INTERNAL MATERIAL HANDLING AT VOLVO CONSTRUCTION EQUIPMENT BRAÅS

Degree project Advanced Level - Business Administration
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Acknowledgement

In a time-frame of ten weeks we have had both the privilege and responsibility to accomplish a full study regarding the internal material handling at Volvo Construction Equipment in Braås. The helpfulness and support from a wide range of employees at Volvo CE Braås made the fulfilling of this study possible. We wish to thank especially the project owner Mikael Svensson and project contact Linda Oredsson at the Global Logistics Development in Arvika and Braås for always being there for us. We are also grateful to Volvo CE Arvika and Volvo Trucks Gothenburg.

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Summary

Degree project Advanced Level - Business Administration, School of Management and Economics at Växjö University, Business Process and Supply Management, FE3054/IB3504, Spring 2008

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Title: Internal Material Handling at Volvo Construction Equipment Braås

Background: Material handling is a large part of a company’s internal work and represents between 15% and 70% of the total cost of a manufactured product. By improving the internal handling of material, more efficient distribution and manufacturing flows are possible. The material handling process is an input to the production and assembly process that has to be defined and mapped so that it can be improved. The material handling process studied at Volvo CE Braås includes goods receiving, storage, packaging as well as the order/delivery process to assembly, and will finish with the material transport to the assembly line.

Research questions:

- How can the material handling process, from goods receiving to assembly line, at Volvo CE in Braås be described by using VSM?
- What kinds of waste can be identified?
- By proposing a future-state map, how can the identified problems and waste be reduced or eliminated?

Methodology: This thesis is a descriptive case study and was conducted with a deductive approach. Data was collected by our own observations, personal interviews, statistics, benchmarking and questionnaire. The scientific credibility of this thesis was secured by for example using many sources, avoidance of assumptions, studying a common process and following standardized steps of the VSM tool.
**Conclusions:** The material handling process was described in the separated areas of goods receiving, storage and assembly line. Visualization was given in a current-state map. Five different kinds of waste were identified. Finally, suggestions of improvements were presented along with a future-state map.

**Suggestions on future research:** A more detailed VSM including information flow and lead times could be studied. Scenario simulations of critical areas within the material handling process could be performed. Furthermore, an ABC classification of articles and storage locations can be done to optimize storage.
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<td>Construction Equipment</td>
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<tr>
<td>JIT</td>
<td>Just In Time</td>
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<td>LCD</td>
<td>Liquid Crystal Display</td>
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<td>NNVA</td>
<td>Necessary but Non-Value Adding</td>
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1 Introduction

Increasing competition in the business environment has influenced production industries during the last decades. Also Volvo CE Braås needs to adjust to these changes. A new Volvo production system was recently developed. In order to define a level of implementation the current situation needs to be analyzed. The main objective of this thesis is to describe the internal material handling process at Volvo CE Braås and give suggestions on how to improve it. A continued disposition will show the structure of this thesis and a timeframe picture, how the work of this thesis was scheduled and how the work was finally performed.

1.1 Background

In the last decades companies have faced more and more competition on the world market\(^1\). Today it is common practice to source and supply globally\(^2\). This is a great potential for the manufacturing companies, but also an increasing necessity for cost-effectiveness, which alone is not enough anymore.\(^3\) Because of the high competition, companies have to change internal processes continuously\(^4\). The intensity has increased more and this results in shorter life-cycles, shorter lead times and more need of flexibility.\(^5\) These, and also the focus on time and responsiveness, link the external market changes with internal activities to stay competitive\(^6\).

Lean management is a concept developed by the Japanese company Toyota Motor Corporation to create fast and flexible flows in processes. It helps to improve the quality and productivity and minimizes all unnecessary stages in the production that do not add value.\(^7\) There are several tools that can be used to reduce waste and improve processes, for example value-stream mapping (VSM) and takt time (a method of translating true quantitative customer requirements into production targets\(^8\) and balancing the workload among the operators and different work stations\(^9\)). VSM refers to the drawing of an

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1 Dickmann, P. (2007) p. 6
3 Dickmann, P. (2007) p. 6
5 Dickmann, P. (2007) p. 6
8 Seth, D. & Gupta, V. (2005) p. 51
9 Volvo CE Intranet
existing state map and afterwards developing a prospective map with improvements. By decreasing the amount of inventory and by handling it more effectively the company will be able to reduce waste.

Material handling is a large part of a company’s internal work and represents between 15% and 70% of the total cost of a manufactured product. Furthermore the material handling in average takes 55% of all factory space and 87% of the production time. By improving the internal handling of material more efficient distribution and manufacturing flows are possible. It is important to have the right materials in the right amount and at the right place to perform well. Other advantages of a well-organized way of handling material are lower inventories and improved safety. This leads, in addition to the just mentioned advantages, to the opportunity of large cost savings for the company.

In Volvo Group a new production system was recently developed in order to measure and improve the production processes. This system is called Volvo Production System (VPS) (Figure 1.1). The foundation is the “Volvo way”, which implies the whole organization’s business environment. The goal of the VPS is to satisfy customers by continuous improvements, built-in quality and JIT, which are reached through stable processes and teamwork. JIT includes material supply, continuous flow processing, takt time, pull systems and flexible manpower system. The material handling process is an input to the production and assembly process that has to be defined and mapped so that it can be improved. In the VPS, this part is named as material supply and includes different processes like transportation, goods receiving, packaging, inventory, assembly line ordering and feeding.

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14 Arnold, J. R. T. et al. (2008) p. 2
16 Svensson, M. Volvo CE, Manager of Global Logistic Development, 2008-03-26
Today the theoretical perspective of for example inventory management has been deeply studied. It is, however, not that common used in companies and a gap exists between theoretical solutions and real problems of companies. With this thesis a theoretical perspective connected to an empirical perspective can help to overlap the existing gaps.

1.2 Problem discussion

The Volvo Group has been a growing business over many decades. But market change, shorter life cycles and higher expectations of customers have forced Volvo Group to increase speed along with a higher quality demand. As a result, the different business areas of the Volvo Group have tried to adapt to the changes in their business environment. Today, each production location has its own way of organizing the production, the material flow and an overview of how processes are handled are missing. For the implementation of the new VPS it is necessary to have a common base at all production plants. In addition, a level of implementation needs to be identified for each plant, since the plants have developed differently. In order to do that it is necessary to draw detailed maps of the current situation and to identify the methods that are already in use. There are a large number of methods, hereafter referred to as principles, which can be used in a material handling process. For example assembly line ordering and feeding can be based on principles such as kanban, sequenced deliveries etcetera.

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17 Svensson, M., Volvo CE, Manager of Global Logistic Development
The gathered information can also be used to compare the different plants with each other.\textsuperscript{19} Moreover, the identified principle or principles can be assessed with the help of theory and comparison with best practice companies.

The company is facing difficulties with resources allocated on activities that do not add value to their products. In other words, the company is increasing their costs but cannot increase the price on the products. Resources that can be used to increase the value of the products are tied up in the non-value adding activities. Therefore these non-value adding activities should be eliminated or at least minimized. One main focus of VPS is the elimination of non-value adding activities, waste. This is not an uncomplicated task. First waste has to be identified; and many questions have to be answered before this can be accomplished. Like for example, what can be regarded as waste? Furthermore, can these activities be completely eliminated or are they crucial for the functionality of the process? This requires a structured work effort. The VSM is a functional method aimed at reorganizing production systems\textsuperscript{20} and its ultimate goal is to identify and eliminate all types of waste\textsuperscript{21}. The “value stream” identified with this method reveals all procedures, that are value adding and non-value adding in the existing production flow\textsuperscript{22}.

The production process at Volvo CE Braås consists of a vast amount of sub processes; so where to start identifying and eliminating waste? The material handling process, which is a part of the production process, is one broad area in which various improvements can be done. Material handling is moving, storing, protecting, and controlling material\textsuperscript{23}. The material handling for Volvo CE Braås is divided into following six categories, which the company refers to as inbound strategies; supplier, transportation, warehousing, supply, packaging and assembly line. Inbound strategies refer to all incoming goods to the plant. The last four inbound strategies are internal (occur within the factory) and are better suited to be grouped into one project. These four inbound strategies can then be divided into the single areas this thesis will mainly focus on (Figure 1.2). This includes goods receiving, storage, packaging as well as the

\begin{itemize}
  \item \textsuperscript{19} Svensson, M. Volvo CE, Manager of Global Logistic Development, 2008-03-26
  \item \textsuperscript{20} Lasa, I. S., Laburu, C. O. & Vila, R. D. C. (2008) p. 40
  \item \textsuperscript{21} Abdulmalek, F. A. & Rajgopal, J. (2007) p. 225
  \item \textsuperscript{22} Rother, M. & Shook, J. (2003) p.3
  \item \textsuperscript{23} Tompkins, J. A. et al. (2003) p. 164
\end{itemize}
order/delivery process to assembly, and will finish with the material transport to the assembly line. The material handling within the manufacturing area is not included.

Within this scope of the four chosen inbound strategies (warehousing, supply, packaging and assembly line) some questions arise. The first, warehouse strategy, concerns which kinds of warehousing are used/will be used in the future? Supply strategy; how does the physical and administrative handling looks like from warehouse to line and how will it look like when implementing VPS? The packaging strategy provokes questions like what type of packaging material exists today and what will be the future needs when implementing VPS? Finally, the strategy with assembly line in focus, following questions should be in consideration; what does the work stations look like and what kind of demands can occur when cross functional teams will implement takt time, pull systems and strive to drive waste out of the line?

1.3 Research question

As a result of the problem discussion above, the importance of a current state map of the internal material handling process (continuously referred to as material handling process) at Volvo CE Braås can be clearly understood. Furthermore, the identification of existing waste is an important task, which has to be accomplished before the new VPS is implemented. In accordance with the statements the following research questions were formulated:

- How can the material handling process, from goods receiving to assembly line, at Volvo CE Braås be described by using VSM?
- What kinds of waste can be identified?
By proposing a future-state map, how can the identified problems and waste be reduced or eliminated?

1.4 Objective of the study

The objective of this study is to describe the current material handling process from goods receiving to assembly line at Volvo CE Braås with the help of the tool VSM. Furthermore, existing non-value added activities should be identified. Moreover, solutions about how to eliminate the identified waste and how to balance the material handling processes should be suggested. Therefore, a future state map for the material handling process should be presented. The recommended changes should help Volvo CE Braås to decrease time and costs in the studied areas, balance the takt time and provide a fundament for the implementation of VPS and the possibility to compare with other plants of the company.

1.5 Disposition of the thesis

The Master thesis will be continued in following disposition (Figure 1.3). Each arrow can be identified as a single chapter of the thesis.

1.6 Timeframe

The following timeframe (Figure 1.4) was created in order to plan the continuous work for the thesis.
This predicted timeframe was then compared to the real development at the end of report writing (Figure 1.5). Besides adding an additional task, namely “benchmark”, also the study of theory, the collection of empirical data, and the whole report writing have taken more time, then planned in the predicted timeframe. This was mainly due to the additional task of benchmarking, which required traveling to two different plants in Sweden. The changes are visualized in orange.
2 The Company presentation

The chapter company presentation is introduced by a short presentation about Volvo Group to give the reader a general overview about the structure of the company. Furthermore, the Business line articulated hauler in Braås is presented. A description about the background of the articulated hauler business plus additional facts about the production today is given.

2.1 Volvo Group

Volvo Group was founded in 1927 in Gothenburg, Sweden by its former owners Assar Gabrielsson and Gustaf Larson. The official start was, when the first series-manufactured Volvo car was produced. It has since then sold the car division in 1999 and expanded into six other business areas; trucks, buses, construction equipment (Volvo CE), penta, aero and financial services (Figure 2.1). Additional, a number of business units were established in order to support the business areas in development, purchasing and service. The main business units are: Volvo 3P, Volvo Powertrain, Volvo Parts, Volvo Logistics, and Volvo Information Technology.24

Figure 2.1 - The organization of the Volvo Group25

Volvo Group ranks today among the world’s largest manufacturers for construction equipment and busses, and world’s second largest manufacturer for heavy trucks26. Its

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24 Volvo CE Intranet, accessed 2008-04-10
25 Volvo CE Intranet, accessed 2008-04-10 (modified)
vision is “*to be valued as the world’s leading supplier of commercial transport solutions*”\textsuperscript{27}. Volvo Group has defined the core values: quality, safety and environmental care. These values are based on a long tradition and influence the corporate culture and the way of working.\textsuperscript{28}

Throughout 2007, Volvo Group increased the number of employees to about 100,000. Most of the employees are based in Sweden, France, Japan, USA, China, Brazil and South Korea. The Volvo Group operates production facilities in 19 countries and supplies its products to circa 180 countries worldwide.\textsuperscript{29} The company increased net sales in 2007 by 10 % to SEK 285 billion, compared to the previous year. Furthermore, the total operating income increased since 2005, stable by SEK 2 billion every year, to SEK 22.2 billion in 2007.\textsuperscript{30}

### 2.2 Volvo CE Braås

The articulated hauler is a vehicle used to transport large volumes of material in terrain that is difficult to access (Figure 2.2). In 1966 the first series-produced hauler was manufactured in Braås. Then, the production plant was owned by Lihnell's Vagn AB (LIVAB). 1974 the company merged with Volvo Group and has since then been a part of it. Today, the articulated hauler production is a Business Line (BL) within the Business area Volvo CE and since 2005 merged with the Loader BL to the Hauler-Loader Business Line (HLBL). Volvo CE is one of the main business areas of the Volvo Group (Figure 2.1). Different kinds of equipment are offered in this Business area (e.g. wheel loaders, excavators, motor graders, compact machines etcetera) (Figure 2.3). The products are used for general construction, road construction, mining, forestry and other areas. The articulated hauler is one of the major products.\textsuperscript{31}

\textsuperscript{27} The Volvo Group (2007) p. 2
\textsuperscript{28} The Volvo Group (2007) p.2
\textsuperscript{29} The Volvo Group (2007) p. 1
\textsuperscript{30} The Volvo Group (2007) p. 5
\textsuperscript{31} Volvo CE HLBL, internal presentation
The headquarters for the articulated hauler production is in Braås (Sweden). A second production plant is situated in Pederneiras (Brazil) whereas there, only assembly is executed. The production plant in Braås includes besides assembly also the manufacturing of components like front and rear frames, and bodies. Furthermore, the administrative departments (e.g. human resources, economy), aftermarket support, research & development (R&D) as well as IT, purchasing and global marketing are situated there. The total workforce of the production plant is about 900 employees at the moment.

In 2007 the new E-series of articulated hauler was launched which have even better off-road performance, productivity, comfort and safety for the operator. The series consists of four models: the smaller A25E/A30E and the bigger A35E/A40E. All four models

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33 Volvo CE HLBL Internal presentation
are produced at Volvo CE Braås. During 2001 and 2007 the production volume has increased by 86%. In 2005, a number of 50 haulers per week were produced. Today, even more than 50 Haulers are produced and a strong increase is planned for the next years. Volvo CE Braås leads the development of articulated haulers and with a market share of 34 % also holds the world leading position in manufacturing and selling articulated haulers.
3 Methodology

The purpose of this chapter is to present how this thesis was conducted. The scientific perspective is mainly positivistic since the study of the material handling process follows theoretical frameworks. Moreover, a deductive approach using theory as basis to explain the studied process was chosen. Both qualitative and quantitative research methods where required to conduct this descriptive case study. Primary and secondary data were collected by different methods. Finally, the scientific credibility and reliability for this thesis are debated.

3.1 Scientific perspective

The scientific perspective concerns the researcher’s knowledge of theory and how the author sees the empirical reality. There are two general perspectives; the positivistic and hermeneutic perspective.\(^{37}\) In the positivistic perspective the researcher uses a general theory as a framework to support the study and build hypothesis that can be tested on the research subject in the real world. The researcher should stay objective and study the research subject from a distance.\(^{38}\) The hermeneutic perspective claims that it is not possible to do a perfectly objective interpretation of a situation. The researcher uses own preferences and assumptions, in order to create an interpretation of the situation aimed for the study.\(^{39}\) Here, subjectivity is used to understand the situation.\(^{40}\)

Scientific perspective of this thesis

This thesis mainly has a positivistic perspective since it uses general theory, such as lean production and VSM, as support to conduct a study of the material handling process at Volvo CE Braås. First information about the chosen theories were gathered and later on used to study the research subject. This allows little subjective values since theory is used to interpret the empirical findings. To further explain this thesis follows the VSM in order to map and analyze the current material handling process. Theories like material handling, kanban and waste were gathered to explain different strategies that the company uses.

\(^{40}\) Patel, R. & Davidsson, B. (1994) p. 27
3.2 Scientific approach

There are two scientific approaches; deductive and inductive. The deductive approach can be seen as a validating way and the inductive approach as a discovering way.\(^{41}\) In the deductive approach the researcher starts with theories and predictions about the expected empirical findings. This should then be verified by collected data.\(^{42}\) Moreover, with theory as a starting point an assumption about how a phenomenon works in reality can be made\(^{43}\). A deductive approach is for example using theories about organizational structures to define the organizational structure of a specific company\(^{44}\). The inductive approach is the opposite of the deductive. Here, theories are developed using the collected data. The researcher starts to discover patterns in the data that can be summarized in models and theories.\(^{45}\) This approach is common in explorative research or case studies. The purpose of the research or case study would then be to study a few objects in order to make a general assumption that in turn, after several case studies, can be translated into theory.\(^{46}\)

**Scientific approach of this thesis**

The deductive approach is used in this thesis. The validating way, is an approach to explain the material handling process by using existing theories. In this thesis, theories about material handling and kanban are presented in the theory chapter along with the VSM model. It is used to define the material handling process at Volvo CE Braås. This is related to the first research question. Theories about waste were used to identify different kinds of waste at the company. This primarily relates to the second research question. The theories about kanban and VSM are used to answer the third research question in order to suggest possible future changes.

3.3 Research method

The choice of research method depends on the purpose of the study and how the researches will analyze the gathered information. There are two methods, quantitative

\(^{41}\) Patel, R. & Tebelius, U. (1987) p. 17
\(^{43}\) Patel, R. & Tebelius, U. (1987) p. 17
\(^{44}\) Andersen, I. (1998) p. 30
\(^{46}\) Andersen, I. (1998) p. 30
and qualitative. The quantitative research method is appropriate when the empirical findings can be measured or valued numerically.\textsuperscript{47} Surveys and mathematical models are examples of methods used in a quantitative research. In the qualitative research method the researcher wants to acquire a deeper understanding about a specific subject, event or situation. In this research method observations and interviews are common data collecting approaches.\textsuperscript{48} In conclusion, the quantitative variables are characteristics that the research object has more or less, for example length. The qualitative variables on the other hand are characteristics that the object has or does not have, for example gender (man/woman).\textsuperscript{49}

**Research method of this thesis**

This thesis used both the quantitative and qualitative research methods. The collected quantitative data were statistics of for example number of deliveries, lead time and inventory turnover. These figures were used to identify waste or shortages in the studied material handling process to be able to suggest improvements. In order to gain a deeper understanding of the present state of the process a qualitative research method was used. This is for example knowledge about how the material is replenished, stored and received.

### 3.4 Case study

The decision of doing a case study lies in the type of study that will be conducted. The case study method is a research of a specific object or phenomenon.\textsuperscript{50} An advantage of case studies is that the studied subject is happening in a real life situation. A disadvantage, however, is that the result of an isolated case study cannot tell whether the studied subject is common or that similar circumstances are prevailing in other organizations.\textsuperscript{51} Case studies are suitable for research questions that are formulated as

\textsuperscript{49} Rosengren, K.-E. & Arvidson (2005) p. 187
\textsuperscript{50} Merriam, S. B. (1994) p. 24
\textsuperscript{51} Wallen, G. (1996) p. 115
Moreover, case studies are conducted for different purposes and named based on these. Two are mentioned below:

- To formulate hypotheses is called an explorative case study.
- To exemplify and illustrate is called a descriptive case study.

A third case study called explanatory case study is used when cause and effect correlations are needed to explain a complex situation. All different kinds of case studies are conducted in an extensive way which means many observations about few information units.

