes. The interviewee believes that delay time list is not accurate. Double working is the most known waste in this station since not only time is wasted for re-treatments, the operators, transportations, and cassettes are wasted. Defected plates should be loaded on the cassettes and sending them to the beginning of process for re-treatment or other stations to repair. The ideal process from interviewee’s point of view is sending the cassettes gate to gate instead of sending to Mellanlager and waiting there. This leads to fewer missions and less delay time.

H5, H4, BLM - 25. April.2018
In this station at the beginning, plates are sorted based on the length of each plate and delivery type such as ship or train. The operators have the opportunity to check the next five destinations of each plate. When the painting and blasting is done, the plates are loaded on cassettes based on their length. Plates that are less than six meters should be sent to another station called Småplåten for sorting based on delivery type. The plates that are more than six meters are sent to H4 for sorting. When 90 percent of a cassette is full, they order a mission and in the case that there is no available cassette on time they have to stop the line. With respect to the delay times, it could be mentioned that delay time starts when the machine does not work for six minutes, and ends when the machine starts working again. The interviewee claimed that sometimes they received a plate with defects and they have to send it to other stations for repair. They always have a cassette on which they load plates with defects and it takes two or three days to fix the defects. The most significant waste in this station is lack of internal transportation between H5 and H4. Currently the plates are painted and blasted in H5 then they are loaded on cassettes and sent to H4 or Småplåten for sorting. Sometimes the H4 or Småplåten do not have free place for these cassettes and they send the cassettes to Mellanlager. It should be mentioned that the working process in H5 is faster than H4. H5 is working continually and H4 is a batch.