Development of a framework for designing a Material Supply System
-A case study at Volvo CE in Hallsberg

Master of Science, Supply Chain Management –Master Thesis

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ABSTRACT
For many companies today a growing number of products as well volumes paves the way for new challenges. The development today forces companies to make rationalizations within operational activities to enhance the competitive advantage in a more violent market place. At the same time companies must rearrange activities and at the same time achieve the wanted performance. However, these challenges has been approached in this thesis through creating a framework that proposes a new Material Supply System that enables companies to still become competitive when supplying material to assembly stations. This thesis has furthermore filled the gap of earlier researches regarding of considering the whole Material Supply System instead of only concerning the in-plant section of a Material Supply System. The necessity to consider the whole Material Supply System can be explained through the supplier related contextual factor that has been elaborated within this thesis. This is essential when dealing with circumstances that aim to create the best possible conditions for the assembly station when fetching parts, since decisions back in the chain has an impact of how the material can be presented at the line.

Furthermore, the framework considers the whole view by not sub optimizing when designing the new Material Supply System. Many other approaches only use to optimize on local level and hence this study expands the current research by using an approach that optimizes on a global level to achieve expected performance for the whole setting. However, to carry out the framework 61 different information sources (articles, books, brochures, websites etc.), interviewing respondents within two different companies and best practices from internal databases has given the result of this framework. As a result, the creation process has been a complex process from the beginning to shape the end result, where many different interrelations between theories have been connected to a finished framework. The second purpose was to apply the framework within the context of Volvo CE and according to the result it provide opportunities for Volvo CE to reduce the inventory levels within the plant by pushing back inventories to a third part provider, decrease the material handling, eliminate the use of forklifts, create more smother and straighter flows from the supplier, better presentation of the material for the operators etc. However, the whole approach to define the Material Supply System has been iterated through the approach by defining a Material Supply System in accordance with a whole view perspective. Thereby, the two performance areas suggested by Volvo CE; decrease the inventory levels respectively enabling better ergonomically conditions has been attained.

ACKNOWLEDGEMENT
Throughout the fall 2013, this master thesis has been carried out in collaboration with Volvo CE in Hallsberg and Chalmers University of Technology. From the beginning to the end, the project has been challenging, but has also rewarded us with a great and valuable experience. The master's thesis has given us the opportunity to work with experienced people from various departments within Volvo CE. We would like to express our gratitude to the employees who have supported and facilitated our study.

Special thanks are directed to the department of logistics, who all have contributed with extensive information and been helpful with our many questions. Further thanks goes to Volvo Powertrain in Skövde, for their willingness to help and guidance and warm reception at two study visits.

Lastly, we especially wish to thank our two supervisors at Volvo CE; Morgan Carlsson and Urban Eriksson. We would like to thank Lars Medbo, our supervisor and examiner, for his valuable feedback and support throughout the project. We are also appreciating the help from Suyeon Seo that assisted with several illustrations that are published throughout the thesis.

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1 INTRODUCTION

1.1 Background

Volvo Construction Equipment (Volvo CE) is one of the leading manufacturers of construction machines on the global market. Volvo CE's product range consists of wheel loaders, excavators, articulated haulers, road construction machines and compact machines with production facilities located in Europe, Asia, North America and Latin America (Hallsberg brochure, 2011).

In this report the focus will be on the production facility in Hallsberg which is Volvo CE's main factory for the production of cabs or operator working environments. Currently, the factory also builds other system components such as oil and fuel tanks which are together with the cabs used in the production of articulated haulers, wheel loaders, excavators and backhoe loaders. The factory is based on the make-to-order principle and manufactures customized solutions.

The customers of the Hallsberg factory consist of other plants within the Volvo CE and the production is dependent on the end users demand and requirements (Hallsberg brochure, 2011). In order to improve the competence and to maximize the investments in the cab operations a decision was taken in 2011 to centralize all European cab production to the factory in Hallsberg. Previously, the factory was mainly focusing on cabs for haulers and wheel loaders but as a part of the new strategy cabs for excavators were added to the production line. In the initial phase the cab production increased with approximately 20% and inherently enlarged the variations of items to be assembled in the end products (Volvo Construction Equipment, 2011). Until today the production volume and the spread of items have grown even further due to a higher demand of cabs and that customers are requiring more customized cab options. Since the Hallsberg factory is specialized on the cab production it is projected that the growing trend of production volume will continue and the number of the current 14 suppliers are expected to grow. Some suppliers are connected straightly to Volvo CE and some suppliers goes through a hub and then further to the company.

With the increasing production volumes different kinds of challenges have appeared for the factory in terms of material handling and supply. One of the most exposed sections on the production line is the plate lining operation which is also defined as the point-of-use in this report. At the plate lining process the basic cab fixture is received from the welding operation and the operator is welding on smaller items on to the product. At present the items are presented in small boxes and pallets in front of the operator based on the continuous supply principle. Since the cabs are customer specific the operator needs to pick the right item from the right container to weld onto the fixture.

As the number of different types of items has increased, the display of components has been impeded from a positional as well as a structural dimension. Due to the space limitations around the workstations it is difficult to position all boxes and pallets easily accessible for the operators. Furthermore, it is also problematic to present all parts in a systematic manner to simplify the picking process. As a consequence, the picking process becomes ineffective. A second challenge that the Hallsberg factory is facing is how to manage the inbound flow of goods from the suppliers. At present, there is no appropriate storage area for the incoming material due to capacity constraints. Instead a high stack rack is utilized which is located in direct connection with the plate lining operation. The upper part of the racks is used to store incoming goods temporarily before being needed in the welding process. The lower part of the rack is utilized as the area to display the items containing various types of pallets and boxes. Already today, the space is barely enough to keep the incoming goods and when the volumes are expected to increase new storage solutions are needed.

In order to meet upcoming requirements on higher efficiency it is important that the Hallsberg factory finds solutions to the addressed problems. Hence one need to look over flows from suppliers to the reception of goods and then also the internal flow including material feeding to work stations. In this case it is essential to investigate a new inbound distribution strategy for the company.

1.2 Purpose

The purpose of this thesis is to create a framework that functions as a guideline for improving the material- and information flows from the suppliers to the point-of-use at Volvo CE in Hallsberg. A framework in this case is a template of actions that should be conducted for each material flow, i.e. a step to step guide of what should be done in order to design the material- and information flows.

Furthermore, the framework should be a universal one i.e a framework that can be compatible with Volvo CE in Hallsberg as well other Volvo CE factories in Sweden and factories with similar environments. The framework will be based on well-known methods that have been applied in comparable settings before. The aim to create a universal framework is to enable other similar cases be applied with the same framework.

To summarize this case, the first purpose is to create a general framework and the second purpose is to apply the framework in the context of Volvo CE in Hallsberg to find suggestions on improvements.

1.3 Limitations

The scope of this project only comprises the material- and information flows from the suppliers to the plate lining process, and hence only material that concerns the plate lining process. Furthermore, no external transport arrangements as well changes on the current material and control system will be conducted in this project.

1.4 Research questions

This section treats research question that will be answered under the time when the project is running. In this case hypotheses will be verified under the project time. Research questions that are searched to be answered are:

RQ1. What material feeding principle is preferable at the plate lining process for each article?

Feeding principles in this case is the type of system that should be used to feed the assembly process from the stocking point to point-of-use. To solve the problem with space limitations at the plate lining operation it is important to examine alternative methods to feed the material into the point-of-use from the goods receivement, i.e. the internal flow. The first research question will give an answer on how to choose a different feeding principle in order to solve the storage problems.

RQ2. How should the material flows from the suppliers to the goods receivement be arranged?

This research question aims to be answered to illustrate the future state of the material flow arrangement from suppliers to goods receivement, i.e. the external flow. This in order to find the most appropriate method to improve the material flows.

RQ3. What material flows will go through the hub?

This question intends to answer what material flows that will go through a hub. In this case some flows may need to be used together with a hub or whether not, in order to efficiently store the articles and components.

2. METHOD

This chapter will describe the methodological way of completing the master thesis. Through this chapter one can gain the understanding of which tools and methods that has been used during the timeframe of the project. However, the methodological section follows by firstly describing the methodological procedure to reach the final result. Thereafter the included parts within the methodological procedure will be elaborated one by one.

2.1 The procedure

In order to be able to reach the final result an approach has be carried out to fulfill the aim of this master thesis, see Figure 1. The procedure consists of four major constituents that aim to lead this thesis to the expected outcome, i.e. problem formulation, data collection, analysis and lastly validity. However, the problem formulation aims to identify the right problem within the limitations of this thesis. Thereafter the data collection section will describe how the information to this thesis has been captured. Thirdly, an analysis part with aim to describe how the framework is carried out and then further implemented. Lastly, validity of the result for this master thesis will be conducted.