**Case study of this thesis**

The first research question of this thesis, that aims to describe the material handling process at Volvo CE Braås, is a “how” question and conducting a case study is then an appropriate choice of research method. The type of case study that was used for this thesis is the descriptive case study. The advantage of using the descriptive case study is that it illustrates how the material handling process looked like at the time of conducting this thesis by mapping the process. Observations of the different areas included in the material handling process at Volvo CE Braås, goods receiving, storage, ordering from the assembly line and internal transportation was done over several days during a six week period. The second research question aims to identify waste in the described process. Furthermore the third research question aims to eliminate or minimize waste this needs an explanatory case study approach. The explanatory case study approach would be a cause and effect assessment of the identified waste and ways of eliminating or minimizing this waste. This would be necessary in order to present reliable results.

### 3.5 Data collection

There are two types of data; primary and secondary. The primary data is all material that has been collected by the researcher for a specific study. Collecting this data can be

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done through interviews, observations or questionnaires. Interviews can be held by personal direct contact, phone, e-mail or other communication media. Moreover, there are three different types of interviews; structured, semi structured, and unstructured. In the first, structured interviews, questions are predetermined and asked in a specific order. In semi structured interviews predetermined questions are not used. However, the interviews are held for a specific subject. During the interview questions are formulated to bring more understanding about this subject. The third interview type is not bound to a specific subject and therefore questions cannot be designed.

Observations can be done in different ways. Participating observation, the researcher participates in the studied activity. The researcher can also just observe the activity either with the observed objects knowledge or in secrecy. Observations are often a time consuming method but can retrieve more objective information. In collecting data by conducting a questionnaire the researcher does not have to be present when the answers are filled out. The questions can have different levels of structure and standardization. The structure indicates to how leading the questions are and the order in which the questions are arranged. The standardization is regarding to what extent the respondents are exposed to the same questions. Moreover, standardization has to do with the way the respondents can give their answers, open or closed categories. Closed categories are when the respondents are given a number of different alternatives which they can choose from for their answer. The open is the opposite, the respondent formulate an answers with his/her own words.

Secondary data are material that were collected and analyzed in another purpose than for the actual study. The difficulty lies in retrieving the right information. Also, there is a risk that secondary information contains the researcher’s subjectivity. Secondary data is all written material and a way to study written material like books, brochures and articles is called literature studies. However, there is no type of source that is better than the other. They complete each other, therefore the use of more than one type of source

is recommended.\textsuperscript{61} One benefit with this method is that the researcher, under a short time and scarce resources, can acquire a great deal of information. Moreover, it is a method that will increase the researcher’s knowledge about the subject. However, it is important to question the secondary data since it is not always clear how the information was gathered and in which purpose.\textsuperscript{62}

Data collection of this thesis

Both primary and secondary data were collected for this thesis to gain a wider perspective. The primary data was collected by interviews and observations. The interviews were mainly semi structured in order to let the respondents answer without limitations and to get a broad explanation about the topic. The information was mostly gathered through face to face meetings (Table 3.1), but also telephone conferences and e-mail contact. Observations were made to get a picture of the current performance and workflow, and to measure lead-times. Volvo CE in Arvika and Volvo Trucks in Gothenburg were visited in order to benchmark their principles. Observations and interviews were conducted during the visits in order to collect information about the two plants assembly line ordering and feeding principles, their storages, internal transportation etcetera. The main purpose with benchmarking the two plants was to find out which principles could be considered to be successful and preferred over others. Moreover, benchmarking other plants introduced other views of how to organize the flow of material from goods receiving to assembly line.

The assembly area at Volvo CE Braås have over 18 workstations and to interview or observe each one would require more research time than what was available. However, in order to cover as many workstations as possible in the assembly line a questionnaire with seven questions was handed out (see appendix I). The purpose for this questionnaire was to identify deviations, problems and possible improvements that the assembly line workers experience.

Due to the large amount of interviewed employees sources are not mentioned in the empirical, benchmarking and therefore also not in the analysis chapters.

\textsuperscript{61} Yin, R. K. (2003) p.86
Interviews at Volvo CE Braås conducted between 7th of April and 21st of May 2008:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position/Department</th>
<th>Type of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linda Oredsson</td>
<td>Global Logistic Development</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Jerry Fransson</td>
<td>Responsible for material handling</td>
<td>Personal interview, factory tour</td>
</tr>
<tr>
<td>Dan Fransson</td>
<td>Foreman material handling</td>
<td>Personal Interview</td>
</tr>
<tr>
<td>Carl Sigfridsson</td>
<td>Instructor Material handling</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Karl-Erik Davidsen</td>
<td>- / Logistics department</td>
<td>Personal interview, factory tour</td>
</tr>
<tr>
<td>Gun Andersson</td>
<td>- / Logistics department</td>
<td>Email contact</td>
</tr>
<tr>
<td>Mursad Sinikovic</td>
<td>- / Logistics department</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Charlotta Franzén</td>
<td>- / Internal production pool</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Jonas Holmqvist</td>
<td>- / Internal production pool</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Magnus Harrsjö</td>
<td>- / Internal production pool</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Karolin Emanuelsson</td>
<td>- / Goods reception</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Fredrik Åberg</td>
<td>- / Goods receiving</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Anita Andersson</td>
<td>- / Goods receiving</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Sven Johansson</td>
<td>- / Goods receiving</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Frank Bengtsson</td>
<td>- / Goods receiving</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Ulf Svensson</td>
<td>- / Goods reception</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Linus Ankarberg</td>
<td>- / Goods receiving</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Leif Karlsson</td>
<td>- / Goods receiving/ Internal transportation</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Rickard Alm</td>
<td>Assembler</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Bennie Ivarsson</td>
<td>Assembler</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Sven-Olof Åberg</td>
<td>Assembler</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Sakib Islamovic</td>
<td>Assembler</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Lars Johansson</td>
<td>Assembler</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Ronny Johansson</td>
<td>Assembler</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Thomas Andersson</td>
<td>- / Manufacturing engineering</td>
<td>Personal Interview</td>
</tr>
<tr>
<td>Sven Olsson</td>
<td>- / Manufacturing engineering</td>
<td>Personal Interview</td>
</tr>
<tr>
<td>Tommy Larsson</td>
<td>- / Material control</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Susann Stålberg</td>
<td>- / Material control</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Annsofi Andersson</td>
<td>- / Material control</td>
<td>Personal interview</td>
</tr>
<tr>
<td>Eva Svensson</td>
<td>- / Material handling</td>
<td>Personal interview</td>
</tr>
</tbody>
</table>

Table 3.1 - Overview of interviews Volvo CE Braås
Interviews at Volvo CE Arvika conducted between 7th of May and 8th of May 2008:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position/Department</th>
<th>Type of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mikael Svensson</td>
<td>Manager of Global Logistic Development</td>
<td>Personal interview, telephone interview</td>
</tr>
<tr>
<td>Charlotta Adolfsson</td>
<td>Global Logistic Development</td>
<td>Personal interview, factory tour</td>
</tr>
<tr>
<td>Kristian Magnusson</td>
<td>Global Logistic Development</td>
<td>Personal interview, statistics</td>
</tr>
<tr>
<td>Åsa Bäck</td>
<td>Global Logistic Development</td>
<td>Personal interview</td>
</tr>
</tbody>
</table>

Table 3.2 - Overview of interviews Volvo CE Arvika

Interview at Volvo Trucks Gothenburg conducted on 12th of May 2008:

<table>
<thead>
<tr>
<th>Name</th>
<th>Position/Department</th>
<th>Type of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenth Andersson</td>
<td>- / Supplier relationship management</td>
<td>Personal interview, factory tour</td>
</tr>
</tbody>
</table>

Table 3.3 - Overview of interviews Volvo Trucks Gothenburg

The secondary data was collected from books, articles and the Internet. The search engines (e.g. Elin, Emerald, Business Source Premier and Science Direct) used to find scholarly articles were accessed through Växjö University’s library database. Search words as VSM, value stream, material handling, packaging, takt time and waste have been used to find information about the topic. Information from Volvo Group’s intranet was used to find internal data about VPS and the material handling process. Moreover has internal statistics been considered about waste, shortages etcetera.

3.6 Scientific credibility

To reach a high quality of the empirical study a number of criteria can be used to judge the credibility.\(^{63}\)

3.6.1 Validity

The validity concerns only measuring what is intended to measure and that nothing else influences the result. It helps to avoid systematical mistakes. It connects empirical findings with theory by the focus on the collected data’s validity in proportion to the specific research question.\(^{64}\) The validity can be increased by having interview questions that are explicit and not one-sided.\(^{65}\) In qualitative research the content of

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validity is broader in comparison with quantitative research, and includes also authenticity, creditability and understanding.  

**Construct validity**

The construct validity is important to secure an objective judgment when collecting data. This may be a problem, especially in case studies. To ensure validity many sources of evidence should be used when collecting information. A linkage between the construction of data collection tools, theoretical frameworks and empirical data create a chain of evidence. Furthermore the case study should be reviewed by key informants.

**Construct validity of this thesis**

The construct validity of this thesis is high due to the large range of sources. Many employees of different positions in different areas at Volvo CE Braås, Volvo CE Arvika and Volvo Trucks Gothenburg were interviewed (Table 3.1, Table 3.2, Table 3.3). Furthermore, statistics given by the company were analyzed. Moreover, the identified techniques currently in practice were reviewed and criticized by comparison to theoretical data. The continuous work of this thesis was revised by stakeholders and the tutors at the company who can be regarded as key informants.

**Internal validity**

This criterion is useful when determining a cause and effect relationship between some specific actions. It is needed to look at many events and not just assume that event x is caused of y but actually of event z. The logic is only relevant for causal or explanatory case studies. It is also important that no inferences are made without an action is directly observed but only based on interviews or documentary evidence. This can be avoided by doing pattern matching and address rival explanations.

**Internal validity of this thesis**

This thesis has a high internal validity since assumptions were avoided in the cause and effect relationship used to identify waste. Furthermore, this was used to eliminate or

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minimize them. This relationship was assessed by information gathered from the interviews with several employees in different positions and areas and also put in to comparison to theory. This has provided the thesis with many different views which were taken in to account. Moreover, the information gathered from interviews was compared with observations, measurements and statistics.

External validity
The external validity deals with the problem if it is possible to generalize the case study’s findings to other studies. If the result can be used in similar cases the external validity is high. This kind of studies is usually stated to offer a poor basis for generalizing. Case studies do, however, rely on analytical generalization and the result from the empirical findings is striving to be generalized to some broader theory.\(^{69}\)

External validity of this thesis
Several observations were carried out at Volvo CE Braås for this purpose. Since this is a study of the material handling process at one Volvo CE plant it cannot be guaranteed to be of use to other external plants. However, the basis for material handling process is more or less the same in many production companies regarding goods receiving, storage and transportation. Therefore, a generalization of the results would be possible but depends on how similar the comparing company is to Volvo CE Braås.

3.6.2 Reliability
The purpose of reliability is that the same result can be achieved also by another investigator and at another point of time. To make this possible a case study protocol or database can be used to document the procedures. If the study can be recreated by following the same procedures as described in the protocol or database, it has a high reliability.\(^{70}\)

Reliability of this thesis
This thesis has a medium reliability due to the following facts. The VSM tool that is used to describe the material handling process at Volvo CE Braås has standardized steps

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that need to be followed. All the statistics used in this thesis can be retrieved from the company’s database. However, if the same study would be conducted in the future the results will probably differ because of continuous changes in the material handling process. Furthermore, the interviewed employees were mostly randomly chosen and therefore another study might choose different people. This can lead to different information. On the other hand to compensate for this a large number of employees in different positions and areas were interviewed. The thesis itself can be regarded as a form of protocol since it describes the course of action and results.

3.7 Summary

The following figure presents in a short summary the methodological choices made by the authors. It is an overview of the techniques that were used (Figure 3.1).

Furthermore, Figure 3.2 on the next page presents a summary of the authors’ approach to secure scientific credibility.
<table>
<thead>
<tr>
<th>Scientific credibility</th>
<th></th>
</tr>
</thead>
</table>
| **Construct validity:** | - Large range of sources  
- Personal measurements  
- Continuous reviewing by key informants  |
| **Internal validity:** | - Avoidance of assumptions  
- Personal observations to secure information from interviews  
- Information gathered were compared to theory  |
| **External validity:** | - Current data is related to Volvo CE Braås  
- Material handling process is a general process which can also be found in other companies  
- If similarities exist, results can be generalized  |
| **Reliability:** | - The thesis follows standardized steps of the VSM tool  
- A high number of randomly chosen interviewees  
- Developments in the company may influence future studies  
- Thesis itself can be taken as a form of protocol  |

Figure 3.2 - Summary of scientific credibility
4 Theory

The theory chapter will explain the necessary strategies and principles that will help to analyze the empirical data at Volvo CE Braås. The sub chapter material handling explains the necessity of packaging material, how low- and high frequent material should differ in its storage location and the process of part-feeding to the assembly line. Furthermore, the main model VSM with a step by step approach is introduced. Finally, the lean principle kanban and with it the classification and elimination of waste is presented.

Figure 4.1 presents the framework of the theory covered in the following chapter. Furthermore, it is pointed out how the theory is going to be used in order to answer the research question of this thesis.

4.1 Material handling

Material handling is a definition that can be widely used and covers moving, storing protecting and controlling material. It contains for example movements of material in boxes and pallets in an industrial distribution system and collecting refused material in a waste management system.

Another definition of material handling is “[…] providing the right amount of the right material, in the right condition, at the right place, in the right position, in the right sequence and for the right cost, by the right method(s)”71. The right amount highlights how much inventory the company should have. Using a pull-system with only the

needed amount is the most preferable way. This could be possible with JIT and small load sizes. Another way of improving the right amount of material is to reduce the setup time. When picking the material manually, the most common errors are too many or few pieces, or the wrong item. To secure the right material an accurate identification system can be used, for example with help of an automatic barcode-based system or by having an easy system for item numbering. The material should also be delivered in the right condition, which can be specific for different customers or material.  

The received goods can be packed or unpacked, painted or unpainted and sorted by article or kitting specifications but always without damage. Another option is to get the items in customer-specified returnable containers. The most preferably way is to transport the material directly to the right place where it is used and not stored in storage in between. This term deals therefore with both transportation and storage. To have the material in a right position will make it easier to handle it and reduce the time of searching and handle the goods. This is more critical in automated systems than in manually systems. In automated systems, for example in robot handling operations, the position needs to be exactly right to be able to find the material.

To use the right sequence of activities for example in distribution operations will make the material flow more efficient. This can be improved with help of work simplifications that reduce unnecessary actions. If the operation cannot be eliminated it may be more efficient to combine some steps and make changes in the sequence. The right cost means, that the company should find the most efficient material handling system, which works with a reasonable cost. Finally, it is important to use the right method(s) to be able to handle the material in the most appropriate way. Usually a combination of different methods gives the best result.

The material handling is an important part of the overall facility design process and has to be adapted to the current situation. There is, in other words, not a single way of

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72 Tompkins, J. A. et al. (2003) pp. 164-166
solving problems that occur in the material handling system design. By using the most appropriate way and making improvements, the company can face a reduction of costs due to lower inventory and more efficient and balanced manufacturing and distribution flows but also improved safety. When reducing the number of times the goods are handled also a reduction of material handling equipment is possible.\textsuperscript{76}

There are many principles that can help the company to improve the material handling in practice thanks to the ability to analyze, plan and manage systems and activities\textsuperscript{77}. The following ten principles are the most common used in material handling. Planning the work in advance can help to find the right actions and can be as simple as to define what material needs to be moved to what position and when. This leads to a plan of how and who will make the transportation.\textsuperscript{78} The plan should be developed by all the people who somehow will be affected by the used equipment. It should focus on both the strategic objectives and the direct needs.\textsuperscript{79} The company should also try to standardize the work and have less variation in the material handling process\textsuperscript{80} regarding methods, equipment, controls and software. The work principle tries to make material handling processes simpler and to reduce unnecessary transportation and handling. To ensure safe and effective activities the ergonomic principle has to be considered.\textsuperscript{81} Another way of making it easy and fast for the employees is to use a principle for unit loads. If material can be stored and moved as a unit and not as single items it will help to improve the handling.\textsuperscript{82}

The meaning of space utilization principle is to use the available space effective and efficient by for example eliminating unorganized work areas. The system principle integrates information flow with physical material flow. It uses methods to identify, determine location and status and control handling of material.\textsuperscript{83} By using automated methods like computer-based systems, the company can combine information in an

\textsuperscript{76} Tompkins, J. A. et al. (2003) pp. 163-169
\textsuperscript{77} Zandin, K. B. (2001) p. 10.31
\textsuperscript{78} Tompkins, J. A. et al. (2003) pp. 163-169
\textsuperscript{79} Zandin, K. B. (2001) pp. 10.32-35
\textsuperscript{80} Tompkins, J. A. et al. (2003) pp. 163-169
\textsuperscript{81} Zandin, K. B. (2001) pp. 10.32-35
\textsuperscript{82} Tompkins, J. A. et al. (2003) pp. 163-169
\textsuperscript{83} Zandin, K. B. (2001) pp. 10.32-35
effective way. The *environmental* issue deals with total energy consumption but also with recycling and reusability of pallets. The principle of *life cycle cost* counts the total cost of new equipment or method used for material handling. All principles that are used will help to solve problems that can occur in the material handling process.

### 4.1.1 Packaging material

To be able to have an efficient material handling, the company needs to use appropriate packaging material. There are different alternatives how to pack goods during handling, transportation and storage as a unit load. The most common method is to put the material, both large parts and cartons with small parts, together on pallets. They are in 90% made of wood but can also be composed of plastic or metal. The pallet is considered as one of the most important innovations for material handling in the 20th century. It made the distribution and storage more efficient and also gave the opportunity to improve protection of goods. The pallets can easily be handled by forklifts, piled on top of each other when using a collar and reused. There are several designs of pallets owing to the transportation (e.g. truck, ferry) and the material packed. There are, however, some standard sizes that are used. This makes it possible to handle the pallets more efficient thanks to pallet pool systems. The companies can rent pallets instead of owning them. This system minimizes the transportation of empty pallets and the extra space to store them, and increases the utilization.

### 4.1.2 Storage

Storage exists because of the problem to match the demand and supply of material. It helps to maximize the space, labor and equipment utilization, material accessibility and material protection.
Disposition of material in storage

There are two different ways when planning the storage space; fixed/assigned and random/floating location storage. With fixed location storage each material has its special location and should not be stored anywhere else. To make this possible, the location is empty when the specific good is not stored. The storage space needs to be large enough to store the maximum amount that will ever be on hand.\textsuperscript{97} An advantage when using this system is the possibility to separate the material into different groups depending how frequently they are used. Goods that are needed often should be stored close to where it enters and leaves the storage (Figure 4.2).\textsuperscript{98} This requires, however, much information to achieve efficiency and high throughput.\textsuperscript{99}

![Figure 4.2 - Material storage by frequency]\textsuperscript{100}

In random location storage the material can be stored in any available location and does not have a specific location. This results in lower storage space needed than using fixed location because of the possibility of lower amount of empty locations. However, if the safety stock is large in random location storage, there may be no differences in storage space between fixed and random location storage.\textsuperscript{101}

Another way of sorting the goods in storage is the weight and how they are to handle. Heavy and hard-to-handle material should preferably be stored close to the point of use and not too high. This will minimize the needed handling and transportation to and from the storage. The size of material should also fit the location size and not be stored in a

\textsuperscript{97} Tompkins, J. A. et al. (2003) pp. 431-435
\textsuperscript{100} Tompkins, J. A. et al. (2003) p. 442 (modified)
\textsuperscript{101} Tompkins, J. A. et al. (2003) p. 431-435
too large location. This demands storage with different location sizes. Material that is very large or shaped in an unusually way can be stored in an open space to reduce handling and storage problems.\textsuperscript{102}

\textbf{Automated storage}

Automated storage and retrieval system (AS/RS) has been used since the 1950s to eliminate non-value activities\textsuperscript{103}. It helps the company with material handling and storage control in factories\textsuperscript{104} by a fully automated and computer controlled system\textsuperscript{105}. It is today used as a connection within the material flow and supports for example manufacturing and distribution\textsuperscript{106}. By introducing the system, the manually retrieval time can be reduced up to 70\%\textsuperscript{107}. It helps to save labor costs and improves the inventory control, safety, throughput levels and material flow\textsuperscript{108}. Moreover offers AS/RS good accuracy and high floor-space utilization but also better use of time and equipment\textsuperscript{109}. Even if the system still is widely used it is not as common today with large AS/RS as before because of the focus on reduced inventory levels and JIT. Small-scale AS/RS are, however, continuously often used for storage and order picking.\textsuperscript{110}

The system can be separated into two different shuttle storage categories; single command and dual command. In single command the machine picks up a load, transports it to an empty location and deposits it in that location before returning empty to the input/output. This variant works with either storage or retrieval. In dual command the machine deposits a load in the same way but also picks up another load before returning to the input/output.\textsuperscript{111}

\textbf{4.1.3 Part-feeding to the assembly line}

In order to secure the material availability at the assembly line, the part-feeding process is important. This part-feeding process has to ensure that the necessary purchased and

\begin{thebibliography}{99}
\bibitem{Tompkins, J. A. et al. (2003)} p. 444
\bibitem{Hur, S. & Nam, J. (2006)} p. 1613
\bibitem{Bozer, Y. A. & Myeongsig, C. (2005)} p. 367
\bibitem{Malmborg, C. J. (2000)} pp. 4599-4603
\bibitem{Malmborg, C. J. (2000)} pp. 4599-4603
\bibitem{Bozer, Y. A. & Myeongsig, C. (2005)} p. 367
\bibitem{Malmborg, C. J. (2000)} pp. 4599-4603
\end{thebibliography}
manufactured material is available at the work center, to facilitate that the required operations can be fulfilled.\textsuperscript{112} The main process is the transport of material from warehouse to workstation at the assembly line\textsuperscript{113}. Besides that, the material can also be supplied by sub-assembly lines or vendors. Two kinds of material can be separated: sequential parts and non-sequential parts. Sequential parts are delivered by a sub-assembly line or a vendor, in the sequence needed. These parts are produced in accordance with production sequence. Sequential parts are normally delivered directly to the assembly line by the vendor or the sub-assembly line. Non-sequential parts are stored in the warehouse of the company and are delivered in boxes to the line, while production continues.\textsuperscript{114} The cost of the process consist of two main components: holding costs (inventory costs) and handling costs (transportation)\textsuperscript{115}. Moreover, this process is vital for the decision of the inventory level and the stock out at the assembly line\textsuperscript{116}.

Besides the main supply to assembly line, it also has to be considered in which form of packaging the material will be supplied. (Different possibilities of packaging are presented in chapter 4.1.1). To achieve high productivity objectives, standardized work methods are often indispensable. Therefore, standardized containers are then used for the material handling process between storage and assembly line. Different container like plastic and metallic or pallets can be used and each may be offered in different sizes. Furthermore, the containers should always include the same amount (as carried out in a JIT approach) and the same kind of material when delivered to the line, to obtain a better control of the process.\textsuperscript{117} Additionally, the route of the feeder and the number of tours should be considered to coordinate the part-feeding process to the assembly line even better\textsuperscript{118}. However, an even volume in the production sequence can help to level the consumption of parts\textsuperscript{119}.

\textsuperscript{112}De Souza, M. C., De Carvalho, C. R. V. & Brizon, W. B. (2008) p. 480
\textsuperscript{115}De Souza, M. C. et al. (2008) p. 480
\textsuperscript{117}De Souza, M. C. et al. (2008) pp. 481-482
\textsuperscript{118}Choi, W. & Lee, Y. (2002) p. 131
A long with the part-feeding process to assembly line a problem called “Line-feeding problem” has developed. Different studies concerning this matter have been carried out. These studies are mostly solved with the help of integer programming models\textsuperscript{120}, heuristic approaches or mathematical algorithm\textsuperscript{121}.

### 4.2 Value stream mapping

Value is for a customer, having the right product and quantities when needed and where needed. Furthermore, a valuable product must fulfill the task the customer wants it to do. This has to be done in a satisfied and continuous way. Value meets the existing and the recognized needs of the customer for a price the customer is willing to pay.\textsuperscript{122}

#### 4.2.1 Value adding

According to Monden, all operations in a plant can be assigned to one of three categories.\textsuperscript{123} The three categories are:

- Non-value adding (NVA);
- Necessary but non-value adding (NNVA);
- Value-adding (VA).\textsuperscript{124}

Non-value adding action can also be named pure waste and should be removed entirely. These actions can include operations like waiting time and double handling. Necessary but non-value adding operations are needed at the moment due to existing processes, but could be eliminated. To reduce or eliminate these operations major changes are required. Examples for this category are: long walking distances to pick up parts, the unpacking of delivered material or unnecessary handling of tools.\textsuperscript{125} The last category, value-adding is often the smallest part of all operations. Such manual operations add value to a product through the conversion or processing of raw material or semi-finished products. Possible operations are: forging of raw material, sub-assembly and painting of parts.\textsuperscript{126}

\textsuperscript{120} De Souza, M. C. et al. (2008) pp. 480-489
\textsuperscript{122} Arnold, J. R. T. et al. (2008) p. 430
\textsuperscript{123} Monden, Y. (1994) p. 179
\textsuperscript{126} Monden, Y. (1994) p. 179
4.2.2 Value stream

Rother and Shook define a value stream as:

“ [...] all actions (both value added ad non-value added) currently required to bring a product through the main flows essential to every product [...].” \(^{127}\)

The main flow can either be the flow in production from raw material to the end customer, or the flow when designing the product from idea to launch. The value stream perspective differs from the process flow perspective. In contrast to the process flow, the whole flow is pictured and optimized rather than an individual process. This flow is not only limited to the “door-to-door” production flow inside a plant, but can also be extended across companies and facilities up to the end customer, to get the whole picture (Figure 4.3). \(^{128}\)

![Figure 4.3 - Total value stream](image)

4.2.3 The four steps of VSM

Value stream maps were originally known as “material and information flow maps” \(^{130}\). As a training method for lean management it was first developed by the Toyota Motor Corporation in the late 1980s \(^{131}\). With these maps it was possible to picture the whole process, performed to make a product, on a one page diagram \(^{132}\). Today, value-stream mapping is an instrument to balance the flow, improve productivity and to redesign the whole manufacturing system rather than discrete production processes \(^{133}\). The tool

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129 Rother, M. & Shook, J. (2003) p. 3 (modified)
VSM helps to observe and to get a clear picture of the material and information flow. The value stream, as explained above, will be visualized as the product makes its way through the process. A map, from supplier to customer\textsuperscript{134}, is created using a predefined set of standardized icons (Figure 4.4)\textsuperscript{135}.

![Sample of standardized VSM icons](image)

VSM is compared to many other tools not a quantitative tool which counts the number of non-value-added steps, lead time, distances and the amount of inventory. VSM, in contrast, is a qualitative tool that illustrates how processes should be structured in order to create a good flow.\textsuperscript{137} It is a useful tool that helps to detect the sources of waste (non-value adding activities) and to find lean tools for the reduction or elimination of waste\textsuperscript{138}. In order to use VSM appropriate one should undertake the following four steps shown in Figure 4.5.

\textsuperscript{134} Rother, M. & Shook, J. (2003) p. 4
\textsuperscript{135} Abdulmalek, F. A. & Rajgopal, J. (2007) p. 225
\textsuperscript{136} Icons are according to Rother, M. & Shook, J. (2003)
\textsuperscript{137} Rother, M. & Shook, J. (2003) p. 4
\textsuperscript{138} Abdulmalek, F. A. & Rajgopal, J. (2007) p. 224
First a product family should be selected. Second the current-state map can be drawn. In the third step the future state map with the suggested changes will be developed. The arrows show that these two procedures are overlapping. Finally, one should build-up a work plan including suggestions on how to implement it.

**Selection of a product family**

The first step, selecting a product family is an important step before starting. A product family can be defined as a group of products that uses similar steps and equipment in the production process. In order to identify the product family one should go the end of the value stream which is close to the customer. Trying to draw a map of all produced products is too complicated and confusing.

**Current-state map**

After the product family is chosen one can start to collect the information to draw the current-state map. The information needed to draw the map can be gathered on the shop floor of the company. As suggested by Rother & Shook one should first just take a quick walk along the value stream to get an overview. In the second step the information for each process should be collected. The starting point for information gathering should be at the shipping end (close to the customer) and then continued upstream. The advantage is, that the process that is mostly linked to the customer and its demand, will set the tempo for other upstream processes. Furthermore it is important that one measures the time needed for the different processes on its own. Finally, a

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value stream map should be drawn by hand. Under each pictured process box one should add a data box. This box should be filled with information on for example: number of people, cycle time, working time minus breaks etcetera. On the bottom a time line should give information about the time needed for each process and the waiting time between processes. Furthermore, the information flow (electronic and manual) should be pictured in the map. This is depicted with arrows between the partakers.

**Future-state map**

The main purpose of VSM is to draw a future-state map, to show how much better the value stream could be. In order to do that, the current-state map needs to be analyzed. The goal of the future-state map is to develop a lean value stream. To accomplish that only what is needed and when it is needed should be produced. A number of guidelines suggested by Toyota can be used to achieve this in the future-state map. Examples of the guidelines are (for a full list, please see Rother and Shook 2003)

- Identify the takt time. Takt time, is the rate at which a company should produce in order to fulfill customer demand. Moreover, it helps to match the pace between one process and another process. The takt time can be calculated by dividing the available working time, with the customer demand rate per day.

- The flow of material between individual processes should be guided either by continuous flow or pull method (Kanban). Continuous flow refers to the production of one piece that is directly after one process forwarded to the next process without interruption where as the pull method means that customer demand triggers the production of the item.

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145 Seth, D. & Gupta, V. (2005) p. 47
149 Lasa, I. S. et al. (2008) p. 41
The introduction of a supermarket when continuous flow is not possible. A supermarket is a buffer or storage area situated at the end of a production process. The pull method is used to withdraw a product from the supermarket and also to give the signal to produce a new product to refill the supermarket. Often plant layouts, plant locations and process machinery have to be taken as given and should not be addressed first when suggesting changes. The sources of waste which do not depend on such given conditions should be primary focus.

Work plan and achieving work plan

After the future-state map is developed a work plan on one piece of paper should be written. The work plan should include information on what should be carried out, when and how it should be done. Goals should be set as measurable goals in a timeframe that is possible to achieve. This work plan must be reviewed according to the plan and the changes should be evaluated of being successful or unsuccessful.

4.3 Waste

Activities within a company can be divided into following three types; non-value adding, necessary non-value adding and value-adding. Two of these activities can be defined as waste since they do not add value to the product. The necessary non-value adding are activities like unpacking deliveries, walking long distances etcetera. Minimizing such activities to start with should be enough since major changes are needed in order to eliminate them. However, the pure non-value adding activities should be eliminated completely. 95 % of lead time is estimated to be non-value added activities. The Toyota Motor Corporation identified seven types of waste; overproduction, waiting time, transportation, inventory, processing, motion and product defects. Recently an eighth waste was identified, which is missed opportunities.

158 O'grady, P. J. (1990) p. 39
The eight types of waste

The waste from overproduction is when more products than what is demanded are produced. Moreover, this waste could also be due to products produced earlier than needed and therefore have to be kept in storage until delivery to customer can be made. Overproduction is considered to be the worst type of waste since it disrupts the flow of goods and increases storage time. The production of excess products might also lead to difficulties or delay in detecting defects. Waste of waiting time is when products are not being worked on or moved. Furthermore, waiting time can also be workers are waiting for next activity, part, service etcetera. Transportation of goods does not add value therefore all transportation activities are waste. However, some transportation is necessary and elimination is impossible. Instead transportation should be minimized due to the damage risk when moving goods around.

Inventory can be considered as a cover up for problems in production and/or quality. The inventory-level has to be reduced to uncover these problems. Furthermore, it is stated that many manufacturers have moved towards smaller lot sizes in order to improve process and product quality and that this in turn reduces rework. Using expensive and complex solutions when a simple solution is just as good, this is called processing waste. Workers might feel the urge to overproduce in order to compensate for the large investment for the complex solution. Furthermore, emerges processing waste if the wrong kind of machine is used, the process does not run in a proper way or incorrect tools are applied.

The waste of motion is about workers movements; fetching tools, stretching, bending and so on which are wearing and can affect productivity negatively. Product defects imply that companies are producing defected products on purpose. If the defected material is not identified early in the production process, a lot of time is wasted by the

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162 Hoske, M. T. (2004) p. 21
165 Hoske, M. T. (2004) p. 21
try to use this incorrect part in the next production step, or by waiting for a new correct part or even by sorting out and reworking the defected parts. In addition, the defects are direct costs and should be considered as a chance for improvements. In the service business this type of waste is errors in data or documents. Underutilized people are considered to be missed opportunities. This can lead to obstructing the information flow between employees, suppliers, customers, investors etcetera.

### 4.4 Kanban

The kanban system, developed around the 1980s by Toyota Motor Corporation, is a card or computer signal carrying information. The kanban system, which is one example of the pull system, is an important part in JIT production. The kanban card or signal is sent from one workstation to the previous when a need arises, which means that all forwarded material have to be issued by a kanban. In other words, the current workstation sends an order to withdraw from the previous workstation (see illustration in Figure 4.6). The flow of material is controlled by kanban cards or signals and as a result of controlling production flow and inventory, production time and work-in-process can be reduced.

Furthermore it is stated that ordering based on pull can reduce inventory and simplify planning. However, if the kanban system is used incorrectly the outcome can be the

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176 Hultkrantz, O., Medbo, L. & Wänström, C. (2001) p. 113
opposite, high inventories and low delivery service. The kanban system is appropriate for items that have an even internal consumption or an even external demand. Therefore, not all items in a production flow should be included in a kanban system.\textsuperscript{182}

There will always be a need of inventory or storages. However, they should only be considered as buffers and be stored close to the consumption location to assure immediate delivery. Kanban cards should also control the buffer levels by sending a signal when replenishment is needed.\textsuperscript{183} It is stated that kanban is an inventory control system and might not be the best choice when production is initiated by customer order since this does not secure an even flow of material.

There are two types of kanban; production and transportation. The production kanban provides information regarding for example batch size and other operational data. The transportation kanban signals a need to replenish material at a workstation. All material or items should have specific packaging that can hold a specific quantity necessary for the kanban system to work. This packaging could be plastic boxes, containers, pallets or other suitable packaging for the specific item.\textsuperscript{184} The pallet, box or container itself can be regarded as a kanban card or signal that initiates withdrawal and production.\textsuperscript{185} Moreover, kanban can be a single-card or two-card system. The single-card system, illustrated in Figure 4.7, is suitable when distances between workstations (WS) are short. In the single card system the card is called production order kanban (POK). The short distance allows the workstations to share one buffer; outbound buffer for WS 1 and inbound buffer for WS 2.\textsuperscript{186}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{single_card_system.png}
\caption{Figure 4.7 - Schematic diagram of a single card system.\textsuperscript{187}}
\end{figure}

\textsuperscript{182} Hultkrantz, O. et al. (2001) p. 114
\textsuperscript{183} Olhager, J. (2000) p. 236
\textsuperscript{184} Olhager, J. (2000) p. 235
\textsuperscript{185} Hultkrantz, O. et al. (2001) p. 116
\textsuperscript{186} Kumar, C. S. & Panneerselvam, R. (2007) p. 394
In the two card system distances are longer between the workstations. This requires separate buffers, inbound and outbound, for each workstation. The two cards are called production order kanban (POK) and withdrawal kanban (WK). In Figure 4.8 following course of actions take place. A WK is initiated in order for WS 2 to consume items from its inbound buffer. In turn, a WK is sent from the inbound buffer of WS 2 to the WS 1 outbound buffer. The items in the outbound buffer have a POK attached which is removed when being withdrawn. This POK is sent to WS 1 in order to produce new items to replace previously withdrawn items.

![Figure 4.8 - Schematic diagram of a two card system](image)

**4.5 Summary**

The chapter above covered the necessary theory to answer the research questions. First material handling was defined and the importance about having the right material when needed, where needed and for the right costs was pointed out. In addition, the relevance of packaging, storage and part-feeding to assembly line are indicated. Second, the tool VSM is explained and a step by step approach on how to apply VSM is given. Moreover, the eight types of waste are described and possibilities on how to eliminated them. Finally, kanban and especially the two type’s production and transportation kanban are explained.

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The following chapter presents the empirical data gathered at Volvo CE Braås. First of all, the goods receiving process is explained. Secondly, inside, outside and external storage locations of the company are introduced. Furthermore, the process of storing material will be described. Finally, the process of assembly line feeding and ordering will be explained, including the results of a questionnaire handed out to the assembly line employees. The sources for each collected data are not presented.

The following Figure 5.1 illustrates the structure of this chapter and how the subchapters are related to each research question.

The haulers are assembled with many different materials, for example does the biggest hauler, A40, consist of 1307 different articles. This material is both produced within the company and purchased from suppliers. Some of the purchased parts are large and expensive, for example engine and cab, while other are small and used in a larger amount such as screws and nuts. There is a number of different ways how to handle and store the different material. Even if there are some standardized methods how to work it exists deviations in all areas that belongs to material handling.

## 5.1 Goods receiving

The process of goods receiving starts when trucks with raw material and components from suppliers or other factories within the Volvo Group arrive to Volvo CE Braås. The employees in this area work most often two shifts Monday to Thursday and one shift on Friday. The trucks arrive usually Monday to Friday between 6 am to 10 pm but in exceptional cases also in the weekends. Mondays, Wednesdays and Thursday are the
busiest days of the week. Much material from abroad are received on Mondays but also from Swedish suppliers. On Fridays the flow of incoming material is, most often, the lowest. Figure 5.2 shows the incoming trucks during three weeks (week 15-17, 2008). However, the first week does not include Monday (2008-04-07). The company tries to even out the flow by transferring some of the deliveries to Fridays. It is, however, difficult because of foreign truck drivers who are dependent on ferry routes.

There is also a difference of incoming trucks during the day. The flow is higher in the morning and lower during the lunch-time and in the evening. Figure 5.3 presents the total amount of incoming trucks separated in hours between week 15 and week 17.

Three forklift drivers unload and handle the received material. Pallets and small boxes which are stored inside are unloaded and put in a line outside in connection to the inside goods receiving. Pallets which are stored outside are put directly by the outside storage. Those are mostly easy to separate from inside pallets because of the bigger size. Larger
parts, like cabs, are usually unloaded at the same place but transported to their outside storage location. Tires and metal plates are, however, unloaded in their specific storage-areas. The forklift driver tries to count bigger parts and pallets but when he is busy and unloads hundreds of pallets he might trust the invoiced number of pallets even if he counted something else. This might lead to that one or more pallets are missing but this is not noticed at this stage of the process.

At the same time as unloading, the truck driver goes to the goods receiving reception and hands over a waybill and delivery note. All suppliers are supposed to invoice in Volvo CE Braås’s system but for some suppliers this is too expensive or they might have problems with their system, or incorrect quantity has been added. If this work has to be done manually the time spent may increase from about 30 seconds up to five minutes.

The receiving clerk registers the received goods with help of the delivery note in the computer system. When receiving engines a delivery note for each item is faxed from the supplier. The receiving clerk matches these with the waybill from truck driver and the forklift driver confirms over the phone that the engines are physically there. This is done due to the high price of engines and that only few are received once a day. Axles, which also are expensive, are controlled so that the right amount is delivered. This component is received sequentially three times a day. Cabs are specifically ordered for each customer and as well received in sequence three times a day. Those two materials are the only ones that are received in sequence to the company. All other parts are received according to production plan. The receiving clerk talks on the phone with the forklift driver who unloads the cabs. Together they check the article number on the cab and in the list.

Papers from truck drivers who deliver tires and metal plates are given to the receiving clerk by another employee but the ones for metal plates are not handled in goods reception. Metal plates are received from a Swedish external storage once a day and from an external storage in Germany two to four times a week. Those deliver what Volvo CE Braås orders according to the production plan. Other suppliers deliver, if needed, in batches one to two times a week. Tail gates and front covers have to be
controlled as well since the company often has received too many compared to the invoicing from the supplier. If the received quantity does not match the invoiced number of items a manual change will be done. A report is then filled out and given to the material controller. The last step in goods reception is to close the order. This is usually done automatically. This is done before the pallets are received at the goods receiving line. No feedback is given to the receiving clerk about if all pallets were actually received.