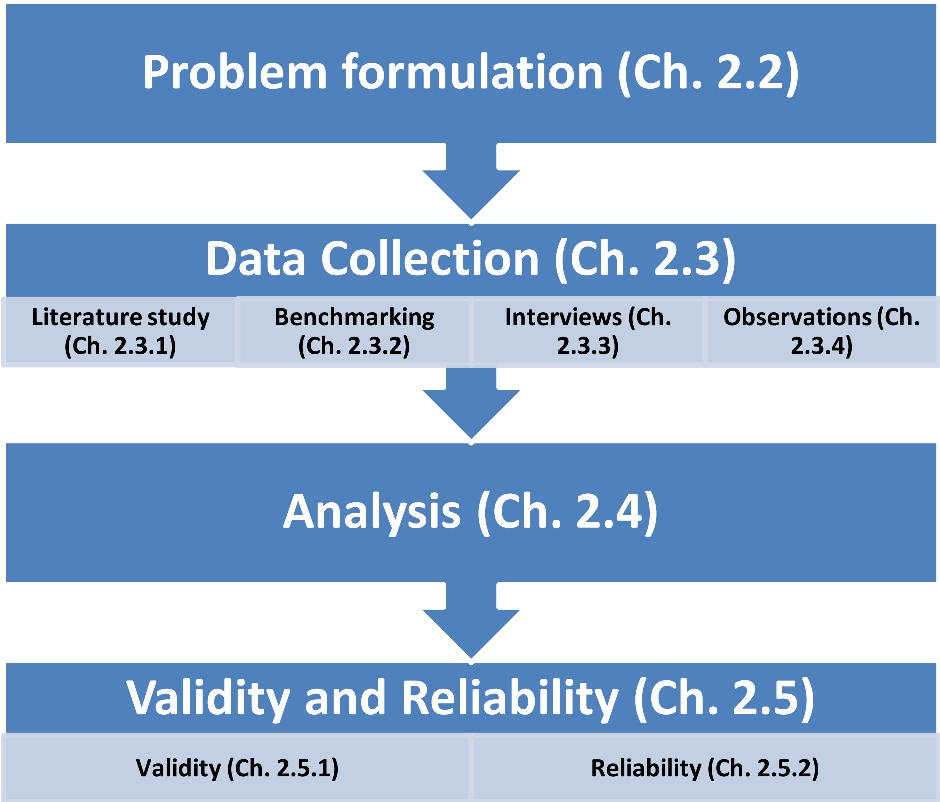

Figure 1. *Illustration of the procedure to carry out the final result*

2.2 Problem formulation

Firstly a problem formulation within the first step of the procedure has been conducted. The procedure to overcome a complete problem formulation in order to be able to attack the right problem has been conducted through mainly interviews with involved personnel as well additional data collection. Through the collected information from interviews as well collected data an investigation process has been conducted to specify the problem. By knowing about the right problem further processes in the methodology has been aligned with the right problem area and the purpose of this project has then in the end been fulfilled. However, the limitation has been the boundaries of our focus within this thesis, which has been followed to create the end product. Furthermore, all the research questions have been a great checkpoint to whether our purpose has been fulfilled and thereby be able to conclude the result of this master thesis.

2.3 Data collection

This section will describe how the knowledge has been collected from different mediums. When talking about knowledge it can be divided within tacit respectively explicit knowledge. Tacit knowledge refers to knowledge "within the head of a person", i.e. personal interpretations and delusions, whilst explicit knowledge refers to knowledge documented and captured within pictures, texts or recordings (Dalkir, 2005).

According to Björklund & Paulsson (2003) primary data comprises of data captured from interviews and observations. However, data captured in a primary manner can be seen as data that appears for the first time without being published earlier in another medium (Dahmström, 2000). Secondary data refers to data captured through interpretations derived from primary data (Patel & Davidson, 2003) acquired earlier within another context (Eriksson & Wiedersheim-Paul, 1999). Thereby, both tacit and explicit knowledge will result in a final explicit product (Dalkir, 2005).

Furthermore, the creation of the framework has been an iterative process where the data from different sources has given this thesis nuanced perspectives from various sources. However, the knowledge has been captured through four major ways:

- Literature study (Chapter 2.3.1)
- Benchmarking (Chapter 2.3.2)
- Interviews (Chapter 2.3.3)
- Observations (2.3.4)

2.3.1 Literature study

The purpose of the literature study is to review what has been found by other authors up to date within the research area, and to gain knowledge to build up the framework but also to support the analysis and the following discussions. However, during the master thesis relevant literature for the study has been reviewed, such as: theories within material feeding principles, the Material Supply System and its constituents, the design of a Material Supply System, fundamental logistics, lean methodologies, total Cost of Ownership and lastly decentralization/centralization.

All the information to the literature study has been acquired through scientific articles within all the aforementioned areas. Other sources such as course books from former courses as well doctor theses. However, the doctoral thesis "In-plant materials supply: supporting the choice between kitting and continuous supply" from Chalmers University of Technology written by Hanson (2012) has had an great impact on this master thesis. This since it provided the latest research within the area of material supply and that the thesis covered factors that other authors doesn't cover, such as the whole picture of an in-plant Material Supply System and its performance areas. Furthermore, all the articles has been carried out from various databases, such as Emerald Insight, Google Scholar, Elsevier Science, Taylor and Francis, International Journal of Industrial Engineering and Management and other international journals. However, the theoretical frame of this thesis is presented in chapter 3 of this master thesis.

2.3.2 Benchmarking

The second way of gathering information is through the benchmarking that aims to acquire external information (Dalkir, 2005). This session aims to be a complement for the current literature study and knowledge within Volvo CE in Hallsberg. The benchmarking has been conducted at Volvo Powertrain in Skövde (Sweden) and it was interesting to see how another company within the Volvo Group worked with the same issues. However, the site visit in Skövde was useful for the framework constructed for this thesis and valuable best practices from Volvo Powertrain in Skövde could be collected. In this way, similar problems within Volvo CE in Hallsberg could be approached through findings that were not able to find within the literature. Thereby, the site visit resulted in findings regarding of new ways of improving and hence, was a valuable input for this master thesis.

2.3.3 Interviews

Several Interviews has been held with relevant stakeholders, this in order to get a picture of how the factory works at present and get valuable views and opinions from personnel within Volvo CE in Hallsberg as well personnel within Volvo Powertrain in Skövde. According to Fontana and Prokos (2007) an interviewing process can be conducted in different ways, such as structured, semistructured and unstructured. A structured interview refers to ask several persons with the same pre-defined questions, whilst an unstructured interview refers to keep interview without any structural way of asking questions and hence not restricted way of asking (Fontana & Prokos, 2007). A semi-structured approach is an interview consisting of both restricted questions and open questions without restrictions (Wengraf, 2001). However, this thesis has used both unstructured and semi structured strategies when interviewing persons from different professions. The table 1 illustrates the professionals and operators interviewed within this master thesis.

Table 1. *Information about the interviews*

Name	Position	Company
Johnny Berg	SAP Support	Volvo Construction Equipment, Hallsberg
Morgan Carlsson	Manager Logistics	Volvo Construction Equipment, Hallsberg
Sean Cater	Inbound Logistics Engineer	Volvo Construction Equipment, Hallsberg
Örjan Ekland	Operator at the platelining process	Volvo Construction Equipment, Hallsberg
Urban Eriksson	Logistic Development and Factory Master	Volvo Construction Equipment, Hallsberg
Fredrik Svanerud	Financial Controller	Volvo Construction Equipment, Hallsberg
Jenny Sahlström	Logistic Pillar Drive	Volvo Powertrain, Skövde
Per Weinö	Packaging Engineer	Volvo Powertrain, Skövde
Caroline Jonsson	Consultant	Puzzle as Brand
Karin Zetterlund	Consultant	Rejlers Ingenjörer AB

All the interviews have been conducted face to face on individual persons by two interviewers every time for each interview session. The gaps from the interviews have been covered through email afterwards. Every interview was noted by the interviewers as well recorded in order to be able to go back and listen again, and every interview took from 20 minutes to about two hours to complete. In order to get a great picture over the current organization within Volvo CE in Hallsberg supervisors, material planners, transport planners, logistic developers, production technicians, operators and forklift drivers on the shopfloor was interviewed in order to get a nuanced picture of the whole setting. To add several professionals within logistics development as well package engineers were interviewed at Volvo Powertrain in Skövde, and the same procedures to interview was conducted even there.

2.3.4 Observations

As the lean philosophy advocates the way of understanding a flow is to go to the actual place and observe (Liker & Meier, 2006). This step will be conducted in order to be able to get the context of the problem and the truly understanding of the current situation. These observations and interaction in the reality has been used to create a flow map to map the flows from supplier to point-of-use of the plate lining process. All the observations within Volvo CE in Hallsberg will be a part of the current state section (Chapter 6). However, observations have even been conducted at Volvo Powertrain in Skövde to gain the context of their material supply system.

2.4 Analysis

The analysis part within the methodological strategy consists of two parts, the development of the framework and then the application of the framework through a case study at Volvo CE in Hallsberg. However, the result from the framework derives from all data collection methods and has been iteratively carried out. Furthermore, the framework has then been applied in the current state of Volvo CE in Hallsberg together with landed cost calculations. Hence, a final result has been reached by following all the steps within the framework.

2.5 Validity and reliability

This section will discuss the validity and the reliability of the master thesis. The validity and reliability is used to measure the trustworthiness of this study and aims to secure that the study uses to fulfill its obligations regarding of its relevance.

2.5.1 Validity

According to Krishnaswami and Satyaprasad (2010) validation refers to replicate a study several times to confirm its relevance. However, to validate the findings within this master thesis literature from many sources has been carried out and validated through replicating the findings. Especially, when the framework was carried out, the literature study was a vital part of the framework as whole. Furthermore, the VPS concept from the company side straightly derives from best practices and principles within the Volvo Group and should thereby be validated or tested by many users. However, when looking at the relevance regarding of the observations and interviews conducted to be able to describe the current state at Volvo CE in Hallsberg a workshop for improvements and validation was performed by several professionals within the company. This enabled common feedback from several parts where the information within the described section could be validated. Information that were not corresponding to the participators view could be changed in a common session to strength what one person said. Furthermore, all the interviews was recorded and could thereby be listened again and at same time email conversations afterwards could bring gaps filled.

2.5.2 Reliability

According to Krishnaswami and Satyaprasad (2010) reliability refers to the quality of the data and how accurate the data is. However, some reliable problems occurred when the cost analysis was conducted since the packaging cost could not be calculated exactly due to difficulties to predict the outcome of the changeover from the current state to the future state. Furthermore, when the volume increases was considered within the cost calculations it still prevails doubts about whether these can be seen as accurate. To conclude from this calculation, no exact numbers can be published but the numbers can indicate if the solution is favorable to implement. However, regarding the data collected from the MRP-system all the data was controlled in the reality at the line in collaboration with operators. Furthermore, all the articles were individually measured by the thesis workers; thereby one could get reliable data for the sizes of each article. Since there were some few errors when collecting weight data of all the articles, it was pretty obvious to see whether the article is light or heavy. Hence, it should not be any complications regarding of the weight of each article. However, when the database of the articles were finished a double check was conducted to see that everything correspond to the reality. This together with the shop floor operators at the plate lining process.

3. LITERATURE STUDY – MATERIAL SUPPLY SYSTEM

This section aims to describe all the essential elements of a material supply system with major concentration in material feeding principles, this within the limits of the thesis. This means that material feeding principles will be a central element and hence affects the rest of the material supply system design. In order to be able to design the system some introducing affecting factors of the material supply system will be elaborated. In the end the design process will be described to grasp the improvement process behind when building the new system.

3.1 Material supply system

Throughout this section, relevant theories will be presented in relation to the purpose of the thesis. Since the aim of the thesis is to develop a framework for designing the MSS from the suppliers to the Point-of-Use, the literature review will cover previous studies on MSS (Material Supply System). The first section will define what is meant by a MSS in this study, since the term MSS is very broad. Subsequently, the constituents of a MSS are described and previous findings on the design process are presented which clarifies the theoretical contributions of this thesis.

3.1.1 Definition of the MSS and its constituents

Depending on the circumstances the term “materials supply” can have different meanings (Fredriksson, 2011) and this section provides a description of what is meant by the term throughout this thesis. In the literature a “Materials Supply System” is defined as a system that supplies material from the suppliers through a focal company to the industrial buyers. A Material Supply System therefore consists of material flows between as well as within plants, and includes both the physical flow of goods and their planning and control (Johansson, 2006). The aim of the Material Supply System is to supply the production units with items and materials (Jonsson, 2008) in order to prevent production disturbances.

Following from the definition of “Materials Supply System” the concept can be applied in a broad sense. However, since the scope of the thesis is on a limited section of the supply chain, the focus throughout the study will be on materials supply from the first tier suppliers until the point of use at the focal company. The highlighted Materials Supply System can be divided into two different sections where the first part represents the supply of materials between the suppliers and until the goods reception of the company, denoted as “inbound materials supply system”. The second sector takes place from the goods reception and onwards referring to “in-plant materials supply”, which includes the delivery of materials up to the assembly station but also how the parts are presented for the operator (Hansson, 2012). An example of a “Materials Supply System” that will be considered in the thesis is illustrated in Figure 2, which can be seen as a subsystem of a Materials Supply System that involves the total supply chain network until the customer (Hanson, 2012).

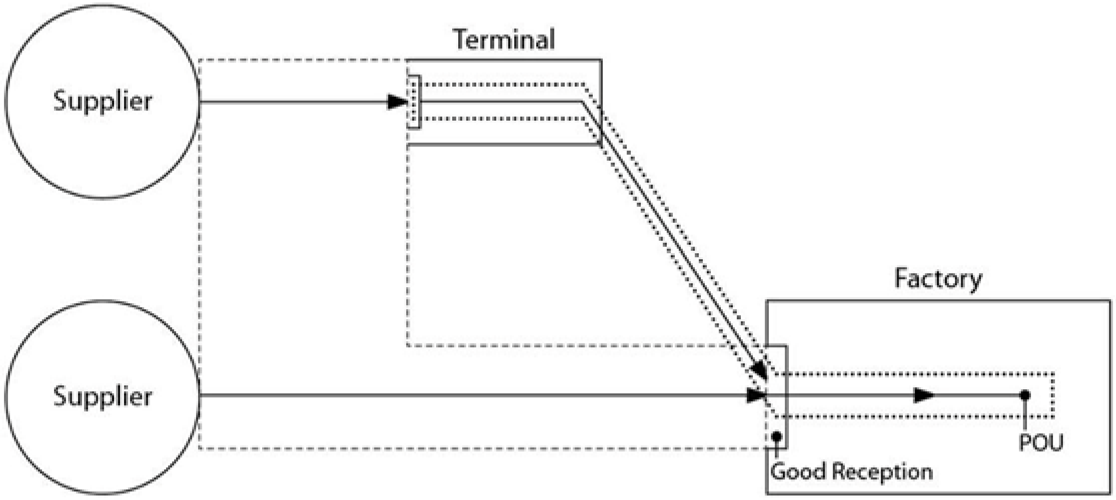

Figure 2. *Example of a material supply system from the first tier suppliers to the focal company*

The goods reception separates the two sections and is defined as the point where the company takes over the title of the supplied material from the suppliers. Furthermore, at the goods reception the material is reported into the company's information system and the goods will be available for production. Commonly, the goods reception is in direct connection with the plant but there are also possibilities that the goods reception is located in an external terminal, for example if the storage area within the plant is limited and further storage is required. Then the material is stored at the terminal and transported to the plant when there is a demand at the point of use. Even though the terminal is physically dislocated from the plant and run by a third part provider, it can still function as a goods reception as long as the terminal uses the same information system as the focal company in order to enable information sharing between the companies. When the goods is received at the terminal the goods will also be registered in the information system and will be available for use in the production, and the process is equivalent with a goods reception that is operated by the focal company. It is important to distinguish between the two sections when considering the design process of the inbound- and in-plant material supply system. Since the inbound material supply system also involves the suppliers it will be more complicated to make changes in the configuration in comparison with the in-plant material system.

A "Materials Supply System" can be described and modeled in several different ways. Johansson (2006) has developed a comprehensive model of a Material Supply System consisting of six design areas: materials feeding principle, storage, transportation, handling, packaging and manufacturing planning and control. Since the model covers all relevant elements for designing an "Inbound materials supply system" and an "in-plant material supply system", the model is a feasible option in this thesis. Furthermore, Hanson (2012) extends the model by Johansson (2006) and focuses on the "configuration of a material supply system", which refers to how a material supply system is arranged in terms of all of the constituent design areas. Hanson (2012) also states that since the material feeding principle constitute a central element of a Material Supply System it is necessary to be aware of its relation to the other elements of the material supply system. Thus, the following chapters 3.2 - 3.7 describes the elements that is included "in-plant material supply system" and "inbound material supply system" and their relationship to the choice of material feeding principle. In chapter 3.8 theories on the design of material supply systems are presented and finally in chapter 3.9 the Total Cost of Ownership principle will be introduced. However, the Material Supply System will hereafter be abbreviated to MSS in this thesis.

3.2 Material feeding principles

This section will describe the three different material feeding principles that one can apply to provide assembly processes with required material. These three material feeding principles are continuous supply, kitting and sequencing. All the mentioned material feeding principles will be individually analyzed regarding of advantages, disadvantages and given factors that influence whether the feeding principle is beneficial or not in a certain context.

As illustrated in the figure below (see Figure 3) material feeding principles can be classified regarding of how material is sorted and the selection of part numbers that is located in the border of the assembly line. To clarify regarding the how material is sorted, one provide more material what is needed, which is the case of continuous supply whilst kitting refers to provide what is exactly needed. Thereby when using kitting one uses a specific amount of material dedicated for a specific assembly object (Hanson, 2012).

The second classification selection of parts refers to if all articles are presented at the line or only some selected. Furthermore, the material feeding principle sequencing is not included in the matrix since sequencing can be seen as a material feeding principle under the category of kitting (Hanson, 2012). The difference between kitting and sequencing is basically that sequencing only feed single articles whilst kitting feeds several chosen articles (Hanson & Brolin, 2013)

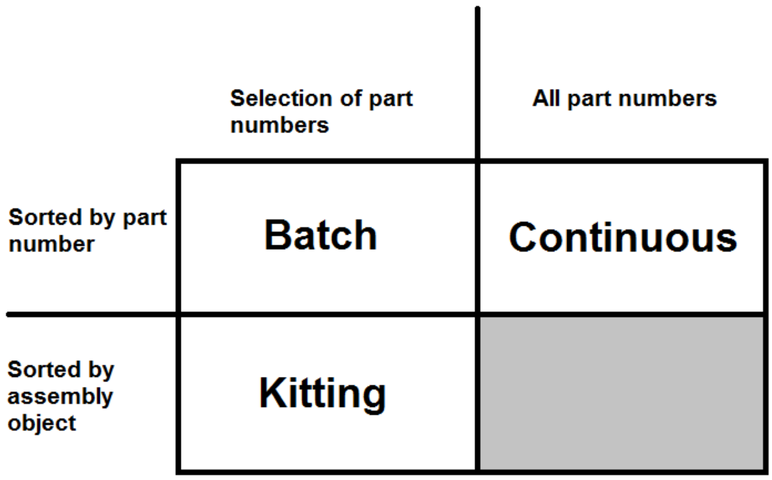

Figure 3. *Categorization of the material feeding principles, inspired by Hanson (2012)*

3.2.1 Kitting

According to Brynzér and Johansson (1995), kitting is an approach to collect specific parts in one unit load (container, package etc.) to feed an assembly or sub-assembly process. Thereby several kits can provide different assembly operations with specific prepared parts dedicated for a certain product type (Brynzér & Johansson, 1995). The preparation of kits is performed in a specific storing area where pickers prepare kits for production (Hua & Johnson, 2010).

The initiation is conducted through an order sent to the kit preparation area, where the picker then picks all the required articles. Each kit can in this case be seen as a specific kit that is customized regarding of the demand derived from the initiator or customer. Furthermore, kits can be prepared regarding of whether the kit is dedicated for one station or several stations. Thereby one can distinguish between stationary kits and travelling kits, where the latter is for several stations and the first for dedicated stations. When talking about stationary kits, these kits only serve one station and thereby dedicated for a specific station and product. Travelling kits substantially serves several stations where the kit follow the assembly object until the kit is consumed. For one assembly object several travelling kits can be used to complete the assembly object (Limere et al., 2011).