5.1.1 Goods receiving lines
There are a big variety of materials that are received at Volvo CE Braås. The collis can exist of wooden pallets containing different kinds of articles. It can also be larger parts like cabs, engines and axles and furthermore cardboard boxes. The collis which need to be handled are almost completely equal Mondays to Thursdays. On Fridays are, however, less collis received from suppliers. Figure 5.4 shows the total flow of collis during four weeks (week 14-17, 2008).

![Figure 5.4 - Amount of received collis per day](image)

The flow is, however, not even during the day. Most of the collis are handled in the morning. The flow is then decreasing and in the evening and night even lower. Figure 5.5 illustrates the total amount of collis handled in the goods receiving line during four weeks (week 14-17, 2008). This is separated in hours to see the flow during the day.
When the received pallets are registered in the computer system, the forklift driver gets a work order to add the pallets on a belt conveyor that takes them to the goods receiving line. The forklift driver checks the amount of pallets by entering the article number and loads the entire order on the belt conveyor. If the whole order cannot be found, and there are many pallets waiting, the pallets are placed on the side to be handled later. If the received goods have not been registered and therefore no work order been sent to the forklift driver, he may call the receiving clerk to have the order registered faster. This may also be the case if the delivery note is missing.

Different kinds and sizes of material and packaging materials are received from outside on the belt conveyor to the main goods receiving line (continuously called goods receiving line) (Figure 5.6). Most common are wooden pallets but there are also plastic boxes, small cardboard boxes consolidated in a wooden pallet and cardboard boxes containing parts from new suppliers or maintenance- and office material.
When the belt conveyor has taken a wooden pallet inside to the goods receiving line the lid, collar and string are removed and sorted. Each pallet has an item number that the goods receiver manually enters in the computer system to create a lot flag which shows for example amount, colli- and check number (Figure 5.7). When printing the lot flags, the goods receiver has to confirm the printing for each flag.

![Diagram](image)

**Figure 5.6 - Goods receiving line**

<table>
<thead>
<tr>
<th>Colli number</th>
<th>Barcode (colli)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barcode (check number)</td>
<td>Check number</td>
</tr>
<tr>
<td>Main storage place</td>
<td>Receiving place</td>
</tr>
<tr>
<td>Article Number Name</td>
<td>Barcode (article)</td>
</tr>
<tr>
<td>Packing code</td>
<td>Kg Tot</td>
</tr>
</tbody>
</table>

**Figure 5.7 - Lot flag Volvo CE Braås**

The colli number of the lot flag is created in sequence. It is crucial that the first pallet of the order receives the lowest incoming number to make it easier for the inside working forklift drivers to put the pallets in the order of the first-in-first-out principle (Fifo).

Every wooden pallet has to be confirmed before the lot flag can be printed. This is, however, done before the goods receiver knows how many pallets that are coming. The number of lot flags is consequently equal to the amount of pallets in the computer system and not necessary to the actual number received on the line. If the arrived quantity does not match the number of lot flags a fault is noticed. The goods receiver
usually puts the remaining lot flag in a folder until the end of the shift or the next day to see if the pallets or collis is found outside or received by the next delivery. If it is still missing, the lot flag and a verbal report are given to an employee who contacts the supplier. Sometimes when there are only few pallets outside an outside forklift driver is asked to search for the missing pallet immediately.

The amount of goods in the wooden pallet is counted when the parts are large and few. Small items and parts in other packaging materials are not controlled unless they are pre-determined to be inspected. This is marked in the computer system and could be because of several reasons, for example former lack of quality, new component or need of quantity check. Other motives for indication in the computer system can be shortage at assembly line. In some cases the goods receiver has to split or merge an order. This could happen if the given amount of parts in the computer system and the actual number in the wooden pallet are not in accordance. It is important to make sure that the lot flag with lowest incoming number is attached on the first pallet, which should contain the lowest quantity if there is a difference.

Another problem that sometimes occurs is that suppliers do not deliver in the suggested packaging material but in cardboard boxes. The material has to be repacked to pallets which takes additional time. Figure 5.8 presents the summarized hours spent on repacking to pallets during January to March 2008. Included is also repacking to other packaging material (see below for further information about repacking to small boxes). It could also happen that the pallets are only half full or almost empty. A report is then filled out by the goods receiver and handed to an employee who contacts the supplier.
When the lot flag has been printed the status of the pallet is changed manually. This gives the inside forklift drivers a work order to pick up the pallet. If the goods receiver forgets to change status this is soon noticed by the forklift driver since there is no work order for the waiting pallet. He will then remind the goods receiver and the mistake can easily be solved. Materials that are in other packaging materials than wooden pallets are sent through the line without registration or attached lot flag. The material is forwarded on the continued belt conveyor which is separated into five lines (Figure 5.9). There is no main difference for the material type in those lines but line one, two and four are general used for the wooden pallets L and K. Line three is preferred for the bigger wooden pallets G and H since it in this line can go straight. The L-pallet has the standard size (Euro pallet), K half the size of L, G little longer than L and H the longest pallet. The goods receiver tries mainly to put the same kind of material in the same line to make it easier for the forklift driver to stack them up in the right order in accordance to Fifo.
For plastic boxes that are standardized for Volvo Group (continuously called small boxes) the item number is entered in the computer system to check if a control is needed. The pallets are then forwarded on the continued belt conveyor. A forklift driver picks up the small boxes and takes them to the goods receiving line for small boxes. This is located next to the storage for small boxes (Figure 5.10).

If it is a shortage of the material, those small boxes get a preferred handling but go through the storage before transported to the assembly line. The shortage can be noted because of a phone call from the assembly line or marked in the computer system. The goods receiver for small boxes enters the item number into the computer system and prints a lot flag for each small box containing item number, the amount of pieces and a barcode. The lot flag is attached to each small box before a belt conveyor takes it to the automated storage. If a small box is missing, this will be noticed in the same way as for wooden pallets with a remaining lot flag. The goods receiver checks if the box is somewhere else on the belt conveyor or on its way to this area. The pallets with small boxes of the same material should come together but sometimes they are split. If a wrong lot flag is attached, the system does not notice. It is also not noticed if the goods receiver forgets to change the status in the computer system. The material can then be in storage without the employees’ knowledge. The total amount of received small boxes per day over four weeks (week 14-17, 2008) is illustrated in Figure 5.11.
Sometimes goods that are supposed to be delivered in blue boxes have the wrong packaging. This leads to that the goods receiver has to repack the material. A control report is filled out and sent to another employee who charges the supplier. This report contains the type of pallet the goods were received in, the type of pallet the goods were moved to (small box) and how many minutes the activity took.

For small materials that are packed in cardboard boxes and consolidated in a wooden pallet a lot flag is printed for each pallet in the goods receiving line. This lot flag is not attached but only put in the pallet. When no notification about quality-, quantity checks or shortage etcetera exists, it is forwarded on the continued belt conveyor.

There is a time gap between the registration of the goods received and the time when the goods are handled physically in the goods receiving area. This gap differs during the day. Most of the collis are handled by the outside forklift driver and goods receiver within one hour but exceptions can be noticed. For pallets this is also including the waiting time outside after unloading, and the short waiting time on the belt conveyor. Figure 5.12 illustrates the total hours taken to handle the goods in goods receiving during four weeks (week 14-17, 2008).
5.1.2 Review of main points for goods receiving

- Uneven flow of incoming trucks and collis during the day
- Different collis are handled differently for example wooden pallets that are stored inside are forwarded on a belt conveyor and cabs are unloaded and transported immediately to their storage location.
- Tires and metal plates are not unloaded at the main goods receiving area but close to their storage location.
- Small boxes have to go through the main goods receiving line and then be transported by a forklift to the goods receiving for small boxes.

5.2 Storage

After the material handling at the goods receiving area is finished the goods are forwarded to a belt conveyor. At that point the forklift driver takes over for internal transport. As mentioned before, at the end of the goods receiving process a status change in the system sends a work order for each pallet to the forklift driver. Each forklift has a small computer, consisting of screen and keyboard installed. Working with the same system (Mapics), the forklift driver can see the list of work orders that have been placed. Two forklift drivers are responsible to place the material in storage. The storage of material is handled different depending on the packaging the material is delivered in. Furthermore, also the storage location can be found inside, outside and also external if necessary.
5.2.1 Inside storage:
The storage area at Volvo CE Braås encompasses a total of 5238 storage location for wooden pallets in the main storage area. Of these 5238 places, 478 places are fixed storage locations, 4760 can be randomly chosen inside (called buffer places) plus additional 310 buffer places outside. The storage place is optimal utilized if 700 buffer places are still available. The limit for available buffer places is 500 places. Volvo CE Braås does not measure the turnover rate of material in storage. The following Figure 5.13 gives an overview of the storage areas inside the factory.

![Figure 5.13 - Inside storage locations Volvo CE Braås](image)

**Main storage area (called TORGGM)**
The main storage area consists of seven rows of steel shelves. Mainly wooden pallets are stored in this area. The shelves in the main storage offer different sizes of storage places. This varies between storage locations for one pallet and maximum of four pallets piled on top of each other or a pallet with four collars. Moreover, you will find storage locations for smaller wooden pallets (K-pallet, is half of standard pallet L) and long pallets like H- and G-pallets.

The wooden pallets wait for pick up on the belt conveyor right behind the goods receiving area. If possible pallets with the same kind of material should be waiting in
one lane. However, this is not always possible due to the limited space in one lane. The forklift driver checks on his computer screen the placed assignments. Standing in front of the belt conveyor, he chooses one pallet, checks the colli-number of the lot flag and enters it in the system. The system will tell him how many pallets belong to this order. If only one pallet, this pallet is directly transported to the storage. If more than one pallet, the forklift driver piles the pallets that belong together on top of each other (max. 4), taking care that the pallet with the lowest flag number (equals the oldest one for this order) is on top. This is important, so the Fifo principle can be followed when withdrawing material from storage. After the pallets are piled the forklift driver stores the material on the shelves. The storage location can either be a fixed or a random location. If a storage location is fixed (mostly for kits and option parts) the material should be stored exactly at the location printed on the lot flag. However, this is not always possible because the storage location is still in use by an older pallet of the same kind of material. In this case another storage location is randomly chosen by the forklift driver.

If no fixed storage location is given in first place, the location is also randomly chosen by the forklift driver. First of all, the driver checks in the system if the same material is already in storage. If so, the forklift driver will look for an available location that is close to the same kind of material already in storage. A nearby storage place of the same material will make the search for forklift driver that feed the assembly line easier. Furthermore, the storage location should be in a shelf close to assembly line (see Figure 5.13, right hand side). Newly arrived material will never be added to existing storage locations even so there might be space available. However, the forklift driver might relocate pallets that fill a location only half, to a smaller and better suited location. The available storage location is then found by driving around with the forklift and a visual search. After deciding for a storage place, the forklift driver enters the row of the self, the shelf number and the level on which the box is stored into the system. These numbers together, result in the exact storage location. Moreover, a check number which is noted on each shelf will be entered to confirm the location. At the moment no system is in use that assigns storage locations automatically for pallets in the main storage. According to Jerry Fransson (responsible for material handling) there is an existing
system but this is not in use. Furthermore, Frank Bengtsson (employee at goods receiving) mentioned that a system for at least the bigger or higher (many collar) pallets would be very useful.

**Small box storage: (called TORGSB)**

The small box storage is a fully automated high rack storage area and located next to goods receiving (Figure 5.13). It consists of two high rack shelves which can encompass 3456 small boxes. This small box storage only stores small boxes, as the name implies. Figure 5.14 pictures a small box.

![Figure 5.14 - Example of a small box](http://www.ssi-schaefer.de/KS-Produktdetails.1539.0.html) (accessed 2008-05-20)

As soon as the goods receiving process is finished an automated belt conveyor lead the box to a lift. While pulling the box on to the lift, the attached flag on the box is scanned. As the lot flag number is indentified the box is automatically transported to a location within the storage. The storage place is fully automated chosen and controlled by the system. Besides storing, also the withdrawal of material from the storage is handled automatically. The storage and the withdrawal of material can be done at the same time. The automation system of the storage will organize the task. This means, if the process of storing is finished, the lift will not go back to the starting point, without verifying if a work order for withdrawal exists. If this is the case, it will withdrawal the small box and then it goes back to the starting point. During our own observation, it was noticed that the machine has downtimes every day. A technician is called and the machine will be repaired. This happened up to five times within an hour, during observation.

**Shuttle storage (called TORGSK)**

The shuttle storage is a partly automated storage that is mainly used for small parts like nuts and screws. The storage consists of six lifts, three on each side as seen in Figure 5.13. The shuttle storage has a number of aluminum tables inside (Figure 5.15). An
integrated lift, that can move up and down, can pull out a table, move that down to the bottom and forward, so the employee can access the table. If material needs to be stored or taken out of storage a table can be called by typing the storage location into a number pad on the front of the machine. The material can then be added or withdrawn from the table. When this is finished the table is moved back inside of the storage.

The small material that is stored in the shuttle storage usually arrives on standard pallets which are handled at the goods receiving area (see chapter 5.1). The handled pallets also wait on the belt conveyor behind the goods receiving area to be transported to the storage location. The forklift driver picks up the pallets and takes them to an interim storage in the main storage area. An exception is made, if the material fills up a whole pallet or is too large for the shuttle storage. Then the whole pallet is stored in the area with fixed storage locations. In the course of the day the material will then be added to the storage by one employee that is responsible for that. The material stored in the shuttle storage is mainly delivered in small cardboard boxes. These boxes can either be directly stored in the shuttle or if the boxes are too big they have to be repacked. For repacking, three different sizes of blue plastic boxes can be used. The sizes are 200, 300 and 400 and this specifies the number of pieces in a box. Figure 5.16 shows a picture of the blue box.
Later on these blue boxes are also used to deliver the material to assembly line. The blues boxes are always reused without any cleaning and are therefore contaminated with oil and dust. Due to the fact, that the shuttle storage is not fully automated the employee has to find a storage place himself (if no place is already assigned). To check which places are available the employee checks a manually written piece of paper on the side of the machine. This paper will state the different storage locations in the shuttle storage and whether they are empty, half full or full, irrespective of the kind of material already stored. Therefore, different material can be stored in one storage location. When a storage place is chosen and the material is placed on the storage table, the right storage place including quantity needs to be entered into Mapics. Furthermore, the piece of paper on the side of the machine needs to be manually changed to the new capacity of this storage table. However, material for the shuttle storage is rather irregular delivered, so the employees responsible will also do other work meanwhile, for example deliver material from the shuttle storage to assembly line or help at other positions. According to the employee, a plan when material arrives would help them to schedule the day better.

Plate warehouse

The plate warehouse is located in the manufacturing area at Volvo CE Braås (Figure 5.18). This plate warehouse is partly automated and works also like a shuttle storage (Figure 5.17). The metal plates that arrive with a truck are unloaded just outside, close to the plate warehouse. To store the material, a lift with a rack can be called to the backside, which has an opening so the lift can move out.

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The rack can then be filled with new metal plates. The same kind of plates can be piled to a stack on this rack. After the storage location is chosen in the computer system and the article number entered, the automated lift moves back inside of the storage to store the metal plates. The storage of metal plate is handled by two employees who both work part time. During our own observations it was noticed that several piles of metal plates where waiting outside and also inside to be stored. According to Gun Andersson, the production capacity has increased, but not the storage area. Therefore, the plate warehouse built in 1996 is fully utilized. The withdrawal of metal plates is not continuous undertaken as FIFO. Furthermore, the material that has arrived but has not been stored in the plate warehouse is not registered in the system. If a type of metal cannot be found in the storage the employee has to go outside and check manually.

**Engines storage (CTORG)**

The engine storage is located between main storage and assembly (Figure 5.13). This storage consists of a big shelf which can hold up to 30 engines. The engines are sequenced delivered. After the engines are received, they are directly stored in the inside storage. The exact location on the shelf is chosen randomly by the forklift driver.

**5.2.2 Outside storage**

Volvo CE Braãs has besides the mentioned storage places inside, also storages places outside. This is due to the large size of a material and also material that is sequential delivered and not really stored at Volvo CE Braãs. The following map illustrates the
location of the different outside storages (Figure 5.18). Metal plates are stored inside, but due to the location they are also included in this map. In front of the goods receiving area, a big roof that covers 15000 m² is installed.

![Figure 5.18 - Outside storage locations Volvo CE Braås](image)

Most outside goods like axles and large wooden pallets (which are stored in the UTEGODS area) are stored underneath this roof. Furthermore, purchased material which is sensitive to weather conditions is also placed underneath the roof. But others goods are also stored open-air without any weather protection. This is for example the storage area for cabs. These cabs are customized delivered in sequence and will be assembled within the next one to two days. Additional to the outside storage also a small storage for cabs (5 places) is located inside. Before the cabs are used at the assembly line, they will be transported by a forklift driver to the inside storage to dry out and warm up. Most large size articles that are stored outside, like cabs, axles and sometimes engines, have a high turnover rate and are only stored for a short period of time. Furthermore, tires are stored outside. Volvo CE Braås offers different kinds of tires for different terrain and also a variety of brands. The customer can change even after ordering the kind of tire or the brand chosen. On the other hand Volvo CE Braås has to place the orders for tires at least a half year in advance. Therefore, many tires have to be stored. In case Volvo CE Braås does not order the same amount regularly, the supplier will quote the quantity for tires for the next delivery.
5.2.3 External storages

Volvo CE Braås uses also external storage for some material. The following Table 5.1 gives an overview of the different external storages.

<table>
<thead>
<tr>
<th>Location</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Åseda</td>
<td>Tires</td>
</tr>
<tr>
<td>Växjö</td>
<td>Tires</td>
</tr>
<tr>
<td>Braås (Hyab)</td>
<td>Rims</td>
</tr>
<tr>
<td>Skövde</td>
<td>Metal plates</td>
</tr>
<tr>
<td>Hamburg (Germany)</td>
<td>Metal plates</td>
</tr>
</tbody>
</table>

Table 5.1 - External storage locations

Åseda and Växjö

First of all, tires are, additional to the storage at Volvo CE Braås, also stored in Växjö and Åseda. Both locations are circa 30 kilometer away from Braås. The supplier delivers the tires directly to Åseda and then they will be stored there. This delivery is free of charge for Volvo CE Braås. If there is a need for tires in Volvo CE Braås, from the external storage in Åseda, Volvo CE Braås organizes a transfer to Braås. The incurred expenses have to be covered by Volvo CE Braås. The newly opened external storage in Växjö is handled different. Here the truck first delivers to Volvo CE Braås, which is also free of costs. Volvo CE Braås has then to organize a transfer to the external storage locations, which is on the company’s own expense. Furthermore, the transport back from Växjö to Braås is also handled completely by Volvo CE Braås. For the near future it is planned that the suppliers also deliver directly to Växjö.

Hyab (Braås)

Secondly, rims are stored external at a company called Hyab. This company is located in Braås, close to the production plant of Volvo CE Braås. The supplier delivers first to Volvo CE Braås and hands in the delivery papers. After the papers are received, the truck is sent to the company Hyab to be unloaded. Besides storing the rims for Volvo CE Braås, also the painting of the rims is undertaken at Hyab. If demand occurs, the rims will be ordered from Volvo CE Braås and delivered in the amount needed.
Hamburg (Germany) and Skövde (Sweden)
Furthermore, metal plates, additional to the plate warehouse at Volvo CE Braås, are also stored external at Skövde and Hamburg (Germany). Skövde is located circa 250 kilometer away and Hamburg circa 570 kilometer from Braås. The suppliers deliver directly to both external storages. The additional transport form both storages to Volvo CE Braås is handled by Volvo CE Braås. Also the expenses have to be covered by Volvo CE Braås.

5.2.4 Review of main points for storage
- Different storage locations at Volvo CE Braås:
  - Inside storage for wooden pallets, small boxes and shuttle storage for small parts which is called main storage area. Engines and metal plates are also stored inside but at different locations.
  - Outside storage for cabs, tires, axles and utegods for large wooden pallets.
  - External storage locations for metal plates, tires and rims.