As mentioned earlier, kitting is an approach to pick demanded articles for a certain assembly object in one box. By using kitting as a material feeding principle to supply a work station, several advantages and disadvantages can be found. But according to Hanson (2012), kitting can reduce the man-hour consumption at the assembly station. Man-hour consumption is in this case the time it takes to fetch a part, which in this case even includes the time for seeking of parts. This dilemma occurs when many different parts are presented at the line. Thereby kitting can eliminate the seeking time and reduced the fetching time since the material can be prepared outside of the assembly operation and the material be provided closer to the assembler (Hanson, 2012). Whilst this only optimize for the situation at the assembly line, it probably add more man-hour consumption in total since the kit preparation has to be performed on another location. Kit preparation in general requires more material handling which makes the process more labor intensive, which further increases the man-hour consumption in total (Caputo & Pelagagge, 2011). Thereby kit preparation is more costly, but the difference can be somewhat mitigated, since the man-hour consumption is reduced at the line (Limere et al., 2011).

Brynzér and Johansson (1995) furthermore claims that kitting is preferred to be used in contexts of mass customization (Limere et al., 2011) where many different part numbers are included, or in cases of high valued parts and when the quality must be assured. Mass customization paves the way for extensive part circulation which complicates the material feeding process. Thereby the space in the assembly area can be freed up in use of kitting (Limere et al., 2011). Caputo and Pelagagge (2011) claims that kitting is most favorable when one deal with smaller components and when the assembly work is performed more often.

Kitting is also a way to enable better control on the shop floor, this since kitting reduces inventory at the shop floor and thereby release space, which further derives in elimination of obsolete material (Caputo & Pelagagge, 2011). By only having the right material visible at the line, Hanson (2012) mention that the released space can be utilized for new product releases, which according to Caputo and Pelagagge (2011) increase the flexibility.

Regarding the quality aspects that can be achieved through kitting, Caputo and Pelagagge (2011) mentions the possibilities to perform the quality checks when the kit preparation is conducted. It is essential in case to perform correct quality checks since unnecessary stops in the assembly process can otherwise occur. But as the same authors claims, kitting facilitates the improvement of quality, this since quality checks can be performed in an earlier stage. In this way the productivity can be improved since no unnecessary stop occurs and hence the kit configuration consists of correct parts.

In cases where a part doesn't correspond to what the line demands, it can cause downtimes in the production since no parts are available for assembling. This kind of problems creates waste in the production since parts must be found and cannibalization of other kits can occur. Cannibalization is when the operator for instance fetch parts from other kits and thereby ruin these kits from being complete. Therefore complete kits are essential to avoid these problematic obstacles since it otherwise causes extra material handling (Caputo & Pelagagge, 2011). Furthermore, the ergonomic conditions for the assembler can be improved when using kitting, but this requires that the kit design supports the operator (Limere et al., 2011)

3.2.2 Continuous supply

Regarding the material feeding principle continuous supply each material type is individually supplied to the storing point next to the assembly station (Limere et al., 2011). Continuous supply is in some literature abbreviated to line stocking, point-of-use storage system or bulk feeding, this since parts are provided close to the assembly station in individual unit loads (Limere et al., 2011).

Regarding the replenishment of material, material can be replenished through either kanban or scheduled deliveries (Caputo & Pelagagge, 2011). The kanban approach refers to a self-initiated system that sends a signal when material is needed through some kind of re-order point system (Limere et al., 2011), for instance a two-bin system (Hua & Johnson, 2010). A re-order point system in this case refers to when the stock reaches a certain level when new material has to be replenished in order to not be out of stock (Jonsson & Matsson, 2009). Material replenishment can according to Caputo and Pelagagge (2011) also be periodically delivered. In this case material deliveries will be scheduled regarding of which quantities that is needed.

In relation to kitting, continuous supply provides more direct flows with less interruption within the delivery path. The reason is that material straightly can be delivered to the line without material handling activities such as order picking (Hanson & Brolin, 2013). Thereby less people need to be in action of material handling (Caputo & Pelagagge, 2011) due to lower number of material handling activities (Hanson, 2012). Furthermore, continuous supply enables better availability regarding of the flexibility to supply with new material if the part seems to be damaged (Caputo & Pelagagge, 2011). The availability of the material causes more inventories, which can be seen as not efficient, especially when a huge number of material numbers uses continuous supply as material feeding principle. Since the materials occupy space it can prevent the introduction of new product releases (Hanson, 2012). The problematic situation in order to free up space can be solved through smaller material bins that utilize less space. When reducing the sizes of material bins it requires more frequent deliveries and in this way creates more circulation of bins (Caputo & Pelagagge, 2011). Furthermore, the downsizing of bulk quantities in larger bins to smaller ones derives in more material, according to Hanson (2012). Hanson (2012), further expresses that a huge number of material variants increases the man-hour consumption for the operator. Man-hour consumption in this case refers to the time it takes for the operator to get a part from material market (Hanson, 2012). This includes the time to walk to the material market, the time to find the right part and then even the time to fetch the part. (Hanson, 2012; Caputo & Pelagagge, 2011). This means that less number of material in the storage decrease the distances for the operator, which further decreases the time to walk and even the time to find the right part (Limere et al., 2011).

3.2.3 Sequencing

The material feeding principle sequencing refers to deliver individual parts to the line after a sequence. The sequence in this case is the order of the assembly object when the sequenced part has to arrive (Ding & Sun, 2004). Sequencing as material feeding principle only can be seen as a material feeding principle when single parts is sequenced (Hanson, 2012). The sequencing approach can be used either for unintentional or intentional reasons. Unintentional reasons refer to when something unintentional occurs and hence an unintended demand appears. This can be illustrated in cases where reworks must be conducted or breakdown of equipment occurs, which thereby derives in an unintentional demand of material. Whilst intentional demand refers to material supplied in planned sequences (Ding & Sun, 2004).

Hanson (2012) furthermore claims that sequencing mostly serves as a complementary material feeding principle to both kitting and continuous supply. Since only some selected parts are sequenced to the line, sequencing free up space at the line (Johansson & Johansson, 2006), this because no material is permanently stored at the line (Caputo & Pelagagge, 2011). Thereby material can be delivered to the line when needed at a specific location (Baudin, 2004).

By sequencing individual parts to the line material can be located closer to the assembly object, which decrease the walking distance to fetch a part (Johansson & Johansson, 2006) and even give a rise for easier material retrieval (Ding & Sun, 2004). Sequencing as material feeding principle is most suitable for parts that have many variants (Hanson, 2012). Furthermore, sequenced parts can be prepared anywhere, both in the company as well outside of the company (Caputo & Pelagagge, 2011). Furthermore, in case of the flexibility one can attain through use of sequencing regarding the time and location utility material can be delivered in a later stage of an assembly process, for instance in the final assembly where the final configuration will be defined. This in cases of customization when options of an assembly will be assessed later in the stage (Baudin, 2004). Furthermore Baudin (2004) expresses that sequenced material flows requires sufficient computer networks to be able to sequence parts in sequences.

3.2.4 The choice of selecting material feeding principle

As stated in the literature there are several different materials feeding principles to choose from such as kitting, continuous supply and sequencing. Each one of the principles has their specific advantages and disadvantages, but it is also important to recognize what kind of principle that is most suitable for a company in a specific situation. In order to make a successful decision companies need knowledge about when and where each type of principle should be used (Hua and Johnson, 2010). The primarily issue when considering the different types is to comprehend and anticipate the performance-related effects by the selected principle. When choosing a feeding principle it can be expected to affect both the performance of the in-plant materials supply and the assembly (Hanson, 2012) since the MSS is connected to the assembly system by material exposure (Finnsgård, 2009). Hanson (2012) means that the selected feeding principle should enable the MSS to operate with a high efficiency and flexibility as well as supporting the presentation of parts at the assembly stations for the operators. Furthermore, Caputo and Pelagagge (2011) also states that the assembly systems performances are influenced by the effectiveness and efficiency of the MSS.

It is insufficient to only consider the anticipated effects of the choice of material feeding principle, it is also necessary to set priorities between the performance areas. The selection of appropriate priorities between different performance areas are closely related to the context of the in-plant and inbound MSS. Examples of contextual factors that can affect the prioritization are the plant layout and product variety. These factors can have an impact on the space availability and space requirements, and thereby the importance of space efficiency, both at the assembly stations and storage areas. The inbound MSS context covers the locational aspect of the suppliers which will be further discussed in the succeeding section. Another factor that can affect how to prioritize the performance areas are strategic decisions. Changes in production volumes or introducing new product model may result in more variants and components to be needed and presented at the assembly stations, which impacts on the choice of material feeding principle (Hanson, 2012).

The selection of material feeding principle is not an isolated decision apart from the configuration of the in-plant and the inbound MSS. After the choice of material feeding principle is made issues related to the two systems such as unit load size, transport frequency, packaging, location of different material handling activities and materials handling equipment need to be considered. If there has been a decision to change one existing material feeding principle to another one, the configuration of the in-plant MSS may also be altered in order to optimize the effects of the change in feeding principle (Hanson, 2012).

In a similar way, it is also desirable to change the configuration of the inbound MSS in accordance with the selected material feeding principle. Following from the definition, the inbound MSS connects the suppliers with the focal company in terms of deliveries of materials but also by information and financial flows. In the literature, this type of linkage between two or more entities is referred to a supply chain and is applicable in the field of MSSs since it covers organizations that produce parts, components and end products, logistic service providers and even the ultimate customer himself (Stadtler & Kilger, 2005). According to Lee and Ng (1998), one way to enhance the competitiveness of a supply chain is through an improved coordination of the material, information and financial flows. For example, when using continuous supply the company may purchase bigger lot sizes than needed for the production because the supplier can offer a lower price. This result in that the company needs more space in the plant to store the material, more material handling and increased tied up capital which reduces the efficiency of the overall MSS. If the company instead focus on a total cost approach including all relevant costs such as the transportation costs, storage costs and the price of material it may not be justified to purchase the big lot sizes. As in the case of the in-plant MSS, the context of the inbound MSS also needs to be evaluated, which is denoted as the supplier.