5.3 Assembly line ordering and feeding
The assembly area is mainly divided into two lines where each line assembles two types of haulers. One line (small line) 18 employees assembles the smaller haulers, A25E/A30E, and the other line (big line) 25 employees assembles the bigger haulers, A35E/A40E. Hereafter, they will be referred to as small and big line. The takt time for the big line is 85 minutes which means that one hauler is assembled every 85 minutes. For the small line the takt time is 123 minutes. The demand for big line is higher and therefore more effort is placed there. Both lines have a u-shaped structure for most of the assembly work. However, in the last steps, where larger parts are assembled for example the bucket, the flow is straight. There are also pre-assembly lines in between the two main lines. The Figure 5.19 is a simplified illustration of the assembly area; WS is short for workstation. The straight assembly lines and pre-assembly lines consist of a few workstations which are not illustrated in the figure below. The assembly employees work two shifts Mondays to Thursdays and one shift on Fridays. The first shift is between six in the morning to a little after three in the afternoon and the second shift start at three in the afternoon and ends at midnight. The two shifts always have a
meeting at three to share information. The seven forklift drivers that provide the lines with material also work during the same hours. The forklift drivers operate on the transportation routes also referred to as traffic lanes. The lanes are, except for the main lane, narrow and can only fit one forklift. The forklift driver often has to adjust back and forward before the forklift is in the right position for accessing the shelf.

On the long sides of the assembly and pre-assembly lines shelves with material for assembly are stored. This material is kept in wooden pallets, small boxes and blue boxes. There are also marked places for larger pallets and parts on the floor for example engines, axles and batteries. Some larger parts are pre-assembled before they are sent forward to the assembly line, for example engines and tires. However, tires are not pre-assembled in the area illustrated in Figure 5.19 but just outside the area (in the figure that would be outside the upper right corner).

5.3.1 Packaging material

Each workstation use specific material which is always located on the same place. This is called a consumption location and each consumption location has a specific number. The material stored at the consumption locations will be divided into following four categories; wooden pallets, small boxes, blue boxes and larger parts (which cannot be stored in any packaging material). The distribution between how often each category is ordered to the assembly line (wooden pallets and small boxes are for both assembly and manufacturing) in March 2008 and April 2008 are illustrated in Figure 5.20. Blue boxes are most often ordered 39 % (39 % in March) compared to wooden boxes 30 % (32 %),
and small boxes are least ordered with 13% (12%). Large parts stand for 18% (17%) of the orders. Moreover, parts that are delivered to the assembly line or manufacturing without ordering in the system are not included here as for example parts from the pre-assembly lines and shortage material. Shortage material should be forwarded as soon as they have arrived to the goods receiving line. However, sometimes this does not work and the assembly employee has to call and ask for the material to be forwarded. The ordering and feeding for the different categories are further explained below. The section about large parts will also include the parts from pre-assembly.

**Wooden pallets**

The standard way of ordering material that is kept in wooden pallets is that it is ordered by the employees at the assembly and pre-assembly lines. They scan a barcode when there is one part left in the pallet or when the last part is picked, depending on how fast the consumption of the ordered material is. Two K pallets which are half the size of L pallets are stored on the shelves but only one L pallet can fit on a shelf. The barcode, that is scanned, contains information of article number, article description and buffer location at the assembly line. Every pallet should have a barcode attached to the shelf by magnets at the consumption location. The barcode is easily removed to be brought to a computer where the scanning takes place and then the barcode is put back on the shelf. Each line has one computer for ordering purposes which is located almost in the center of a line. For some pallets the barcodes are missing and therefore the employees can have problems to memorize the article number (found on the lot flag attached by goods receiving) and the consumption location number. In situations where the employees are tired or stressed they can forget the numbers on their way to the computer and have to go back to the shelf. In Figure 5.21 the total amount of created work orders of wooden
pallets to the big line during four weeks (week 14-17, 2008) are presented. The amount of work orders decrease further into the day. The most work orders are created at 6 and 7 am; over 350 each during the four weeks.

The ordering of material is not always done immediately when last part has been picked. There are a few reasons for this. One reason is that the employees collect the material, continue to work and later on orders several pallets at the same time for example before a break or lunch. The breaks and lunch are almost at the same time for everybody in the factory. This means that the order placed by the assembly worker before the break will not be delivered during the break. Furthermore, this will lead to that the forklift driver will have more tasks than usual after the breaks and will take longer for the workstation to receive the material. In some cases, this takes one hour and can cause a stop in the assembly work. The assembly employee can let the forklift driver know of the situation in order to hurry the delivery.

Another reason is that the employee forgets to place an order immediately. This becomes obvious when the material is needed and the workstation has to order new material in order to be able to continue. This is most common when the pallet only contains few parts. Some pallets only contain one part and for this pallet it is crucial to make the order immediately after removing the part. The ordering is easy to forget since when the employee removes the part and immediately starts to assemble it, the following activities are started on.
Each pallet order generates a work order for the forklift drivers that are working in the assembly area (six drivers). The assembly area is divided into three zones and two forklift drivers operate in each zone. The forklift drivers have different ways of handling the tasks. However, the main difference is whether they collect the empty pallet from the assembly line first or the full pallet from the storage first. Moreover, it is not routine for how many pallets that are handled at once. Depicted in Figure 5.22 is the total amount of finished work orders of wooden pallets to the big line during four weeks (week 14-17, 2008). This chart show that the amount of finished work orders decrease during the day, which was the same as for the started work orders.

![Graph showing finished work orders for wooden pallets to big line]

**Small boxes**

The small boxes are ordered by one forklift driver that only works on the early shift. This forklift has a scanner which is used by the driver when ordering. The barcode is on the lot flag that was attached by goods receiving. The assembly employees place the empty small boxes on the top of the shelves to send a signal to the forklift driver. Two small boxes can fit on the shelves at the assembly line. Since the small boxes are stored in an automated storage the order generated by the forklift driver is processed instantaneously when scanned by the forklift driver. This means that the boxes are withdrawn from the automated storage and placed on a conveyor where the forklift driver can collect the ordered boxes. The total amount of both created and finished work orders of small boxes during four weeks are illustrated in Figure 5.23. The chart illustrate that the work orders are only between 6 am and 3 pm which are the work hours for the forklift driver.
The forklift has a rack with 5 shelves that can carry 10 small boxes at a time and the boxes are easily placed on this rack with an elevator. This elevator is a platform between the forklift driver and the rack. The ordering and feeding of small boxes is according to the assembly line employees working fine.

Blue boxes
Three months ago a decision was taken about refilling the blue boxes during nights in order to decrease the traffic of forklifts around the assembly line. The assembly employees have the same procedure as for the small boxes; they place the empty boxes on top of the shelves. However, they are collected and refilled during the night by seven forklift drivers. The materials in the blue boxes are mainly fastening material. This material is delivered in small carton boxes and therefore has to be repacked into the blue boxes before being sent to the assembly line. There are three different sizes of blue boxes. The size 200 is the smallest, 300 the middle size and 400 the largest. In the pre-assembly line for engines extra deep racks fit up to six blue boxes in a line. However, all other lines have racks that only fit two to three blue boxes. Figure 5.24 illustrates the total amount of orders for the different sizes of blue boxes within four weeks (week 14-17, 2008). However, the statistics are only for one workstation. The orders are the most for the blue box size 300 with almost 250 boxes in total for the four weeks.
The material (screws, nuts etcetera) is ordered by scanning the attached label (printed at the shuttle storage) with a barcode on the blue box, containing article number and consumption location, at the shuttle storage, where most material for the blue boxes are stored. The following Figure 5.25 illustrates at what time the total amount of work orders of blue boxes to the big line were created during four weeks (week 14-17, 2008). Each work orders equal one box. Almost all orders were made at 12 am; an amount of over 3000 boxes over four weeks.

For some reason all blue boxes are not always refilled during the night. Furthermore, refills during the day are sometimes required. The assembly employee orders by calling the person that is responsible for goods receiving at the shuttle storage during the day. This person places the order in the system, fills a box and personally delivers to the assembly line. However, the transportation is then done with a scooter (a form of a bicycle where you push off with your foot) and not a forklift. The Figure 5.26 shown below illustrates the point of time when work orders of blues boxes to the big line were
completed. This is also considered for a four week timeframe (week 14-17, 2008). The time 4 am had the most finished work orders; an amount of 1700 boxes were delivered to the assembly line within a total period of four weeks. To be mentioned is that these boxes are never cleaned.

![Figure 5.26 - Finishing point for work orders of blue boxes to the big line](image)

**Large parts**

Larger parts are materials which do not fit in the three categories above as for example engines, buckets, cabs and tires. Most large parts are pre-assembled or manufactured except for example cabs and pipes. The pre-assembled parts for example engines, axles, tires and batteries are sent forward to the assembly line as soon as they are finished. For tires this is sometimes not done and the assembly employee has to call the person that is in charge of pre-assembly of tires to have them delivered. However, first the location at the assembly line for the specific part has to be empty. For the other large parts, for example cabs and pipes, lists of barcodes are placed next to the computer used for ordering. However, this can lead to ordering of the wrong material since the article description can be very similar, for example there are parts that have the same description but one is a left and the other a right part. The largest parts are delivered on racks with wheels pushed manually or forklift.

5.3.2 **Review of main points for assembly line**

- The assembly line receives parts in four different packaging materials; wooden pallets, small boxes, blue boxes and racks for larger parts.
- The wooden pallets are ordered by the assembly employee when needed.
- Small boxes are ordered by a forklift driver during the early shift (6 am to 3 pm).
• Blue boxes are refilled during the night.
• Some large parts are forwarded from the pre-assembly lines, other parts are ordered the same way as wooden pallets.

5.4 Questionnaire to the assembly employees

The questionnaire was handed out to each workstation in the assembly area. All workstations received at least one paper with the questions. The figure shows that only for the small and big line there are 18 workstations which mean that at least 18 workstations received the questionnaire. Only 13 questionnaires were collected, however some workstations cooperated with each other when filling out the questionnaire. For example the big line with ten workstations handed in only two to three papers. Moreover, the first and second shift used the same paper. However, they were handled as one answer.

Since the questions allowed open answers some generalizations were made. For instance, answers like approximately once a week were counted as weekly, works fine was interpreted as never and so on. The terms often and seldom could not be generalized into figures about how many times a day or week and were therefore left as is. The summary in Figure 5.27 was made for the answers on questions one to three. The numbers in the different categories are the amount of answers within that range. For example, the answer “seldom” about blue boxes was given four times.

The answers show that ordering material in blue boxes most often occur “seldom” and “weekly”. The term weekly was used for answers between one to a few times per week. Together they hold nine of the 13 answers. The pallets are equally ordered in the two categories “one to eight per day” and “more than eight per day”. The totals of answers were only ten from at least 13 answers. One answer was not filled out and the second two were written in a way that it could have been interpreted as anything from several times a day to only a few times per week.
The Figure 5.28 was made for the answers on question five. Answers on question number four will not be covered in this thesis. However, the findings will be presented to Volvo CE Braås. Moreover, products mentioned in other answers will not be shown in the figures regarding the questionnaire. The answers for how long time went by from when a shortage occurred to when the material was delivered to the assembly line are very scattered. Reasons for this are for example that when a shortage occurs it can be solved within minutes if another workstation has abundance of this material. However, if the material has to be ordered from the supplier then this can take a week until it is delivered. The answers are not complete to whether shortages will lead to a stop but six answers show that it seldom or never stops the work at the workstation. Only one answer state that shortages stop the work but this is seldom for several hours.
Figure 5.28 - Answers on questionnaire question 5

Figure 5.29 was made for the answers on questions six and seven. The answers for problems and improvements are almost directly connected to each other.

Figure 5.29 - Answers on questionnaire question 6 and 7
5.5 Summary

This chapter described the current material handling process at Volvo CE Braås. First of all, the goods receiving process explains the different kinds of material that arrive, the handling and how they are forwarded to storage. In the second part, the different storage locations including inside, outside and external storage and the process of storing material are illustrated. Finally the material supply to assembly line, which includes the different ways of ordering and feeding the material to the line, is depicted. Furthermore, the result of a questionnaire handed out to assembly employees is presented.
6 Benchmark

A benchmark was conducted in order to be able to compare Volvo CE Braås with other plants to collect ideas for improvements. Therefore the production plant for wheel-loader at Volvo CE Arvika (Sweden) and the production plant for trucks at Volvo Trucks Gothenburg (Sweden) were visited. Furthermore, a stakeholder of this thesis was interviewed to gather information about the production plants of Scania in Oskarshamnn (Sweden) and in Södertälje (Sweden). The collected data is presented in this chapter. The sources for each collected data are not presented.

The following Figure 6.1 illustrates the framework supplemented with this chapter. The connection to the research questions can be viewed.

![Figure 6.1 – Framework of empirical findings](image)

6.1 Volvo CE Arvika

The location of the plant in Arvika (Sweden) has been occupied by companies since 1880s. At that time a stock company called AB Arvika Verkstäder was situated there. In 1954 Sweden’s first wheel-loader was launched in partnership with Br Lundberg. The company in Arvika merged and changed names a few times and in 1960 AB Volvo acquired the company, at the time called AB Arvika-Thermaenius.\(^{191}\) The wheel-loader production is a Business Line (BL) within the Business area Volvo CE and since 2005 merged with the Hauler BL to the Hauler-Loader Business Line (HLBL) (Figure 6.2)\(^ {192}\).


\(^{192}\) Volvo CE HLBL, internal presentation
Today around 1200 employees work at Volvo CE Arvika which produces several types of wheel-loaders. The plant location consists of several large buildings for example metal storage, production and assembly. The building where the assembling takes place has different floors. In the basement for example the goods receiving and storage for assembly material is located. An elevator transports the material between the different floors. The material planner checks with suppliers that all large parts are on their way to Arvika before starting the production and assembly of a wheel-loader. If the supplier cannot confirm that the parts will be delivered in time then the production sequence will be changed. Meetings are held for all areas every morning to discuss stops, mistakes etcetera that occurred the day before.

**Goods receiving**

In goods receiving the collis are counted upon unloading the truck by forklift drivers. The collis are placed in one area and then forwarded to different receiving areas by forklift drivers. Metal plates are delivered to the metal storage directly by train. The goods receiving area for assembly material is also divided into a number of different areas which are marked out on the ground and have visual signs. The pallets are counted again when loaded onto the conveyor that leads into the building for goods receiving of material to assembly line. The forklift driver can load a stack of pallets at once since in the beginning of the conveyor there is a machine that releases one pallet at a time.
automatically. The pallet at the bottom is released first and so on. The forklift driver always handles a complete order, which means that all pallets have to be counted for before they are released on to the conveyor. Should any pallets be missing the existing ones would be put aside until all are recovered.

The goods receiver has to enter the item number manually and print flags to attach on the pallets. The figure Figure 6.3 illustrates the layout of the lot flag at Volvo CE Arvika. All flags for one order are printed at once which is the reason for the forklift driver not to send in incomplete orders. The color of the lot flag is changed after a specific timeframe for example yellow flags for January and February, green flags for April and May, in order to easily visualize when the pallets in storage and assembly line were received. When material is received in small boxes they are repacked into wooden pallets before storage.

<table>
<thead>
<tr>
<th>Colli number</th>
<th>Printing date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barcode (Storage number)</td>
<td>Amount</td>
</tr>
<tr>
<td>Storage number</td>
<td>Main storage place</td>
</tr>
<tr>
<td>Article Number</td>
<td>Supplier Name</td>
</tr>
<tr>
<td>Packing code</td>
<td>Kg Tot</td>
</tr>
</tbody>
</table>

Figure 6.3 - Lot flag Volvo CE Arvika

The conveyors after goods receiving are automated and can go in different directions for example to the elevator or directly to the forklift driver in the basement storage. There is a barcode scanner on the conveyor line that reads the barcode on the flag and forwards the pallet in the right direction.

**Storages**

There are several different storage areas inside and outside (in tents). All storages have noticeable and clear signs. Each time a colli is moved from one storage area to another, this is changed in the system. The forklift drivers outside are not allowed to drive inside and vice versa the forklift drivers inside are not allowed to drive outside. Therefore, there is a storage area called the lock (Slussen). Here both drivers are allowed to deliver and collect collis. Material as for example cabs, transmissions and axles are delivered in
sequence. If everything runs as planned, the material is delivered directly to Arvika. Otherwise it is sent directly to an external storage in Hallsberg.

The pallet storage is mainly located in the basement. The storage is not high; only a few levels of shelves. However, there are also storage shelves around the assembly lines which are located on the first floor. The first two shelves are consumption locations and the second two shelves are used as storage. Moreover, storage shelves are placed along the walls on the first floor.

**Assembly line ordering and feeding**

Assembly line works two shifts Mondays to Thursdays and one shift on Fridays. There are three main assembly lines, two lines have the takt time 42 and 60 minutes, which refers to how long until one wheel-loader is assembled. They are located on the same floor and surrounded of shelves with pallets. The third has a takt time of 4 wheel loaders per week. It is assembled on a different floor and has a different layout around it. The line with 42 minute takt time has a LCD (digital screen) installed in the ceiling which shows data about:

- Time left of the takt time
- Time for stops in total for the day
- Number of wheel-loaders behind schedule
- Number of wheel-loaders that have been produced ahead of the plan from the beginning of the year
- Percentage of wheel-loaders that are completed during the day without missing any parts due to shortage
- Real time

The time for stops is registered when a workstation pushes a stop button. This will affect the time for the whole line and works as an incentive for all workstations to cooperate to keep the stop time as low as possible. There were several wheel-loaders waiting outside for different parts that had not been received yet.
There are different ways for the material to reach the assembly line. For large parts like cabs the assembly employee has to order a new cab as soon as the one in the consumption location has been used. The order is placed into a computer system at the assembly line. The forklift driver has 42 minutes (for the 42 minute takt time line) to finish the work order that is created when the assembly places an order. Should the assembly line forget to order the required material in time an employee in charge of solving emergencies like this can be contacted. However, this causes stop time for that workstation.

For smaller material in cardboard boxes the assembly employees have to order at the end of their shift and this will be delivered the next day in time for their next shift. This way they can never blame the previous shift for not refilling this material. These small parts are supplied from the storage in the basement. The forklift driver in the basement receives the work order, collects the material from the storage and then leaves it in the elevator. The forklift driver at the assembly line also receives a work order and can collect the material at the elevator.

The fastening products like screws and nuts are handled by VMI. A material handler checks if fastening products are needed at the assembly lines and orders around noon. When the barcode is scanned the order is sent automatically to the supplier at the same time. The parts are delivered from the supplier around four in the following morning. The forklift drivers deliver the fastening products to the assembly line between 6:30 and 7:00 in the same morning. However, sometimes the assembly employees places orders that are not needed. Moreover, the fastening products and small parts are not repacked into plastic boxes but instead delivered to the assembly line in the original cardboard boxes. The plastic boxes (referred to as small boxes for Volvo CE Braås) that sometimes arrive to goods receiving should never be forwarded to assembly line.

Volvo CE Arvika offers different tires for their customer however they never guarantee that any specific brand or other special criteria is available. If the customer wants a specific tire brand that Arvika for some reason do not have, the customer has to procure
and deliver the tires to Arvika. Otherwise, Volvo CE Arvika can send the wheel-loader with wooden tires and the customer will have to assemble the new tires after delivery.

In the current ordering system (see Figure 6.4) the assembly line employees orders create a work order for the inside forklift drivers and the material are withdrawn from the storage inside. This material should be replenished by material stored in the tent, if there are any, in order to secure Fifo handling. There have been some problems when newly received material have been stored in the inside storage and therefore sent to the assembly line even though previously received pallets containing the same material have been available in the tent. The current solution for this problem is that the work order is forwarded to the outside forklift driver that in turn delivers material to the inside storage.

![Figure 6.4 - Current ordering and material flow at Volvo CE Arvika](image)

The future solution (see Figure 6.5) is to enable both inside and outside forklift drivers to work on the same page which means that both will be able to see all work orders and deliver the needed material to the following location.

![Figure 6.5 - Future ordering and material flow at Volvo CE Arvika](image)

### 6.2 Volvo Trucks Gothenburg

Volvo Trucks is the biggest of the six divisions within Volvo Group (Figure 6.6). The first truck was produced in Gothenburg (Sweden) 1928 and was the second product within the company. Only cars were produced before. Volvo Trucks became a success right from the start and the planned quantity of 500 trucks was soon doubled.\(^{193}\) Today the company is located in Europe, North- and South America, Asia, Australia and

Africa. It manufactures medium-heavy to heavy trucks which are used for long-haul, regional transport and construction operations.\footnote{The Volvo Group (2007) pp. 1, 4-5}

![Figure 6.6 - Division in Volvo Group](image)

**Goods receiving**

Volvo Trucks Gothenburg receives 1500-2000 pallets every day from about 60 trucks. Of those trucks are about 50 time-planned. The company tries to have an even flow of incoming goods but Mondays are busier than other days. When a truck arrives, the driver goes to the goods registration to get a confirmation to unload. The materials are received in a variety of different packaging material. Many items are packed in wooden pallets. Those are, after unloading, put on a belt conveyor by a forklift driver. He also enters a work order into the computer system so that the ACS (Automated Carrier System) is informed to pick up the pallet. When the goods receiver gets the wooden pallet, he attaches a lot flag with pallet identification and barcode. The pallet is also weight to control the amount of pieces and automatically identified before being stored.

Small boxes are received in two different sizes, one as twice as big as the other. Smaller parts like screws and nuts are received in cardboard boxes that are consolidated in a wooden pallet. The company uses sequenced delivery for large components like fuel tanks and cabs. The supplier receives a delivery schedule for capacities of raw material to be able to plan the deliveries. Another message with more detailed information about chassis number and article number for each needed part etcetera is sent to the supplier. This is done after a production plan is created, which is done daily for 15 days ahead. The supplier is then able to deliver in JIT with a sticker on each part which tells what chassis the material belongs to. The supplier for tires delivers to an external storage in Ghent (Belgium), where they also are assembled. The tires are then sent sequenced with 4-5 trucks every day. Trucks with metal coils are coming another 4-5 times every day.
The coils get a small lot flag with information about receiving date. Long distance suppliers, from for example South Africa, deliver material to a hub in Europe before it is delivered to the company.

**Storages**

The storages for wooden pallets and small boxes are fully automated high rack storage. The storage places/locations depend on how often the material is used. High frequent parts are placed close to the hand in/hand out and low frequent items further away. The company uses Fifo for material stored in those storages. Large parts like fuel tanks cannot be stored in wooden boxes. Those are put in suitable racks which can have different kinds of the same items. They are packed by the supplier on the rack by the last-in-first-out principle (Lifo) according to the trucks that are planned to be produced. Those components are not stored at Volvo Trucks Gothenburg but go directly to assembly line when received from supplier. The company tries to store all material inside, which most often is possible. However, it might be that one of the storages is full and material has to be stored outside.

**Assembly line ordering and feeding**

Each day 144 trucks are complete build up (CBU) at Volvo Trucks Gothenburg. Around 40 of those are more customized than the other. The assembly line is separated in two flows which are mainly the same. Each line produces different kinds of trucks in different work stations at the same time. They have a limit of around ten different models every shift. The different models and the assembly order of them are decided according to the plan. The assembly employees work in 2 shifts. Each work station has an automated system (Swisslog) which moves the assembled parts forward to next work station in the assembly line. This is done according to the takt time. Two work stations use a carousel with one station on each side. This is used to deliver the pre-assembled axles from one work station to the other, which connects the axles to the chassis.

The company uses 99.9 % kanban when feeding the assembly line. Only some low volume material is repacked and supplied in the needed quantity. The assembly employees order materials in wooden pallets when needed with help of a wireless
scanner. The barcode are either attached on the shelf where the pallet is placed, or in a list close to the computer. Items which are in small boxes and cardboard boxes are put on the same shelves as wooden boxes. There are either one or two small boxes (depending on the size) with the same content. For smaller parts six cardboard boxes containing the same material are put in a row on the shelf. In some cases the cardboard boxes are replaced with blue boxes. Those are, however, only used in small amount in few areas. Small boxes and cardboard boxes are continuously replenished by a forklift driver. This is done through a milk round which goes around the whole assembly line. The assembly employees put the empty small boxes on top of the shelf to give a signal that more material is needed.

The forklift driver is responsible both for ordering and feeding all boxes, which has to be done within four hours. When an empty small box is found the barcode is scanned. An order is then sent to the automated high rack storage to bring out that material. The small boxes are then provided in to 8 different racks depending on the consumption location. If a rack is filled the forklift driver picks up the whole rack and delivers all the small boxes. At the same time as looking for empty small boxes, the forklift driver also searches for empty places on the shelves for cardboard boxes. In some cases those are handled with VMI by external companies. This was more common before but the VMI-replenishment has today decreased. Large parts like chassis are sequenced received to the work station. Since there are different models assembled all the time, the needed chassis is determined according to the production plan. Internal manufactured parts are also delivered sequenced from a buffer area.

The assembly line has a big LCD to inform the employees about:

- Time left of the takt time
- Real time
- Number of trucks assembled
- Number of trucks behind schedule
- A little oval circle illustrates each work station. This circle is green if everything is running but changes to orange or red if there is a problem.
Another LCD shows data about:

- Percentage of trucks that has good quality from the beginning. This is shown both for each work station and as a total for all stations.
- Real time

6.3 Scania

The benchmark information of the company Scania, specifically the production plants in Södertälje and Oskarshamn, were collected during an interview with the stakeholder Mikael Svensson, Manager Global Logistics Development Volvo CE HLBL. He has visited both production plants several times to share knowledge and to learn from each other.

The company Scania, was established in 1891. Scania builds trucks and buses, sells industrial and marine engines, and also offers service related products and financing services. Since 1891, more than 1,000,000 trucks and buses have been delivered. The company concentrates mainly on the heavy transport segment. Today, Scania is operating among the world’s leading manufacturer of heavy trucks and buses.\textsuperscript{195} At the production plant in Södertälje, the production of components, engines as well as trucks and bus chassis takes place. This production plant has 5,190 employees.\textsuperscript{196} The production plant in Oskarshamn is responsible for the production of cabs. The workforce of this plant sums up to 2172 employees.\textsuperscript{197}

In the following chapter, the name Scania is used to name both mentioned production plants at once. Scania sets a high value on the use of methods, principles and standards. Scania is very keen in finding new methods or principles. If a new principle cannot be approved, the principle will be abandoned and the search for a new one starts. Everybody as to follow these routines, in order to secure that a workflow is always carried out the same way. The main focus of the company is to identify all existing deviations. These deviations are neatly called “candy”. This should imply that Scania

\textsuperscript{195} http://www.scania.com/about/scaniahistory/ (accessed 2008-05-21)
\textsuperscript{196} http://www.scania.com/about/world/Production_Units/sodertalje_sweden.asp (accessed 2008-05-21)
\textsuperscript{197} http://www.scania.com/about/world/Production_Units/oskarshamn_sweden.asp (accessed 2008-05-21)
wants to find these deviations, like everybody likes candy. In their opinion, this is the only way to improve.

**Goods receiving**

The main fact that was mentioned about the goods receiving process is the truck routing. At Scania the supplying trucks arrive on schedules basis, every 30 minutes. Then the truck is unloaded and the pallets are handled. The goods receiving desk has 30 minutes to handle the load of one truck until the next truck arrives. This helps Scania to control the amount of pallets better and also the workflow is more taked.

**Storage**

Scania, has built a new automated warehouse, a couple years ago. Then, a lot material was stored at the company itself. Today, Scania tries to minimize their storage as much as possible. Instead, the material should be delivered, when needed, direct to the assembly line. As a result, the fully automated storage cannot be fully utilized. According to Mikael Svensson, the trend is to get away from big fully automated storages. These storages make it difficult to adjust to capacity changes. Conversely, the automated storage at Scania in Oskarshamn helps Scania to fully control the material in storage. The pallets that arrive are automatically scanned and weight. If there are any discrepancies the pallet is moved to the side and checked by an employee.

The material is also withdrawn under full control, and thus the stock level can be fully monitored. The withdrawn material from storage is considered to be consumed and will not be shown in the stock level. The material delivered to the assembly line is regarded as the only safety stock. If the stock level in storage is 0 for a material (which occurs directly after the material is withdrawn) a new order will be placed at the supplier. The supplier is instructed to deliver the material within one day. A problem occurs if the material delivered to the line last longer than just one day (e.g. 1 month). New material is ordered, but actually not needed until in one month.
Assembly line ordering and feeding

The goal at Scania is to have a less material as possible stored at the assembly line. Only what is needed should be stored. The production plant in Oskarshamn, assembly of engines, has a short takt time of three minutes. According to this also the line feeding is takted. The forklift drivers have fixed routines for delivery and pick up of small boxes. Each time, eight boxes are delivered to the line and also eight empty ones are picked up. This is done in a continuous flow. Furthermore, a train is used that drives every 30 minutes around the assembly line to pick up empty pallets and fill up new pallets. The pallets itself have wheels and can therefore be changed without lifting them up. Two preferred methods at the assembly line are: 2-bin system (frequent material) and kitting line (infrequent material). For the kitting, an employee receives a list with all items needed. These items will then be packed to a kit in the same takt as engines are assembled. First all items needed for workstation 1, then all items needed for workstation 2 etcetera are kitted, and then delivered in sequence to the line.

The employees at the assembly line are not responsible to order material. The line feeding is completely handled by the logistics department. They have to secure that the material arrives as needed at the line. However, for some workstations, a 1-bin system is still in use. Here the employee at the line is responsible to order material. Scania is not very satisfied with that. The assembly employee has to order new material as soon as the last piece is takes out of the box. Sometimes, this is forgotten and no new material is delivered. As a result, a shortage for the next engine assembled occurs. Moreover, the order for new material can be done too early. When new material arrives, the box is might not be empty yet. The box is exchanged, the remaining material stored at the side till it is needed.

6.4 Summary and the conceptual model for this thesis

In this chapter information about the material handling process of three companies are presented. First of all, the information gathered during a visit at Volvo CE Arvika and Volvo Trucks Gothenburg is depicted. Furthermore, the material handling process at Scania Oskarshamn and Södertälje is described.
The Figure 6.7 illustrates the conceptual model developed in order to answer the research questions. Furthermore, each section gives a summary of the information covered in the previous chapters. The conceptual model is the basis for the following analysis.

![Conceptual model for this thesis](image-url)
The following analysis begins with the introduction of the chosen product family and in the second step the presentation of the current-state map in order to answer the first research question. In the second part a cause and effect diagram shows the identified waste which will be analyzed thereafter. In the third research question analysis of suggestions on how to improve the identified waste and a future-state map are presented. Within this chapter the single sources of the empirical data will not be named.

The analysis of this master thesis will be conducted by using the model VSM presented earlier in the theory chapter. The four steps of VSM suggested by Rother and Shook will be followed. However, a work plan for a specific timeframe is not requested by the company, and therefore not developed. Furthermore, the model VSM will be adjusted to the deductive approach of the authors. The analysis is structured according to the research questions. The following Figure 7.1 illustrates the three research questions and their connection to theory and empirical findings.

![Figure 7.1 - Framework of the analysis](image)

### 7.1 Research question 1:

- How can the material handling process, from goods receiving to assembly line, at Volvo CE Braås be described by using VSM?
In order to answer the first research question and describe the material handling process at Volvo CE Braås the first step, select a product family, should be performed. In the second step, the current state map should be presented and analyzed.

### 7.1.1 Product family

The selection of a product family is the first step when conducting VSM. A product family can be characterized as group of products which follow the same steps and use the same equipment during the production process. The product family should be chosen by looking at the end of the value stream of the company, which is closed to the customer.\(^{198}\)

The product family chosen for this thesis is the big line A35/A40. Both haulers are produced at the same assembly line and follow therefore the same assembly steps. The reason for selecting the big line is the higher demand from the customer for this product. Thus, the number of big haulers assembled during one day is higher, compared to the number of small haulers (A25/30) assembled during one day. The material handling processes for the big line is therefore higher frequented compared to the small line.

### 7.1.2 Current-state map for Volvo CE Braås

The current-state map is the second step in VSM. This map can be drawn after the necessary information is collected.\(^{199}\) The material handling process at Volvo CE Braås can be described with the help of the current-state map. The current-state map is adjusted to the deductive approach of this thesis and will therefore be illustrated in a modified way.

The following symbols were used to illustrate this current-state map (Figure 7.2)

![VSM symbols used in current-state map](image)

*Figure 7.2 - VSM symbols used in current-state map*

\(^{198}\) Rother, M. & Shook, J. (2003) p. 6

1. Sequence ball = Sequence delivery
2. Process box
3. Data box = The data box gives information about the process (e.g. number of pallets)
4. Inventory symbol = illustrates a point at which additional waiting time was observed.
5. Arrow = symbolizes a transport from one process to the other. The arrow points in the direction of the material flow.

Figure 7.3 pictures the current-state map of Volvo CE Braås. An enlargement of the map can be viewed in appendix II.

7.1.3 Analysis of the current-state map

The items, in the current state map, are only a selection of the articles received at Volvo CE Braås. A current map for all items received would not have given an overview as intended by the authors. However, the items chosen include all existing ways of goods receiving, storage and assembly line.
Goods receiving

The goods receiving process starts when trucks with raw material and components arrive from suppliers or other factories within Volvo Group at the unloading area. The number of trucks that arrive per day can vary during the week. The number of collis includes all items received with no distinction between larger, smaller parts and wooden pallets. The amount of collis received every day is almost the same. As can be seen in the current-state map, the amount of incoming collis is not in relation to the incoming trucks. The reason for the variation of amount of arrived trucks but an even number of collis may, according to us, be due to the different sizes of collis. It can be assumed that large parts are delivered in a bigger amount on Mondays. Each truck cannot bring for example as many cabs as wooden pallets, and therefore the amount of collis per truck is lower. However, the flow of incoming trucks during the day is not even which is connected to the amount of received collis per hour (Figure 7.4).

The uneven flow of collis lead to the fact, that the forklift driver has more to do during some hours. A result of this is, according to us, that the control of number of collis is lower these hours. If a colli is missing, it will take longer to notice and it will be almost impossible to find a specific pallet. An uneven flow of handled collis makes, in our point of view, it difficult to plan the work. The handling would be easier if the flow is equal during the day. Short after the peak of incoming trucks (6 am) an increasing amount of received collis can be noticed in the goods receiving (Figure 7.4).

According to theory there are different alternatives how to pack goods during handling, transportation and storage as a unit load\(^\text{200}\). The most common method is to put the

material\textsuperscript{201}, both larger parts and cardboard boxes with small parts\textsuperscript{202}, together on pallets. At Volvo CE Braås wooden pallets and plastic boxes are received. Smaller parts are also received in cardboard boxes consolidated in wooden pallets. Except for tires and rims, the larger parts like axles, engines and cabs are usually supplied on a particular rack. We reached the conclusion that the different packaging materials are necessary for an efficient handling.

Sequential parts are delivered by a supplier in the needed sequence\textsuperscript{203}. Cabs and axles are received in sequence three times per day to deliver the amount needed in production. The sequence balls situated on the transport arrows of cabs and axles in the current-state map symbolize the sequence delivery of these parts. We think this is a good solution since it leads to less storage for the company. Furthermore, the forklift driver and receiving clerk know in advance when the goods are coming. This results in that routines can exist which make it possible to plan the work. When the same materials are received in the same cycle-time, the handling may be both easier and faster.

In theory it is mentioned that pallets can easily be handled by forklifts, piled on top of each other when using a collar and reused\textsuperscript{204}. Both larger parts and small parts can be easily consolidated on a pallet\textsuperscript{205}. The pallets that are stored in the outside storage area do not go through the inside goods receiving line. We came to the conclusion that this is a good way of handling pallets that are stored outside. The advantages of this solution are less transportation and that the goods receiving line has less pallets to handle inside. All other pallets are, after unloading and transportation, standing outside in a stack and the forklift driver can only put the pallets one by one on the belt conveyor. The waiting is shown in the current-state map as an inventory symbol. In our opinion this way of handling is time-consuming. This leads, according to us, to unnecessary waiting time not only for the employee but also for the goods.

\textsuperscript{201} Molina-Murillo, S. A. et al. (2005) p. 25
\textsuperscript{204} Lumsden, K. (2006) pp. 520-521
The small boxes are first handled in the main goods receiving line and then transported to the goods receiving line for small boxes. This results in more transportation and waiting time. We believe that the system today is not the most preferable one. The double handling for small boxes is, in our opinion, unnecessary. Moreover, if small boxes would not be handled in the main goods receiving line, more other wooden pallets could be handled. On Mondays to Thursdays the incoming quantities of small boxes are almost the same. On Fridays the incoming quantities for small boxes are lower. This is due to that the goods receivers only work one shift on Fridays.

Storage

Storage exists because of the problem to match the demand and supply of material\textsuperscript{206}. It helps to maximize the space, labor and equipment utilization, material accessibility and material protection\textsuperscript{207}. As it can be seen in the current-map Volvo CE Braås uses inside, outside and also external storage locations.

Metal plates are, beside the external storage in Skövde and Hamburg, also stored at Volvo CE Braås in partly automated plate warehouse inside. However, it was noticed that a large amount of metal plates is waiting outside the storage at Volvo CE Braås (symbolized with the yellow triangle). The reason given by the company is the increase in production volume, but no simultaneously enlarged warehouse. In our opinion this is not organized in a good way. First the metal plates are stored far away and have to be transported to Braås on the company’s expense. Secondly, the material is stored again in Braås for unknown timeframe until finally used. Due the fact that Fifo is not continuously used when withdrawing metal plates from the plate warehouse, some plates might be stored for an indefinite time. Furthermore, the material that is waiting outside is not registered in the system and can’t be found when searching for it.

Volvo CE Braås also has external storage locations for rims and tires. Tires are stored in Åsedå (Sweden) and Växjö (Sweden), but the handling differs between both storages. The storage in Åsedå is supplied by the supplier directly. The tires are ordered from the external storage according to production plan and transport on the expense of Volvo CE

\textsuperscript{206} Tersine, R. J. (1994) p. 6

\textsuperscript{207} Tompkins, J. A. et al. (2003) pp. 430-431
Braås to the production plant. The newly opened external storage in Växjö is handled different. Currently, the material is delivered first to Volvo CE Braås by the supplier. A second transport takes the material to Växjö and a third transport back to Braås when demand occurs. Furthermore, the tires wait additional time in Braås before picked up for the transport to Växjö. This is symbolized again with the yellow triangle. Besides these two external storages, Volvo CE Braås also operates a big outside tire storage area in the yard at the production plant. We think that the handling for the transport to and from Växjö is unnecessary. Volvo CE Braås is aware of this fact and is already negotiating with its suppliers to solve this matter. Furthermore, we call the fact into question if the big storage area at the production plant itself is necessary to have.

Rims are also stored external at the company Hyab in Braås. This external storage is close to the production plant of Volvo CE Braås. The delivered rims are directly unloaded at Hyab and also the painting of the rims is undertaken at Hyab. The rims will then be ordered according to production plan and delivered in the amount needed. In our opinion this is organized in a good way. The external storage location is close to Volvo CE Braås and the material is only ordered and delivered when needed. Furthermore, the painting of the rims is carried out at Hyab, which can be seen as a value adding task and should therefore not be changed. As value adding classified can be all operations that add value to a product through the conversion or processing of raw material or semi-finished products.\textsuperscript{208}

In theory it is mentioned that one way of sorting the goods in storage is by weight and how they can be handled. Heavy and hard-to-handle material should preferably be stored close to the point of use and not too high. Material that is very large or shaped in an unusually way can be stored in an open space to reduce handling and storage problems.\textsuperscript{209} Volvo CE Braås uses an outside area to store material (Figure 5.18). This is mainly done for big parts that cannot be stored inside and sequential delivered parts that are only stored for a short period of time. Material delivered in sequence includes cabs (G-TORG) and axles (C-TORG). Both have a high turnover rate and are usually used within one to two days. Before the cabs are used for assembly they will be

\textsuperscript{208} Monden, Y. (1994) p. 179
\textsuperscript{209} Tompkins, J. A. et al. (2003) p. 444
relocated to a small inside storage area to dry off. Furthermore, large pallets which do not fit in the inside storage are stored outside (UGODS). After unloading the pallets are directly taken close to the UTEGODS area. For this reason the arrow pictured in the current map is starting at GR and not at the pallets box.