Subsequently, when designing the MSS from the suppliers to the point-of-use one need to consider both the configuration of the inbound and in-plant MSS in order to avoid sub-optimizations. However, compared with the in-plant MSS, it might be more complex to alter the structure of consignments from the external suppliers.For example, it can be normal that the plant has fixed dates when orders can be made to the supplier. Then if the change of material feeding principle encourage more frequent transports it might be difficult to achieve the full potential effects.

From the discussion above, both the configuration of the inbound and in-plant MSS and context of the MSS affect the performances regarding the selection of material feeding principle. The relationships between the configurations and the context are illustrated in Figure 4 and needs to be considered during the selection process of material feeding principle.

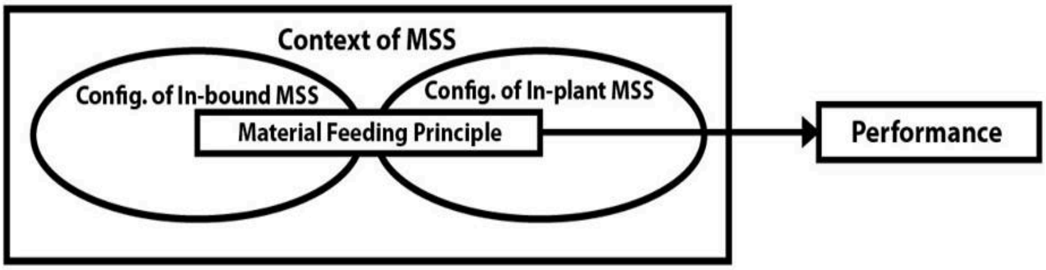

Figure 4. The relationships between the configurations and the contexts, inspired by Hanson (2012)

3.2.5 The context of the in-plant and inbound MSS

As been described previously, the performance associated with the selection of material feeding policy is closely tied to the context of the in-plant MSS (Hanson, 2012). Hanson (2012) defines the "context" as everything that is not part of the inbound and in-plant materials supply system itself, but that can still influence its performance. The contextual factors can be divided into "product- and part related factors", "production-related factors" and "supplier-related factors".

Product and part related factors

The characteristics of the product and components play an important role when designing and making decisions about the in-plant MSS (Hanson, 2012). The applicability of different material feeding principles is highly dependent on the size, volume and weight dimensions of the parts being handled. In production environments where the products and components are fairly small and can be stored in small or medium sized bins kitting is normally preferable (Hua and Johnson, 2010). Limere et al. (2011) also states that the man-over consumption per part can be reduced by kitting small components since it will be possible to transport kits that includes a larger part of components. On the contrary, too large and heavy components may not be suitable for kitting since the content of a kit is constrained by a maximum weight and volume (Limere et al., 2011). In cases when the components exceeds the limitations of the kit, those types of components need to be presented and fed to the assembly station by a different material feeding principle (Hanson and Brolin, 2013). According to Hanson (2012) sequencing is an appropriate material feeding principle when dealing with cumbersome components.

A second factor that influences the choice of material feeding principle is the number of part and product variants (Hanson, 2012). For example, if there are many variants of a product component, normally a lot of space is needed in order to store the part at the assembly station if continuous supply is used. By changing feeding principle and instead kit or sequence the parts with many variants it is likely to free up additional space around the assembly line (Limere et al., 2011). Similarly, Caputo and Pelagagge (2011) also states that continuous supply becomes unfeasible with increasing number of parts owing to lack of space at the assembly stations.

Furthermore, Caputo and Pelagagge (2011) suggest that components with a high-value should be kitted since continuous supply is associated with increasing capital costs. Hanson (2012) agrees on that the inventory levels around the assembly stations will be lowered by implementing kitting. However, since the inventories are moved up to the kitting preparation area the overall inventory levels are not necessary lower (Hanson, 2012).

In a material feeding environment where combination of kitting and continuous supply is used i.e. some parts are supplied by kitting and others by continuous supply, the order for how the operator assembles the components needs to be considered when selecting parts for each principles. One potential benefit that is often associated with kitting is reduced man-hour consumption at the assembly stations. In order to achieve the expected affects it necessary to consider the assembly order when assigning the components whether to be supplied by kitting or continuous supply. If two parts are assembled in connection to each other at the assembly station those parts should also be fetched at the same time at the point of use in order to reduce the time for walking. Even if the two components have been decided to be fed by different principle according to for example variety or value, it can still be beneficial to include both parts in a kit (Hanson, 2012).

Production related factors

Production related factors refer to how the production volumes and the product variety affect the decision of material feeding principle. According to Hua and Johnson (2010) continuous supply is preferable if the volumes are high and product variety is low, for example when the assembly line is dedicated to a single product with few options. However, if the production volume is low and the product variety is high, meaning that several different components are needed to be fed to the assembly line, kitting or sequencing are more suitable options (Hua and Johnson, 2010). The choice between kitting and sequencing in this kind of production environment depends on the characteristics of the components.

Associated with the production volumes and variations, the structure of the assembly process also affects the choice of materials delivery (Caputo & Pelagagge, 2011). According to Caputo and Pelagagge (2011) kitting is preferable when high product demand requires multiple assembly lines working simultaneously since several storage locations needs to be replenished. On the other hand, when the assembly system is composed by a single line with subsequent workstations, continuous supply is preferred if the characteristics of the components allow an efficient parts presentation at the assembly station, since each component can have a single storage position along the line. Generally, a single production line is used when the production mix is stable (Caputo and Pelagagge, 2011) which increases the possibilities to display all the components simultaneously at the work stations.

Supplier network related factors

The supplier network in this contextual issue comprises the network of suppliers regarding of how locations between suppliers and the number of articles can determine whether kitting or continuous supply is more preferable in a certain context. How the supplier network can affect whether kitting or continuous is more preferable in a certain context, it still prevails lack of information in the literature. However, this section will elaborate this extension through reasoning about how the supplier network can affect the choice of continuous supply and kitting. At a glance, Hanson et al. (2011) describes the effects regarding of where the kit preparation is conducted. The study showed that when kit preparation is conducted in a centralized location, the workload can be better utilized and hence more efficient material handling (Hanson et al., 2011).

Furthermore, this elaboration should even allege for material handling further back in the chain, for instance at a supplier location. This since every supplier in this case can be seen as an individual decentralized units that sends material to a centralized unit. However, when the supplier instead sends several parts to the company one should thereby consider whether the supplier can kit the material on-site instead of sending individual packages of each material, which forces upper actors within the supply chain to prepare kits. Since several parts come from the same supplier it should be more efficient to prepare kits at the supplier stage than further in the chain, if following the theory. Hence one can eliminate unnecessary material handling along the way by letting the supplier take care of material handling in an earlier stage (Mathisson-Ojmertz and Johansson, 2000). Furthermore, if the material handling can be performed at the supplier stage, probably no material handling is needed along the way to the plant. Thereby it should be able to prepare the right packaging for presentation of material at the line. However, Limere et al. (2011) expresses that efficiency can be attained when material can be presented in the original packaging, which follows this reasoning very well. Furthermore, suppliers located closely to each other can probably arrange kitting to be able to cater the plant further in the supply chain. As stated in this section, it can be of importance to look over whether the suppliers deliver many parts to the plant and hence, be able to supply finished kits. If this kind of arrangement can be arranged to insignificant higher cost kitting should be issued as more favorable in this case.

3.2.6 Performances associated with choice of material feeding principle the in-plant MSS

As been discussed earlier and stated by Hanson (2012), the choice of material feeding principle can affect several performance areas within both assembly and in-plant and in-bound MSS. Hanson (2012) identifies 8 relevant performance areas in relation to the selection of material feeding principle, which will be described separately in the section below. In other literature the performance area “cost” is also discussed, but since cost is affected by several other areas it will not be handled as an own category in this report. For example, both an increase in man-hour consumption or in inventory levels in associated with an increase in cost. However, when evaluating a logistic system’s performance it is important to consider the cost of the total system which is discussed in section 3.9.

Man-hour consumption

The choice of material feeding principle can affect the man-hour consumption in both assembly and material supply. Furthermore as stated by Hanson (2012), the operational cost of running a factory is closely related to the man-hour consumption. In in-plant MSSs, one way to evaluate the choice between kitting and continuous supply is to measure the total materials handling time related to each principle. Limere et al. (2011) suggest that the time can be expressed in four categories, the material handling time for the assembler at the line, the time for internal transports of components until the point of use, materials handling time of the picker, and finally the time to replenish the supermarket. However, since the focus of this thesis is on the MSS that is extended from the in-plant MSS until the suppliers, it is also necessary to include the external transport time when calculating the total material handling time. Furthermore, when considering the choice of material feeding principle the estimation of the material handling time related to sequencing is also required.

Product quality and assembly support
It has been stated that the product quality in assembly is facilitated by both kitting and sequencing compared to continuous supply, since the operator does not need to concern on what parts to pick to assemble but can instead focus on how to assemble them (Karlsson & Thoresson, 2011). Furthermore, if many part variants are presented at the assembly line by continuous supply, the risk that the operator can forget parts intended for assembly also increases. Another risk is also that the wrong parts are chosen which lowers the quality. However, in order to achieve the potential quality improvements the kitting and sequencing racks needs to be of a high quality themselves and containing all components required at the assembly station (Hua & Johansson, 2010). To ensure the quality of the racks "pick-to-light" or "pick-to-voice" systems can be used to facilitate the picking process for the picker at the kitting preparation area, but these systems are often expensive to install (Brynzér & Johansson, 1995). When kitting is used, well-structured kits can support assembly by functioning as a work function (Medbo, 2003). If the components are placed in the rack in a way that reflects the assembly operation, kitting can reduce the learning times and improve product quality (Johansson, 1991). Hanson (2012) also finds that it can be advantageous to use structures kits instead of unstructured. In cases when unstructured kits are used the operators may need to search for components if many parts are included in the kit, and hereby structured kits can offer better support for the assemblers (Hanson, 2012).

Inventory levels and space requirements
All three types of material feeding principle have both drawbacks and potential benefits regarding inventory levels and space requirements. According to Karlsson and Thoresson (2011) kitting and sequencing is associated with less space requirements than continuous supply at the assembly stations when the components are removed from the storage line side. When using the sequenced material feeding principle there is still a need for individual rack for each individual component i.e. the space required for variants of parts has been deleted but not the space required for the individual articles. As a consequence, if there are many part variants kitting is preferable to sequencing since all parts can fit into one kit container (Karlsson and Thoresson, 2011).

Even though, kitting and sequencing reduces the occupied space around the assembly stations the principles instead require more space upstream of assembly, for the kit or sequence preparation area (Hua and Johansson, 2010). In a similar manner, the inventory levels at the assembly stations will also be reduced by introducing kitting in comparison with continuous supply (Caputo and Pelagagge, 2011). The results are confirmed by Hanson (2012), meaning that component racks, and thereby inventory, were moved from the assembly stations to a kit preparation area that was established. However, the overall inventory levels increased since the kitting is associated with additional process steps (Hanson, 2012).

The introduction of both sequencing and kitting requires available space in the plant to set up the material preparation area. If available space within the plant is limited, a viable option is to relocate the preparation area to a feasible supplier or a third party provider.

Flexibility

It is often argued that kitting is associated with higher flexibility than continuous supply (Bozer and McGinnis, 1992). When kitting is used, only parts needed for a specific assembly object is present at each time. This means that the available space around the assembly stations is higher compared to when continuous supply is used, since the component racks are placed besides the working stations. The availability of space is associated with the level of flexibility in terms of the ability to handle a large number of part variants or fluctuations in production volumes (Wänström and Medbo, 2009). As an alternative to kitting, sequencing can be favorable where few components are assembled on a serial line (Karlsson and Thoresson, 2011). When sequencing is used each component variant is not displayed at the assembly stations in pallets but instead delivered in racks organized in the same sequence as the assembly process. Hereby, product changeovers are not only facilitated by kitting but also by sequencing, as parts and subassemblies are not located beside the assembly stations (Bozer and Mcginnis, 1992).

Control and visibility

In comparison to continuous supply, kitting and sequencing offers a better control and visibility of material flows from the preparation area to the assembly stations. When feeding components to the assembly object solely kit containers or sequencing racks are needed, instead of delivering a wide range of pallets containing the different part numbers (Caputo and Pelagagge, 2011). However, if the material preparation area is located apart from the main material storage, the material flows in to the storage area needs to be controlled in a similar manner as if continuous supply is used at the assembly stations (Hanson, 2012).

If the material preparation is performed externally by the suppliers the material flows inside the factory can also be more direct and even. Since material flows into and out from the preparation area doesn’t need to be managed by the plant themselves, the kits or sequencing racks can be directly transported to the point of use after the goods reception. Furthermore, the visibility and control of material at the assembly stations can also be improved by kitting and sequencing. According to Karlsson and Thoresson (2011) the delivery of kits and sequencing racks reduces the inventory levels since only selected articles sorted by assembly object is displayed which increases the control and limiting the articles exposed to damage etc.

When using kitting or sequencing, it is vital to deliver the kits or sequencing racks to the assembly line in the right order and on the right time. In order to coordinate efficient material flows into the point of use, kitting and sequencing can increase the requirements on the information compared to continuous supply (Caputo and Pelagagge, 2011). To ensure the quality of the kits and sequencing racks, the material preparation area needs to be updated on the sequence of assembly objects but also the accuracy of bill of materials is important. If the material preparation is done at some of the suppliers, the information also needs to be shared with this actor.

Product throughput time

There are only a few publications on how the choice between kitting, sequencing and continuous supply affects the product throughput time. However, based on the existing literature it can be argued that kitting and sequencing hold great potentials to reduce the non-value adding time for the operators at the assembly line (Caputo and Pelagagge, 2011; Limere et al., 2011). By locating the kitting and sequencing racks closer to the assembly object, the time for searching and fetching components can be reduced. The operators will hereby have more time for actual assembly work resulting in lower product throughput time. As stated earlier, when introducing kitting or sequencing there is also a need to setup a material preparation area either inside the plant given there is available space otherwise at the supplier. Preparing and coordinating the kits and sequencing racks require additional resources in forms of man-hour consumption, and if a company focuses on reducing the product throughput time the man-hour consumption can be expected to increase.

Ergonomics
In material handlings the ergonomics aspect is highly relevant for the operators. According to Limere et al. (2011) kitting is favorable compared to continuous supply regarding the ergonomic issues. In particular kitting is associated with efficient parts presentation at the assembly stations which can improve the ergonomics (Caputo and Pelagagge, 2011). This is exemplified by parts can be stored in smaller containers instead of large pallets, and big and heavy items are enabled to be presented in an easily accessible manner for the operators.

Investment cost
Limere et al. (2011) discuss if the implementation of kitting or continuous supply would result in some necessary investment costs. Furthermore, Limere et al. (2011) assume that neither of two systems require any form of automation, and argues that the investment costs are low in relation to the labor costs and is therefore negligible. However, when a company is using sequencing or kitting a “pick-to-light” or “pick-to-voice” systems may be necessary to ensure the quality in the kit or sequencing preparation (Hanson, 2012), which was discussed in the section above. In general these kinds of systems are expensive to install. This is an important issue when handling the MSS that includes the suppliers. For example, a company has decided to change material feeding principle from continuous supply to kitting. As the required space is not available in the plant, the company may try to convince one of its suppliers to start to kit the components and deliver finished kits. In order to ensure the quality of the kits, it would be favorable to install a “pick-to-light” system at the supplier. However, issues on who should make the investment in such a system will be brought up that can deter collaboration between the companies.

3.3 Material, planning and control
The management of material flows and production processes in manufacturing companies is referred to the concept “manufacturing, planning and control” (Jonsson and Mattson, 2009). The term covers the activities concerned with planning and controlling all aspects of manufacturing, including the scheduling of the machine’s capacities and of materials (Vollman et al., 2005). With respect to the planning horizon and the level of detail different planning methods are available. In the long term-planning, mostly the planning object is the end product or the product group, while when executing detailed planning on manufacturing operations or materials planning the planned object is the individual dependent item. At each level there are several planning methods to choose from. The suitability of different planning and control methods are dependent on factors such as demand, products and manufacturing characteristics (Jonsson & Mattsson, 2003).

Independent on what material feeding principle that is used it is necessary to control the material flows through the MSS, e.g. by initiating material deliveries to the assembly stations and to avoid production disruptions by keeping satisfied inventory levels (Hasson, 2012). Therefore not every part of the "manufacturing, planning and control" topic is relevant for this thesis. The significant activities are those concerned with delivery initiation and control of materials flow within and between the factory and the suppliers which are covered in the area of "material planning". Examples of these kinds of planning methods are illustrated in Figure 5.

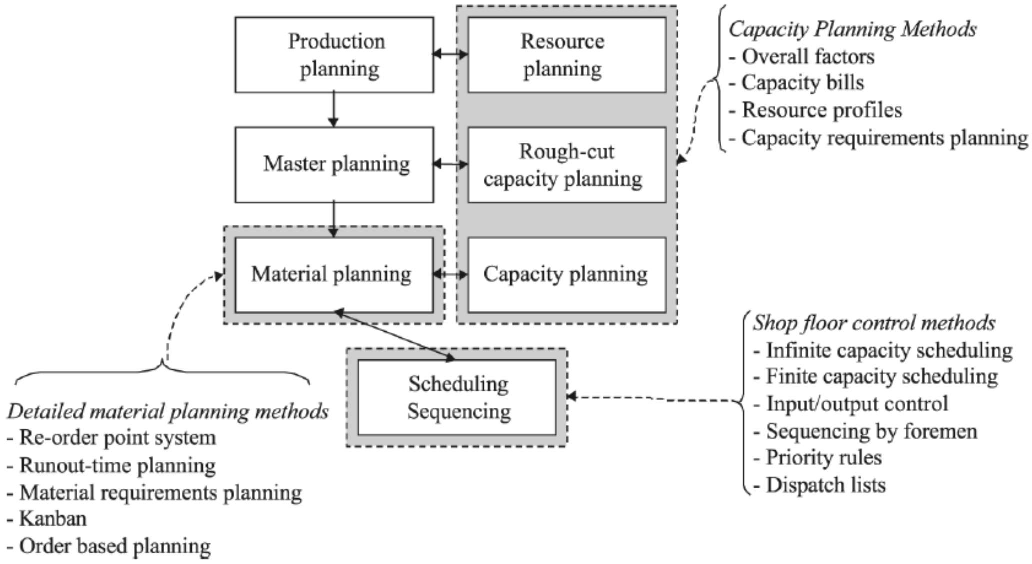

Figure 5. *Examples of detailed material planning methods (Jonsson & Matsson, 2002)*

According to Jonsson and Mattsson (2002) the two basic questions "when and what to order/deliver" and "How much to order" needs to be addressed during the material planning process. As can be seen in figure 5.1 three types of material planning methods are re-order point system, material requirements planning (MRP) and kanban system.

In a re-order point system, an order is made for each part separately (Malstrom and Mason, 2001), based on making a comparison between the quantity available in stock and a reference quantity or re-order point for every item. As soon as the current stock level at the usage point falls below the re-order point an order is sent to the warehouse to procure the desired stock replenishment quantity (Jonsson and Mattsson, 2009). The order quantity corresponds to the estimated demand during the lead time plus a safety stock to cover for unexpected variations in the demand (Jonsson and Mattsson, 2005). The re-order point system is presented in Figure 6.