Another item shown in the current-map is engines. When the engines are unloaded they will be transported to their storage location. The storage is inside on a shelf which can hold up to 30 engines. The forklift driver chooses the storage location randomly and enters it in the system.

Besides the mentioned large material, also smaller material is received at Volvo CE Braås. For these smaller goods different storage location in the main storage area inside are used (see Figure 5.13 for a map for inside storages). The material is mainly received on a pallet, in small boxes and in small cartons, consolidated on a pallet. The pallets are stored in the main storage area called TORGGM, the small boxes are stored at TORGSB, and the small cartons are stored in TORGSK.

According to theory there are two different ways when planning the storage space; fixed and random location storage. With fixed location storage each material has its special location and should not be stored anywhere else.\textsuperscript{210} An advantage when using this system is the possibility to separate the material into different groups depending how frequently they are used\textsuperscript{211}. At Volvo CE Braås the main storage area TORGGM offer a number of 478 fixed storage location. Kits and option parts are assigned to be stored in these locations. However, the fixed storage location is often occupied with the same material kind but from earlier orders. If this is the case, the forklift driver has to choose from a number of random locations.

Theory states that in random location storage the material can be stored in any available location and does not have a specific location. This results in lower storage space needed than using fixed location because of the possibility of lower amount of empty

\textsuperscript{210} Tompkins, J. A. et al. (2003) pp. 431-435
\textsuperscript{211} Thonemann, U. W. & Brandeau, M. L. (1998) pp. 142-143
locations. \textsuperscript{212} Volvo CE Braås also offers a number of 4760 random storage locations (called buffer locations). Most of the pallets received have no fixed location. The forklift driver can chose the storage location on its own. If possible, he will investigate to find a storage location close to the same kind of material already in storage. This can be done on the small computer (keyboard and screen) built in to the forklift. In order to find a suitable location close to this storage location he has to drive around with the forklift and check it visually. No warehouse management system is in use that chooses a location out of the empty buffer location. To find a suitable storage location the forklift driver has to drive around in the warehouse or remember it from earlier transports.

Goods that are needed often should be stored close to where it enters and leaves the storage\textsuperscript{213}. This requires, however, much information to achieve efficiency and high throughput\textsuperscript{214}. We think that main goods storage is overall organized in a good way. The use of both fixed and randomly chosen location gives Volvo CE Braås the possibility to benefit from both systems. On the other hand it has to be mentioned that the fixed storage location is often occupied with older material. Furthermore, the employees in the storage area try to store material for the assembly line in shelves closer to the point where it leaves the storage. This is however, in our opinion not continuous undertaken. In addition, much attendance should be given to the fact that no warehouse management system is in use. To find a storage location a visual search is necessary. Furthermore, the turnover rate of material in storage is not measured, and therefore an overview about the duration of material in storage is missing completely.

Automated storage and retrieval system (AS/RS) helps the company with material handling and storage control in factories\textsuperscript{215} by a fully automated and computer controlled system\textsuperscript{216}. AS/RS offers good accuracy and high floor-space utilization but also better use of time and equipment\textsuperscript{217}. A differentiation can be made between single

\textsuperscript{212} Tompkins, J. A. et al. (2003) p. 431-435
\textsuperscript{214} Park, B. C. et al. (2003) p. 344
\textsuperscript{216} Bozer, Y. A. & Myeongsig, C. (2005) p. 367
\textsuperscript{217} Malmborg, C. J. (2000) pp. 4599-4603
and dual command automated storages\textsuperscript{218}. Volvo CE Braås utilizes a fully automated storage for small boxes (TORGSB) and a partly automated storage for small material like screws and nuts (TORGSK). The automated storage for small boxes can be classified as dual command storage. The material can be stored and withdrawn at the same time without the need for the lift to come back to the input/output point. The storage place is fully automated chosen and controlled by the system. It was observed that the machine has downtimes every day which leads to complete stop of storing and withdrawal. According to us, the small box storage is a very good system to have full control over the material in storage. It is not possible to take out something of storage without be registered in the system. Furthermore, with number of 3456 storage places, this storage can store a high amount of material by using a small amount of space. In comparison the main storage area for pallets contains 5238 storage locations but using much more space. Of course the limit of space in a small box has to be considered and therefore this storage cannot store all necessary material. On the other hand the storage is almost useless in times of downtime. No material can be stored nor taken out. Due to the fact that downtimes occur often, as we would judge it, this also has to be taken into account.

The shuttle storage is a partly automated system. The goods that are stored in the shuttle storage can be picked up at an interim storage. This includes additional waiting and is therefore symbolized with a yellow triangle. The material to be stored is generally delivered in cardboard boxes. Sometimes the box itself is too large to be stored in the shuttle storage and repacking is necessary. The material is repacked into small blue boxes which are continuously reused without cleaning. Moreover, if whole pallets are delivered the material will be completely stored in a pallet. The storage location for material to be stored is not chosen automatically. The employee has to check on paper list where availability in the storage is. When material is withdrawn this also has to be manually entered in the system. We believe that the shuttle storage is not working very satisfying. First of all the machine cannot really be classified as automated. The storing and withdrawal has to be entered manually into the system. The system itself will not control this. Secondly, it can take time to find an available storage location. The used

\textsuperscript{218} Malmborg, C. J. (2000) pp. 4599-4603
piece of paper on the machine is not a good way to organize and control the storage locations. Furthermore, the material often has to be repacked before storing. When the material is later taken out for assembly line this repacking is usually necessary again. In addition the blues boxes used are dirty. In conclusion, the use of the shuttle tend to lead to waste in time, additional work and error probability in the process of storing and withdrawing material.

Assembly line

In order to secure the material availability at the assembly line, the part-feeding process is important\textsuperscript{219}. The current map illustrates both ordering and feeding processes to the assembly line at Volvo CE Braås. The main process is the transportation of material from warehouse to workstation at the assembly line\textsuperscript{220}. The ways of feeding the material to the assembly line at Volvo CE Braås is done mostly by forklifts and for some parts manually. For the blue boxes ordered during the day this is done by a scooter. Except for the narrow traffic lanes that can cause “traffic jam” this seems to be a good solution in the assembly area. The six forklift drivers that are feeding the wooden pallets to the assembly are assigned to different areas. However, the need to cross each other’s paths occurs all the time. This can be due to that they have different routines when feeding the assembly line in the way of collecting empty pallets and bringing full pallets. There is no standard implemented at the time being.

Two kinds of material can be separated: sequential parts and non-sequential parts. Sequential parts are delivered by a sub-assembly line or a vendor, in the sequence needed. Non-sequential parts are stored in the warehouse of the company and are delivered in boxes to the line, while production continues\textsuperscript{221}. At Volvo CE Braås only non-sequential parts exist since they are always stored for some time before being forwarded to the assembly line. It is however unknown for how long the storage time is for the different parts. The sub-assembly parts that could have been sequential parts are rather following a push system which is illustrated in the current state map. The reason that we chose this classification is due to the fact that pre-assembled parts cannot be

\textsuperscript{219} De Souza, M. C. et al. (2008) p. 480
delivered directly to the assembly line. The parts most often wait in the pre-assembly area before the location at the assembly line is empty.

However, if we consider that the sub-assembled parts are not waiting for a long time due to the fact that they are following a production plan then they could be defined as sequential parts. In fact, there could be occasions when the sub-assembled parts are forwarded immediately to the assembly line and then this can be classified as a sequential part. We are however under the conviction that sequential parts are always delivered in the same sequence not just sometimes, for example every thirty minutes or four times a day with the same amount of parts are delivered, which cannot be the case when a production plan has to be followed.

Even though the haulers are produced in a specific takt time (85 minutes) the pre-assembled parts are not delivered in a specific takt. The reason for this could be that the pre-assembly provides parts to both big line and small line which have different takt times. Therefore we are even more convinced that pre-assembled parts are refilled by a push system. The pre-assembly will always need to have a small buffer in order to be able to assure delivery to both assembly lines. Since there is a production plan that has to be followed then it is not the same types engines and batteries that are pre-assembled in the same order. However, being non-sequential or sequential, we believe that the pre-assembly feeding to assembly line is currently done in a good enough way.

Kanban is a kind of pull system; a signal that refilling is required. There are two types of kanban cards; single- and two-card system. In Volvo CE Braås the kanban system is used in two ways; visual and computer signal. Between the assembly and storage the single-card system is used as illustrated in Figure 7.5; WK is short for withdrawal kanban.

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The visual kanban is signaled by placing the small box on top of the shelf in order for the forklift driver to see. The forklift driver then scans the box at the assembly line and this order is processed instantaneously. The computer signal kanban is generated when scanning the barcode for the wooden pallets but this only creates a work order to the forklift drivers. One could debate whether the blue boxes that are also placed on the top of the shelves can be considered to be a visual kanban system. However, placing a blue box on top of a shelf does not lead to an immediate refill which is the case for small boxes and pallets.

The blue boxes are, in our opinion, refilled in a cycle since every night seven forklift drivers collects all the blue boxes that are on top of the shelves to refill them. A constant production rate also leads to a constant level of consumption of parts\textsuperscript{225}. Since the assembly has a predetermined takt time then the consumption of all material should be constant. However, illustrated in the Figure 7.6 this is not reflected in the refilling of the parts. The blue columns are work orders for ordering of the blue boxes and red are then for feeding the blue boxes.

\hspace{10cm} Figure 7.5 - Kanban system at Volvo CE Braas\textsuperscript{224}

\textsuperscript{224} Kumar, C. S. & Panneerselvam, R. (2007) p. 394 (modified)
Last method of ordering material to the assembly line is by calling but this is only done when the normal feeding process has not been enough. The parts that are regularly ordered by calling are blue boxes (according to questionnaire) and tires. The reason for ordering blue boxes could be due to a previous shortage and therefore there were no blue boxes to collect and refill during the night. Another reason could also be since the consumption of the material is during the day.

7.2 Research question 2:

- What kinds of waste can be identified?

Figure 7.7 pictures the cause and effect diagram developed for Volvo CE Braås in order to identify waste. An enlarged version can be viewed in appendix III.
**GOODS RECEIVING**

There are, in our opinion, a number of main sources of waste in goods receiving; long handling time for pallets, double handling, additional transport for forklift driver and manual entering of data. One of the wastes that Toyota Motor Cooperation has identified is waiting time. This occurs when products are transported or waiting and not worked on. This can furthermore be described as a non-value adding activity (NVA). These actions should be completely eliminated. We think that the long handling time for pallets is waste of waiting time. This is caused by the belt conveyor and difficulties to find pallets. The uneven flow of incoming collis per hour is the reason for the difficulties to find pallets.

The fact that the forklift drivers manually have to separate the collis so that only one by one is added to the conveyor takes additional time. In our opinion this leads to waste of waiting time but also to a more difficult handling. When many trucks have to be unloaded in a short period of time more pallets will be waiting outside in turn for being placed on the conveyor.

Double handling was identified at the goods receiving line in the form of repacking and searching for missing collis. This is furthermore caused by that there is no security in

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counting of pallets. It is hard to count all collis to see if any is missing when the number of collis is high. This might result in that the forklift driver does not realize that all collis are not received. When the goods receiver then discovers that material is missing, a search has to start. This can also be identified as waste of motion, which covers additional work for employees\textsuperscript{228}. The missing pallets do not only generate waste of motion but also waiting time for the remaining pallets outside.

Some suppliers deliver goods in packaging material which are not from the Volvo Pool. For this material a repacking is necessary. This is in theory mentioned as waste of motion when work affects the productivity negatively\textsuperscript{229}. This activity is necessary but non-value adding (NNVA) at the moment. Larger changes need to be done before this waste can be reduced or eliminated.\textsuperscript{230} In some cases the goods receiver also has to repack material because of the low quantity of material in the pallets. Repacking makes the whole material handling process longer and other pallets have to wait. The activities are, however, needed as long as the suppliers deliver in these conditions. If pallets with only few small pieces are stored without being repacked, the storage will be affected negatively due to the need of more storage places.

The third main waste adding activity is additional transport for the forklift drivers. This is due to the double handling of small boxes and backtracking. The small boxes are received on the main belt conveyor and checked by the goods receiver if an inspection is needed. The actual receiving handling is, however, done in another goods receiving line. We think that this is not the best solution due to the extra work with two handling places. It is not only a waste of motion but also processing waste. Processing is a kind of waste that appears when for example processes are not run in a proper way\textsuperscript{231}. Because of the mentioned activities, the material handling for small boxes takes long time. This can be referred to as, again, waste of waiting time. It does not only affect the handled small boxes but also other collis which have to wait a longer time in the

material handling process. The backtracking can be identified as processing waste since the flow of material is moving back from almost where it came from.

The last main waste in goods receiving is *manual entering of data*. This waste is caused by typing the item number, changing status and printing of flag. As mentioned before, the waste of motion is activities that employees do without adding value. Moreover is processing waste when machines and systems are not run in a preferred way\(^{232}\). Both these kinds of waste can are included in the manual entering of data. The goods receiver enters the item number and changes the status of the goods manually. These activities are, in our belief, motion waste. The time and effort spent on typing the number and changing the status is small for each pallet but still unnecessary. The activities can moreover be identified with waste of processing. Entering the item number and changing the status manually cannot be the most efficient way with today’s technology. The change of status is done by the employee, which also cannot be the most efficient way. Another waste of processing that we have seen is the manually printing of lot flags. The employee has to enter in the computer system that lot flags need to be printed. This is done for every lot flag, even if the number of printed lot flags always is equal to the amount of received collis in the computer system.

### Storage

The identified main waste source in the storage area, in our opinion, can be classified as waste of inventory, waste of waiting time and waste of transportation. According to theory waste of inventory can be considered as a cover up for problems in production and/or quality\(^{233}\). The inventory-level has to be reduced to uncover these problems\(^{234}\). The *capacity overload in storage*, which is inventory waste, at Volvo CE Braås is caused by the metal plate storage. Metal plates are stored at two external storage locations and also at the production plant in Braås in a metal warehouse. The delivered plates from external storage are also stored again in the storage at Volvo CE Braås. This however is only possible if the plate warehouse has available capacity otherwise the material is just piled up outside waiting for its turn.

\(^{233}\) Hoske, M. T. (2004) p. 21
In the current situation the plate warehouse is fully utilized and this results in additional metal plate piles outside. In our opinion, this is an indicator for a too high level of inventory. Another way of classifying waste is to classify in value-adding (VA), non-value adding (NVA) and necessary but non-value adding (NNVA). Value adding, are operation that add value through the conversion or processing of raw material or semi-finished products. In accordance with theory, no value adding operations can be found when it comes to storing material. But the distinction can be made between NVA and NNVA. When classifying the waste of inventory of Volvo CE Braås concerning metal plates, we come to the conclusion that this is a NVA.

Stop in inserting and withdrawing of small boxes is due to the downtime of the automated storage. This is waste of waiting time since products are not being worked on or moved. Furthermore, waiting time can also be that workers are waiting for next activity, part, service etcetera. The downtime happens often during the day and during that time no small boxes can be stored or taken out. This on one hand leads to waiting time for the employee that would like to store small boxes. On the other hand this also results in waiting time for the employees working with the withdrawal of material. When looking back to the definition of NVA and NNVA, we classify this cause as a NVA.

Transportation of goods does not add value, therefore all transportation activities are waste. However, some transportation is necessary and elimination is impossible. Instead transportation should be minimized due to the damage risk when moving goods around. Additional transportation for the forklift drivers is caused by the absence of a storage program and rearranging of pallets. In the storage area at Volvo CE Braås transportation is necessary in order to move the material to the storage location. But to find the storage location the forklift driver has to drive around in storage and search visual for an empty place. The company is not using a storage program that assigns empty storage locations. Furthermore, it is often necessary to relocate material in storage. This occurs for example when only one pallet is left in a storage place that can

235 Monden, Y. (1994) p. 179
hold up to four pallets. In order to make the large storage place available for new received material the single pallet will be relocated to a better suited location. In our opinion, both matters lead to additional transport in the storage area. More transfer can then also lead to waiting time for forklift driver that want to withdrawal material from storage. Moreover, the relocation of material increases the risk of material to get damaged during the transport. Considering these arguments, these transports can be categorized as NVA.

**Assembly line ordering and feeding**

The identified main waste sources in the assembly line ordering and feeding are according to our opinion: additional work, missing material and traffic jam. The waste of motion is defined as activities such as fetching tools, stretching, bending etcetera that affect the productivity negatively\(^{238}\). The additional work done when ordering at Volvo CE Braås is, in our opinion, caused by barcode scanning for the wooden pallets and repacking. However, since the barcode for the wooden pallets are located at the shelves the scanning also triggers the following activities; walking to the shelf, fetching the barcode, walking to the computer, walking back to the shelf and finally returning the barcode. Other categories that the activities in a plant can be divided into are non-value adding (NVA) and necessary but non-value adding (NNVA)\(^{239}\). The NNVA activities are required for the current situation for example walking long distance to pick up parts. However, the NVA should be eliminated\(^{240}\). The conclusion that we can draw from this is that not only is barcode scanning a NVA activity, since it does not add value to the product, but it also leads to even more NVA activities. Since, value-adding (VA) activities are only activities that add value to the product by changing it to fit the customer expectation\(^{241}\).

When picking the material manually, the most common errors are too many or few pieces, or the wrong item\(^{242}\). The theory also strengthens our conviction of that manually entering an order adds to the risk for receiving wrong material. To secure the

\[239\] Monden, Y. (1994) p. 179
\[241\] Arnold, J. R. T. et al. (2008) p. 430
\[242\] Tompkins, J. A. et al. (2003) pp. 164-166
right material an accurate identification system can be used, for example with help of an automatic barcode\textsuperscript{243}. So, theory suggests barcodes then we believe that somehow it is still important to point out that the manual ordering by assembly employees is a N\textsc{v}a activity. However, which can be said that without ordering by assembly employees around 50 % (large parts and wooden boxes) of the material cannot be supplied to the line in the current situation? This figure can be seen in Figure 7.8. Blue boxes and small boxes were not ordered by the assembly line employee and are therefore not considered as waste at this step.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure7-8.png}
\caption{Distribution of orders to the assembly line and manufacturing}
\end{figure}

N\textsc{v}a activities are activities such as double handling\textsuperscript{244} and repacking is definitely double handling. The statistic for the four weeks (referring to Figure 5.25 and Figure 5.26) of work orders to the big line show that a total amount of ordered and delivered blue boxes were over 3000 boxes. This gives us an indication to how much repacking has to be done only for blue boxes. Even though refilling has been conducted during nights and led to less traffic around the assembly line, orders are stilled being placed during the day. The reason for this can be due to that not all the blue boxes are refilled during the night, according to answers in the questionnaire. Another reason for ordering

\textsuperscript{243} Tompkins, J. A. et al. (2003) pp. 164-166
\textsuperscript{244} Hines, P. & Rich, N. (1997) p. 47
and feeding blue boxes during the day, also identified from the answers in the questionnaire, is due to that there has been a shortage of the material and that this has to be refilled immediately when received at Volvo CE Braås during the day.

We believe that *missing material* is mainly caused by two factors. One, the assembly employee forgets to order the material and does not realize this until the missing material is needed. Two, shortage material that have arrived to goods receiving are not forwarded immediately to the assembly line. The first factor can be due to many underlying reasons. For instance if a barcode is missing then the employee might postpone the point ordering and forget about it later on. The time might be close to lunch or a break and therefore the employees want to hurry up and assemble the parts that they have instead of ordering material for next hauler, step etcetera. We believe that the ordering process for the wooden pallets and most large parts is too time-consuming and that this is in turn discouraging for the assembly employees. This is even mentioned as a large problem in the answers to the questionnaire.

Another problem that was also mentioned by the employees, in the questionnaire, is an information gap between goods receiving and the line. Shortage material is not always forwarded from goods receiving to the line and the result of this is unnecessary waiting at the assembly line. Waste of waiting time is when the work has stopped; products are not being worked on, workers waiting for parts etcetera and are considered to be NVA activities\(^{245}\). However, the shortage of material rarely stops the assembly line and therefore this is not regarded as the main problem for waste of waiting time. The answers on the questionnaire reveal that the balance of material does not always correspond to the real balance and that there is a disorder in the storage. Therefore, the balance and the disorder are the main factors that should be regarded as the cause of shortage of material. Reasons for the balance deviations did come up during our research however due to the complexity in investigating Volvo CE Braås’ system (Mapics) this will be suggested as a further research subject to researchers with more knowledge in information systems.