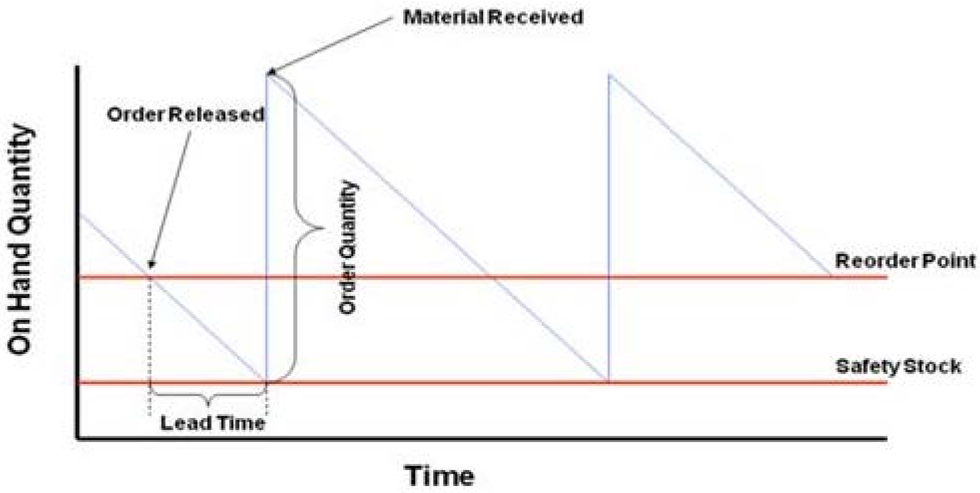

Figure 6. *Illustration of the basic principles for the re-order point system, http://www.reliableplant.com/Read/28195/Inventory-MRO-stocking-levels [Retrieved 2013-10-25]*

Explosion-based inventory systems are used for planning items with dependent demand (Jonsson and Mattsson, 2009), through the relationship between the demand of the finished product and the demand of its constituent's parts by using the bill of material (Malstrom and Mason, 2001). MRP is a popular explosion-based inventory system, where the method is relying on the company's production schedule. Through the production schedule of the finished products the demand for the incorporated subassemblies, components and raw material, both in time and quantity, that is needed for the final product is derived (Bennet and Forrester, 1993). According to Hansson (2009) this type of planning method is appropriate for initiating delivery of parts in the context of a MSS. Consequently, to run a MRP system efficiently different kinds of information is required in the form of production schedule, bills of material, available stock on hand, lot sizing methods, lead times and the sequence of the assembly process (Jonsson and Mattsson, 2009).

A variant of the re-order point system for initiating material flows is the kanban system (Malstrom and Mason, 2001). The control method is based on kanban cards and is used to authorize material movement and stock replenishment based on a visual signal. When a kanban card is released it indicates that materials can be transported from the storage area to the assembly station (Jonsson and Mattsson, 2009). When the replenishment is dependent on the actual stock levels at the consuming units the inventory levels may be lowered since inventory is not accumulated at the work stations. If the kanban system is used in the right planning environment with the appropriate configuration, it can be used to achieve an effective and simple replenishment system with little inventory (Nicholas, 1998).

It should be noted that different control methods can be used throughout the material supply chain. It is possible to use one specific method in the in-plant MSS such as kanban and then a different method to order components from the suppliers such as MRP.

Economic order quantity
The preceding material planning methods concerns the time dimension i.e. when to initiate the manufacturing or purchasing orders respectively when the order should be delivered to the workstation or plant. A second factor that is related to the material planning of material flows is to determine what quantity to order for each part. Every order that is made is associated with order costs, inventory carrying costs and the demand of the parts. In general, the order costs decreases with the order batch sizes, however then the inventory carrying costs increases instead. If the batch size is bigger than the instant demand, the remaining parts need to be stored in inventory incurring inventory carrying costs. By adding the total ordering costs to the total inventory carrying costs and optimising with respect to the quantity, the economic order quantity (EOQ) can be derived as (Jonsson and Mattsson, 2005):

$$EOQ = \sqrt{\frac{2*C_p*A}{v*C_r}}$$

Where
Cp=costs of placing orders
A=annual demand
v=item cost
Cr=inventory carrying cost rate

According to Jonsson and Mattsson (2005) the derivation of the formula is based on a number of assumptions such as the delivery of the order occurs instantly, the price of the parts aren't affected by the order quantity and there are no stock shortages. Even though the formula doesn't depict the actual conditions perfectly in the planning environment, the formula still leads to satisfactory results and is widely used in the industry.

Push-based and Pull-based material planning
A common way to describe the material planning is to distinguish between pull-based and push-based planning. The main distinction between the push and pull principle is based on how production orders and material movements are released to workstations in response to demand. When the material planning is of the pull type, manufacturing and material movement only takes place if the recipient and consumer of the materials have ordered them. Conversely, if instead the initiation and authorization of material flows is controlled by the supplying unit itself or a central planning in forms of plans, the material planning is referred to as a push-based principle. it should be noted that the material planning methods are not characterized by pull or push, but instead their application determines whether the material flows are pull or push based. For example, a reorder point system can both be used by a consuming unit to order material procurement as well as by a central material planning unit to order make to stock for future demands (Jonsson and Mattsson, 2009).

3.4 Transportation

Transportation is to move material from one place to one another place where the material is needed (Johansson and Johansson, 2006). Johansson and Johansson (2006) furthermore expresses that transportation is a service (Lumsden, 2007) to create time and place utility. In this case place utility refers to transfer material where it is needed and time utility to show up when the material is needed (Johansson & Johansson, 2006), where the time utility can be referred to delivery precision (Jonsson and Mattsson, 2009). Furthermore, frequencies of transportation impacts the quantities the transportation vehicle carries. This means that the higher frequency of transportation the less quantity the transportation vehicle will carry, thereby the transportation cost will increase and vice versa. On the contrary, the transportation has a huge impact of which quantities that can be delivered. This can for instance be described when the delivery time can be reduced, which favor for lower quantities delivered (Lumsden, 2007). Lumsden (2007) furthermore expresses that lead time reduction regarding of the transportation time decrease inventory levels at both suppliers and customers.

The transportation in this case can be seen as horizontal movements since material is transported horizontally, which can be separated from vertical moves which comprises material handling moved vertically (Baudin, 2004). In this section the transportation will be divided in internal and external transportation, where internal transportation refers to transportation conducted into the company whilst the external cover transportation outside of the company. Regarding the external transportation it can be arranged by either the buyer of the product, the supplier or an external third part haulier (Johansson & Johansson, 2006). Mostly the transportation is conducted through trucks over land and by boat over the sea. In some cases air-flight can be used to be able to handle emergency and transportation of valuable goods, whilst train and ship transportation are more preferable for goods of lower value. Road transportation lies somewhere in between (Lumsden, 2007). When planning transportations routes it is important to achieve high fill rates in the load carriers to minimize the transportation costs. One way is to utilize the concept of cross-docking which integrates intermediate nodes into a transportation network. Within a cross-docking terminal incoming shipments delivered by inbound trucks, are collected, sorted by destination and directly loaded on an outbound truck that immediately leaves for the final destination. Through cross-docking it is possible to consolidate many smaller shipments so that full truck loads can be transported which enables economies of transportation (Boysen & Stephan, 2011).

Regarding internal transportation, the transportation is performed from the arrival point of material until the point of use in the production when looking in a perspective of material supply internally. The material transportation internally is often performed with material handling equipment, such as: forklifts, pallet jacks, carts, Automatic Guided Vehicles (AGV), conveyors etc. (Baudin, 2004). However, tugger trains that transport small boxes can be used to drive routes called milk-runs. A tugger train in this case is a motor-driven vehicle that carries small trailers with boxes to replenish material at several locations (Limere et al, 2011). This approach is typically runned in Just-In-Time settings that uses a kanban approach to initiate replenishments (Caputo and Pelagagge, 2011; Limere et al., 2011).

3.5 Storage

The function of a inventory is to serve a process with needed material and works as a synchronizing decoupling point between two processes (Hanson, 2012). Furthermore, Chopra and Meindl (2012) expresses inventory as an existing mismatch of supply and demand. When an inventory runs out of material disruptions in the flow will be caused until new material is supplied to the process (Hanson, 2012). When talking about inventories, these can be taking various forms along different process steps. Inventories can be for instance raw material stock, components, finished products and as well partially finished products (Johansson and Johansson, 2006).

Regarding the location where inventories can be settled, material can be stored either outside of the company or even inside of the company. Storages outside of the company can either be managed by the company itself or that a third part provider takes care of material storage (Hagan, 2004). Inventories can be both centralized as well decentralized, which means that centralized inventories refers to only one central location where material is stored whilst decentralized refers to when inventory is located at several locations (Abrahamsson, 1993). In the case of a centralized inventory all inventory is collected at one place and thereby economies of scale can be attained, this since material only need to be stored at one place (Hanson et al., 2011). The situation is different for a decentralized inventory which presents same material at more than one place. This enables closer connection to the location where the material will be used whilst in centralized inventory the material is located more distant away from the consumption point (Battini et al., 2010). Since decentralized inventories is located at many locations more inventory will be created, which derives in more material handling. When dealing with more inventories the cost and the risk for obsolescence will increase (Hanson, 2012). Thereby more capital is tied up which according to Liker and Meier (2006) hides problems such as production downtimes, late deliveries, defects etc., which in the end results in inefficiency.

Therefor many companies supplies material from central storages to replenish several decentralized storages with same material. Battini et al. (2010) illustrates an example (see Figure 7) regarding of several decentralized supermarkets supplied from a centralized storage to be able to gain cost efficiency. A supermarket in this case can be explained as a rack consisting of smaller boxes with material (Liker & Meier, 2006), where the supermarket only carries a maximum level of material (Morgan & Liker, 2006). This approach can be sustained through replenishing the supermarket more frequently (Liker & Meier, 2006).