Lack of space in the traffic lane leads to *traffic jam*. This is waste of waiting time which again is a NVA activity. The reason for this waiting time is that the lanes are so narrow that if one forklift driver is working in a lane another cannot pass and therefore has to wait. Moreover, the lanes are often so narrow that the forklift driver has to adjust his position back and forward several times in order to be able to remove or insert the pallet. This takes time, and other forklift drivers might need access to the same lane. However, we decided that studying the layout of the assembly area could not be covered during our research and therefore this will also be a subject for further research.

The following Figure 7.9 illustrates a summary of the different waste types identified at Volvo CE Braås and its categorization.

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<tbody>
<tr>
<td>Long handling time for pallets</td>
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<tr>
<td>Add. transport for f-driver</td>
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<td>X</td>
<td>X</td>
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<td>Double handling</td>
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<td>X</td>
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<td>Manual entering of data</td>
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<td>X</td>
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<td>Capacityiy overload of storage</td>
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<td>X</td>
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<tr>
<td>Add. transport for f-driver</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Stop in inserting and withdrawing of SB</td>
<td>X</td>
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<tr>
<td>Add. work</td>
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<td>X</td>
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<tr>
<td>Traffic jam</td>
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<tr>
<td>Missing material</td>
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<td>X</td>
</tr>
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</table>

Figure 7.9 - Summary of the identified waste

### 7.3 Research question 3:
- By proposing a future-state map, how can the identified problems and waste be reduced or eliminated?
The material handling is an important part of the overall facility design process and has to be adapted to the current situation. Therefore there is no single way of solving problems that occur in the material handling system design. However, by using the most appropriate way, the company can face more efficient and balanced manufacturing and distribution flows.\textsuperscript{246} The changes that are suggested below and the future state map that is presented at the end have been adapted to fit the current situation at Volvo CE Braås. Moreover, theory states that there is no single way of solving problems and therefore other solutions can be identified by studying the collected data in this thesis.

**Goods receiving**

*Even flow of received collis*

The distribution of goods should make the material flow more efficient. This is possible if using the right sequence of activities.\textsuperscript{247} The incoming flow of collis during the day at Volvo CE Braås is not leveled. Figure 7.10 shows the total amount of received collis during four weeks and how we believe the average amount of incoming collis should be. This was calculated from the sum of all arrived collis (22830) divided by the number of shifts for four weeks in the goods receiving (4*9). Mondays to Thursday two shifts are working but only one on Fridays. The result was then divided by nine hours, which are the hours per shift. This calculation shows that the average amount of received collis should be 70 collis/hour. If the busiest hours could be avoided, the forklift driver would not have the same hurry to unload. This would increase the possibility to notice missing collis at an early stage.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure7.10.png}
\caption{Amount of received collis and the average amount of received collis}
\end{figure}

\begin{footnotesize}
\textsuperscript{246} Tompkins, J. A. et al. (2003) pp. 163-169
\textsuperscript{247} Wijesundera, D. A. & Harris, F. C. (1989) pp. 96-97
\end{footnotesize}
At Scania a delivery schedule is used. The trucks arrive every 30 minutes. This eliminates the temporary storage of pallets waiting to be handled. Moreover, missing collis are noticed faster. Planning the work in advance will help to find the right actions and can for instance tell how and who should deliver material. The company should also try to standardize the work and have little variation.\(^{248}\) The uneven flow of incoming trucks per hour can be one reason for the variation of received number of collis at Volvo CE Braås. We believe that this variation can be reduced if the flow of trucks per hour would be more leveled out. This would give better control of the incoming collis and a possibility to notice missing collis in an earlier stage. However, scheduling the incoming trucks would not necessary even out the number of incoming collis since each truck does not contain the same amount of collis.

The number of pallets waiting outside to be put on the belt conveyor would be reduced with an even flow of incoming collis. This would for instance help the searching for a specific pallet and make it less time consuming due to the lower amount of pallets. Volvo CE Arvika has an improved way of receiving goods; a number of different goods receiving areas which have visual signs. This makes it easier to find a specific colli due to the signs but mostly because of fewer collis in each area.

Due to the fact that wooden pallets are only put on the conveyor one by one, a change may be needed to improve the number of handled pallets. At Volvo CE Arvika this is solved by a machine that separates the pallets. The forklift driver can add a pile of pallets and then continue to work. This is a suggested solution for Volvo CE Braås.

**Automatic system**

A company can combine information in an effective way when using automated computer-based systems\(^ {249}\). Furthermore, by using system principles a company can identify and determine status, and control the handling of articles\(^ {250}\). The work in the goods receiving lines are, however, done manually. The goods receiver has to type the item number for each wooden pallet and small box. A recommendation would be to

\(^{248}\) Tompkins, J. A. et al. (2003) pp. 163-169  
\(^{249}\) Tompkins, J. A. et al. (2003) pp. 163-169  
install a scanner. This would make the work easier and faster. When the barcode is scanned, the computer system should automatically change the status and send a work order to the inside forklift driver. Additionally, the lot flags should be printed all at once. Today a manually selection has to be done for each lot flag, even if all pallets are entered in the computer system. At Volvo Trucks Gothenburg the pallets are weight at the same time as the lot flag is attached. Volvo CE Braås has no control of the quantity of material but trust the suppliers. We think it would be possible to control this at the goods receiving line.

**Lot flag layout**

The layout of lot flag that is used at Volvo CE Arvika has, according to us, some advantages compared to the one used at Volvo CE Braås. As can be seen in Figure 7.11 the information differs. The most important change we suggest is the size of the printing date. This is an easy way to visualize how long the colli has been stored. Furthermore, there are many barcodes on the lot flag used at Volvo CE Braås. As far as we know, none of these are scanned. They are, in our opinion, not necessary. Another improvement that can be implemented is to print the lot flags on papers with different colors for each time-frame. This is used at Volvo CE Arvika and shows even more clear the storage time.

![Figure 7.11 - Lot flags at Volvo CE Braås and Arvika](image)

**Reduce handling of small boxes**

Another possible change we have found is the handling of small boxes in two goods receiving lines. The work principle tries to simplify the process of material handling and reduce transportation\(^\text{251}\). The control that is done in the first receiving line could as well be done in the goods receiving line for small boxes. This would save time for the first

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goods receivers. Some of this saved time should rather be spent on the small boxes’ goods receiving to minimize the additional waiting time. At Volvo CE Arvika the belt conveyor automatically separates the pallets with help of a barcode scanner. The same solution would be possible also for Volvo CE Braås. We suggest that the small boxes are separated from other pallets on an additional conveyor before the goods receiver handles the pallets. This would eliminate the double handling of small boxes and also the forklift transport between the goods receiving lines. We are, however, aware of that this requires a bigger investment and that the number of handled small boxes maybe is too low to be worth it. On the other hand, it would help to handle more pallets and thereby reduce the amount of pallets waiting to be handled.

Storage
In the analysis of the current-state map and also in the Cause and effect diagram different kinds of waste were identified.

Warehouse management system
In the current-state map problems resulting from not having a warehouse management system were pointed out. A suggestion is to implement a Warehouse Management System (WMS) or to adjust the current system in use. We believe that a WMS could help to organize and control the material in storage better including the turnover rate of material. It is not only important to know what is in storage but also how long has material been in storage. First of all, the storage locations would be assigned by the system and this would reduce the time it takes to drive around and search for it visual. This could also lead to less traffic in the main storage area. Second, the WSM should offer the function to chose before storing what size the storage place needs to have (e.g. for 1 pallet or a pile of 4 pallets). Furthermore, the use of fixed and randomly chosen places should be kept, because this gives Volvo CE Braås the possibility to benefit from both systems. Random storage locations results in lower storage space needed than using fixed location because of the possibility of lower amount of empty locations\textsuperscript{252}. Especially for the planned production increase, random storage places are necessary. An advantage when using fixed storage places is the possibility to separate the material into

\textsuperscript{252} Tompkins, J. A. et al. (2003) p. 431-435
different groups depending how frequently they are used\textsuperscript{253}. In our opinion, fixed storage places should be created for special material for example special pallets which are very unstable and high. In addition, it is recommendable to use a categorization depending on the frequent use of the material. This is also carried out at Volvo Trucks Gothenburg. The classification can either be assigned to a specific storage place or to a storage area. However, the implementation of WMS requires investments and a good information system.

\textit{Scheduled metal plate delivery}
As mentioned before is the metal plate storage fully utilized and additional piles of metal plates are stored outside. We suggest a better control of the inventory in storage. Metal plates from external storage should only be delivered when the amount of inventory in storage drops to a defined minimum. For the withdrawal of metal plates, the standard to always follow Fifo should be communicated better and always be followed.

\textit{Maintenance}
The small box storage is a good system which gives the Volvo CE Braås full control over material stored and material withdrawn. However, the downtime of the machine is time consuming. In our opinion, the maintenance for this machine should be done more regularly. The reason for the downtime should be analyzed and eliminated.

\textit{VMI}
In the analysis of the current state map it was mentioned that the shuttle storage is not working very satisfying. We are of the opinion, that improvement can be made. The blue boxes used to repack the material and also for the delivery to assembly line should be eliminated. If the cardboard boxes for some material are too large then we suggest having the supplier deliver in a smaller size or in small boxes. Furthermore, we suggest implementing VMI for the storage of small material. The shortage problem for the fastening material can be solved by the VMI solution that is in use at Volvo CE Arvika. This will secure that the supplier will notice the need before a shortage can occur in the

shuttle storage. The material that has been taken out of storage for the assembly line should be considered as consumed. This is also carried out at Scania. Only the level of inventory in storage should be considered for new ordering, which is carried out with VMI.

Assembly line
In the current map the ordering and feeding was analyzed and this brought our attention to some improvement opportunities. Moreover, in the assembly line both NNVA and NVA activities were identified. The improvement opportunities and ways of eliminating or reducing the identified waste are analyzed below.

Wireless scanners
Even though scanning is a necessary non-value adding activity, it can be replaced by another method of securing the line feeding of wooden pallets. One solution for reducing the waste of motion that occurs when walking back and forward to the shelves just for the barcode it would be easier to have a wireless scanner that can be used at the shelf as was seen at Volvo Trucks Gothenburg. The barcodes can then be fastened to the shelf which will also eliminate the problem of lost barcodes. We believe that one wireless scanner is not enough for one assembly line.

Sequenced deliveries
An additional solution to avoid waiting time at the assembly line is to have the wooden pallets that only contain a few parts and the large parts delivered in sequence, for example if only one large part is needed for one hauler then this should be delivered every 85 minutes. We believe it is easier to sequence the parts that only have to be refilled once each takt time. This will however not be visualized in the future state map since the method cannot be supported with an action plan.

Eliminate repacking of blue boxes
The ordering and feeding process of blue boxes carries a lot of waste as is today for example they are weighted and labeled. This can be identified as waste of motion and waiting time. First we suggest that the material should be kept in the original cardboard
boxes which will eliminate the repacking. The small box ordering and feeding process is working in a good way and since the forklift driver is already picking up boxes at the workstations he can also check if there is a need for ordering additional cardboard boxes as was observed at Volvo Trucks Gothenburg. Another solution as seen at Volvo CE Arvika the fastening material was ordered at the end of each shift in order to be delivered at the beginning of the same shift next day. Either way we believe it is better than refilling during nights. Since then the ordering and refilling are concentrated to one point of time. One factor that we have taken into account in the future state map is that if including the fastening material to the small box process this might lead to disrupting a good system which the assembly employees are already satisfied with. Therefore, the ordering at the end of each shift is illustrated in the future state map.

**LCD**

A constant production rate also leads to a constant level of consumption of parts\textsuperscript{254}. Even though the haulers are produced in a specific takt time (85 minutes) the pre-assembled parts are not delivered in a specific takt. We do not believe that a better solution will have to be implemented for the feeding of pre-assembled parts since there are no mentioned problems. We believe that other improvements are better suited to be followed up. For instance in Volvo CE Arvika a LCD is used for the 42 minute takt time line and we believe that a LCD for the big line can be installed. The LCD can even out the flow in the assembly area since all the workstations will have to start and finish at the same time. Should a workstation not be finished within the takt time then the stop button has to be pushed and therefore the new takt time cannot be started which means that all other workstation have to wait. This will motivate the assembly employees to keep a continuous flow and in turn the consumption of material will be leveled. The LCD would also be helpful for the pre-assembly line to identify at what stage the workstations are.

Scheduled feeding and milk rounds

To achieve high productivity objectives, standardized work methods are often necessary\textsuperscript{255}. There is no standard for line feeding implemented at the time being, which is causing waiting time. Therefore we suggest that the forklift driver’s routines should be standardized and moreover some kind of driving schedules should be implemented. There is one more factor that has to be taken into account. The seventh forklift driver for the small boxes also has to have a schedule in order not to collide with the other drivers or the other way around the other forklift drivers adjust to the time for ordering and refilling of small boxes. The small box ordering and refilling can be done in a milk round as seen at Volvo Trucks Gothenburg. We believe that scheduled feeding can help avoid that more than one forklift driver have to go to the same lane at the same time. Another solution for the space problem would be to change the layout for the assembly area. However, this would probably require large investments and would still leave the issue with an unorganized feeding process. A constant production rate also leads to a constant level of consumption of parts\textsuperscript{256}.

Figure 7.12 pictures the future-state map of Volvo CE Braås. An enlargement of the map can be viewed in appendix IV.

\textsuperscript{255} De Souza, M. C. et al. (2008) pp. 481-482
\textsuperscript{256} Choi, W. & Lee, Y. (2002) p. 124
Figure 7.12 - Future-state map for Volvo CE Braås
8 Conclusion

In the following chapter the three research questions will be answered. The reflections on this thesis writing were mainly that the project had a wide range compared to the time-frame given. Finally, suggestions for future research are pointed out.

8.1 Answer to the research questions

How can the material handling process, from goods receiving to assembly line, at Volvo CE in Braås be described by using VSM?

The material handling process is described in the previous chapter (Chapter 7.1). The current-state map points out how the process is managed today (enlarged current-state map in Appendix 2).

What kinds of waste can be identified?

Five different kinds of waste have been identified; waiting time, transportation, inventory, processing and motion Figure 7.9. The most common is waste of waiting time which was found six times and in all three studied areas; goods receiving, storage and assembly line. The second most common, three times, is the waste of motion and occurs in goods receiving and assembly line. The waste of transportation is found once in goods receiving and once in storage. Furthermore, the waste of processing was identified twice in goods receiving. Finally, the waste of inventory occurs only once in storage.

By proposing a future-state map, how can the identified problems and waste be reduced or eliminated?

The future-state map is illustrated in the previous chapter (Chapter 7.3, enlarged in Appendix 4). The following suggested improvements are sorted from the simplest to more difficult and expensive changes:
Goods receiving

- The layout of the lot flags can be improved by an enlarged printing date, fewer barcodes and different colors for different time-frames.
- An even flow of received collis during the day will make the temporary storage of waiting collis smaller. Moreover, this enables a more correct count of received collis which eliminates later searching.
- By using an automatic system for scanning the barcodes of pallets, sending a work order, changing the status and printing the lot flags at the goods receiving line, will make the handling faster.
- Reduce the handling of small boxes by a layout change of the goods receiving area. The small boxes should not be handled with other wooden pallets by separating the conveyors.

Storage

- A scheduled metal place delivery will reduce the storage of metal plates. Furthermore should Fifo be applied.
- The need of maintenance for the small box storage should be analyzed.
- A VMI-solution for small parts will help to eliminate shortages. In addition, the size of cardboard boxes should be limited to fit the shuttle storage.
- An implementation of WMS will help to organize and control the material in storage. Moreover, WMS can reduce the transportation when searching for a suitable storage location.

Assembly line

- By eliminating the repacking of blue boxes the handling time is reduced. The refilling of small parts will need less effort when cardboard boxes are used.
- Sequenced deliveries adjusted to the takt time for large parts can eliminate waiting time caused when an order was not placed in time.
- A scheduled feeding and milk rounds can lead to better structured transportation. The forklift drivers feeding routines should be standardized to avoid traffic jam. The milk round is only appropriate for the small box feeding.
• Wireless scanners at the work stations should be installed to reduce the actions needed to order a wooden pallet. The barcodes can then be fastened to secure that they are always at the right place.

• Installing a LCD will give the employees a better overview and secure the ability to stay within the given takt time.

8.2 Reflection

When starting this project we were not completely aware of the wide range of the research subject and therefore not enough limitations were set. We have tried to make a deep study as possible but due to the short time-frame we have been forced to limit the scope. The empirical findings at Volvo CE Braås, Volvo CE Arvika, Volvo Trucks and Scania had to be included in a shortened version. We believe first of all that it would not have been possible to analyze everything within the given time-frame and secondly that the size of the thesis would have been even larger.

The methods that we have found as a good solution, for example the ordering and feeding of small boxes to assembly line might need to be improved when the amount of articulated haulers will increase. Since the small boxes are handled only by one person during one shift, this will probably not be enough. The suggestions that we have mentioned are based on the current situation without assumptions of future changes at Volvo CE Braås.

Every step in the VSM tool could not be fulfilled. We aspired to gather more specific data about lead time and turnover-rate. Furthermore the arrangement of material in the different material packaging at the assembly line could have been studied more as well as the material handling process within the manufacturing if the time-frame would have been longer.

We found it difficult to recognize what statistics could be extracted from the internal computer system. Therefore, the effort put on finding the right data was larger than suspected. It was also difficult to know how to use it in a proper way but with help from the company we were finally able to solve this problem as well.
8.3 Future research

In the following points further research subjects for Volvo CE Braås are presented:

- A study could be conducted at a later stage to evaluate if any of the suggested changes in this thesis have been implemented. A more detailed VSM could be done in the future including the information flow, measuring of lead time etcetera. Also the manufacturing area should be included in VSM, since the main value is produced within this area.

- Scenario simulations could be done in order to see how changes in critical areas could affect the company. These scenarios can enclose different aspects within the material handling process, for instance removing the shuttle storage, increase of the space in the assembly area and installation of automatic transportations.

- An ABC classification of the articles stored in the main storage could be done in order to optimize the storage and reduce the transportation. Furthermore, the storage locations could be divided in the same classification.
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Interviews

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Andersson, A., Material Control
Andersson, T., Manufacturing Engineering
Anersson, A., Goods receiving
Ankarberg, L., Goods receiving
Bengtsson, F., Goods receiving
Davidsen, K.-E., Logistics department
Emanuelsson, K., Goods reception
Fransson, D., Foreman material handling
Fransson, J., Responsible for material handling
Franzén, C., Internal production pool
Harrsjö, M., Internal production pool
Holmqvist, J., Internal production pool
Islamovic, S., Assembler
Ivarsson, B., Assembler
Johansson, L., Assembler
Johansson, R., Assembler
Johansson, S., Goods receiving
Karlsson, L., Goods receiving/ Internal transportation
Larsson, T., Material Control
Olsson, S., Manufacturing Engineering
Oredsson, L., Global Logistic Development
Sigfridsson, K.-E., Instructor material handling
Sinikovic, M., Logistics department
Sjöstrand, J., Head of Manufacturing and Engineering,
Stålberg, S., Material Control
Svensson, U., Goods reception
Åberg, F., Goods receiving
Åberg, S.-O., Assembler
**Volvo CE Arvika:**
Adolfsson, C., Global Logistic Development
Barck, Å., Global Logistic Development
Magnusson, K., Global Logistic Development
Svensson, M., Manager of Global Logistic Development

**Volvo Trucks Göteborg:**
Andersson, K. Supplier Relationship Management

**Other sources**
Volvo CE intranet
Volvo CE HLBL, Internal Power point presentation
APPENDIX I

Questionnaire for assembly line

1. How often do you need to order material in blue boxes?

2. How often do you need to order material on wooden boxes?

3. How often do you need to order material in small boxes?

4. For what material do shortages occur?

5. How long does it take to solve the shortage? Does this stop the work?

6. What do you consider to be the largest problem?

7. What improvements would you suggest?
Current-state-map Volvo CE Braås
APPENDIX III

Cause and effect diagram Volvo CE Braås
APPENDIX IV

Future-state-map Volvo CE Braås