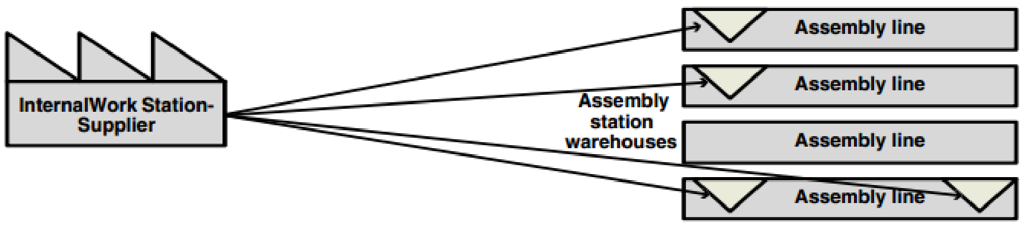

Figure 7. *Illustrates a central warehouse that replenish several decentralized storages (supermarkets) with material, which then further supplies assembly lines (Battini et al., 2010)*

3.6 Packaging

Packaging is one of the most important activities in the supply chain and distribution systems (Chan et al., 2005). It surrounds, enhances and protects the goods we buy, from the point of processing and manufacturing at the factories through handling and storage to the final customer. Without sufficient packaging systems the materials handling would be a complex, inefficient and costly activity (Robertson, 2007). Chan et al. (2007) divide packaging into two major types of industrial packaging and marketing packaging. Industrial packaging is referred to the preparation and protection of merchandise and goods for shipment and storage, and the purpose of consumer packaging is designed to enhance sales acceptance (Chan et al., 2005). In MSS, packaging are used when the goods are transported from the suppliers, through terminals, to the main factory. Furthermore, packaging is also used within the plant to carry components of different assortment from the storage area to the assembly line.

Jönson (2006) defines a packaging system as having three hierarchical levels of packaging: primary, secondary and tertiary. The primary package is in direct contact with the product, the secondary package surrounds several primary packages, a tertiary package is some kind of load carrier such as container, pallet or a rack which consists of several primary and secondary packages in order to be transported or shipped to the next destination. In connection with packaging and material flows, unit loads are often mentioned which is a standardized load carrier with regards to the size and design (Jonsson and Mattsson, 2005). Bagadia (1985) states six basic types of unit loads: pallet, sheet, rack, container, self-constrained unit load and pallet less handling.

In order to understand if a package is good or bad the functions of the package must be appreciated. According to Livingstone and Sparks (1994) packaging has six basic functions: containment, protections, apportionment, unitization, convenience and communication of the product. In a packaging system composed by several levels, the functions need to be viewed from a system perspective. For example, one of the functions of the package system is to protect the product during transportation. This means that if the quality of the secondary package is enhanced the level of protection needed in the primary package may be reduced (Pålsson et al., 2012).

When considering packaging in manufacturing companies it is important to regard the interrelation between the materials supply system and assembly. According to Pålsson et al. (2012), packaging systems are often designed individually with respect to the assembly station and the materials supply system leading to sub-optimization (Tompkins et al., 2010). In workstations, where the assembly and MSS can be physically integrated, substantial time and cost savings can be achieved if the packaging system is adjusted in accordance with the assembly situation and to the components used (Harit et al., 1997). As an example, it is often argued that the size of unit loads and packaging should be as large as possible to avoid extensive material handlings (Jonsson and Mattsson, 2005) and to reduce the number of transports necessary (Hales and Andersson, 2001). However, by using large packaging there are also accompanying drawbacks in form of higher levels of work in process, the space requirements are larger at the point of loading and use (Hansson, 2012) and a greater need for repacking and downsizing (Jonsson and Mattsson, 2005).

In the literature, only little research has been found on the relationship between packaging and the other parts of the MSS (Johansson and Johansson, 2006). However, Wänström and Medbo (2009) emphasis the importance of considering the assembly process when choosing packaging for parts that are fed to the assembly stations through continuous supply, by comparing the Swedish and Japanese automobile industry. The study shows that Swedish companies mainly use standardized EU-pallets placed in component racks to display the parts at the assembly line. The selection of packaging has primary been to design cost-efficient transportation systems without considering the characteristics of the components which has led to inefficient assembly operations. On the contrary, it is noticed that the assortment of different packaging are much larger in a Japanese plant and that the component racks are typically portable and easy to re-design. As a result, Japanese companies have better opportunities to choose packaging that supports and facilitates the assembly work (Wenström and Medbo, 2009). By improving the display of components in a continuous supply situation several advantages can be achieved and the more costly options kitting and sequencing may be avoided. Examples of potential benefits are reduced space requirements at the assembly stations, improved time efficiency, ergonomics for the assemblers and flexibility for product and mix.

In the context of sequencing, both individual components as well as kits can be delivered to the assembly station in a sequence that represents the assembly order. The delivery process often requires specially designed racks to feed the parts effectively (Hanson, 2009). Considering kitting, the kit container can have a formal structure meaning that each part has a fixed position (Brynzér and Johansson, 1995). Since the kit container includes several parts, formal structure can reduce the time for searching for the right part to be assembled leading to a better support for the assemblers (Hanson and Brolin, 2013). However, the disadvantage with a formal structure is that the flexibility is limited (Brynzér and Johansson, 1995)

3.7 Material handling

In relation to transportation, material handling can be categorized as vertical moves (Baudin, 2004). Many authors has provided sections that merges both transportation and material handling together since transportation equipment can be used for both transportation and material handling. These articles mainly focus on the in-plant transportation and material handling (Hanson, 2012). Since this thesis even comprises transportation outside of the plant it may be essential to distinguish between handling and pure transportation.

This section will elaborate the meaning of material handling without any involvement of transportation. In broad sense, material handling can be seen as activities as repackaging and handling of material, where decisions regarding how and where it should be conducted (Johansson, 2007). Klingenberg and Boksma (2010) express materials handling as operational activities that appear along the flow of material. In this way handling comprises activities such as kit preparation, sequencing downsizing of packing and repacking (Mathisson-Ojmertz & Johansson, 2000; Johansson, 2007), but even vehicles that put down as well lifting up material is included as material handling (Fredriksson, 2011).

Material handling is often labor intensive which makes the material handling align the flow vital to study (Klingenberg & Boksma, 2010). By eliminating the material handling along the flow the material handling cost can be decreased, which leads to less complexity in the flow. Furthermore, the risk can be decreased as well the throughput time in the flow, this through elimination of material handling. Furthermore, when eliminating material along the flow one can even decrease the need for administration activities (Mathisson-Ojmertz & Johansson, 2000). But even if elimination of material handling can be of importance to get a better flow, it can also have a value adding aim. This can be illustrated when kitting and sequencing for instance enable the right conditions for the end station. Material can thereby be supplied align with the customer demand (Klingenberg & Boksma, 2010).

Material handling in relation to kitting requires additional material handling to collect all the needed parts. In this case the picking can be performed by either the assembler at the line or some other outside operator (Brynzér & Johansson, 1995). Through this different advantages and disadvantage can be identified regarding of who the picker is. Firstly, by letting the assembler at the line prepare kits higher picking accuracy can be attained (Brynzér & Johansson, 1995), this since the assembler is aware and have an understanding of problems that occurs if low quality kits are prepared (Hanson et al., 2011). Furthermore by enabling kitting close to the assembly line the control will be improved since the assembler can visually control the stocks and the current need at the line, which further decrease the need for costly information systems (Hanson et al., 2011; Caputo & Pelagagge, 2011) and hence administrative duties (Brynzér & Johansson, 1995). Hanson (2012) furthermore expresses that kitting performed by an assembly operator increase the responsiveness to react for faulty kits and also that continuous improvement can be attained easier. In relation to decentralized kit preparation near the assembly line kit preparation can be performed in a centralized setting. By kitting in a centralized setting the space at the line can be freed up (Hanson, 2012) and that inventory can be collected on one place which gives economies of scale (Hanson et al., 2011). Since an outside operator performs the kitting process away from the line the quality of the kits may suffer. Thereby, these faults can be covered by picking support in form of pick-to-light or pick-to-voice systems that enhance the quality. But this solution ends up in a higher investment cost (Hanson, 2012). Furthermore as described in the inventory section, even material handling is often being outsourced to third-part providers in order for the company to focus on their core competency (Klingenberg and Boksma, 2010).

3.8 Design process

When designing the material- and information flows from the suppliers to the point of use, i.e. setting up the MSS, several aspects need to be considered such as the configuration and context of the in-plant MSS but also the configuration of the inbound MSS. As suggested by Hanson (2012) a structured process can be applied in order to consider all relevant aspects, and hereby be able to establish an appropriate MSS. In the literature various design processes are described, some are focused on MSSs design (Johansson, 2006; Hanson, 2012) and others on production system designs (Pahl and Beitz, 1996). Even though the purposes of the described processes are different, many similarities between the recommended phases can be found.

Johansson (2006) presents a design process for the MSS that stretches over several tiers of a supply chain. The context of the design process is focused on product development projects meaning that the design process takes place before the system is operationalized. The model consists of the four phases of planning, concept development, system-level design and detail design and the structure of the model is based on previous research originated from e.g. Pahl and Beitz (1996). In the planning phase the main objectives of the MSS is established as well as the requirements on the MSS throughout the design process have to be considered. The concept development phase of the MSS design is important for preparing the subsequent parts of MSS. In this stage different MSS concepts are evaluated to identify the most suitable options for the company. Furthermore, Johansson (2006) identifies various material flows in an MSS that can be viewed as sub systems in the MSS. The material flows are classified into three different types; flows from suppliers to the work stations, flows of semi products between work stations and flows from the final work station to customers (Johansson, 2006). In the System-level design phase those three material flows are considered from the perspective of the configuration of the MSS, namely material feeding principle, storage, transportation, handling, packaging and planning and control (Johansson, 2006). In the last step, the detail design phase each of the design areas of the configuration are designed in detail. However, the only exception is the choice regarding the material feeding principle which instead should be considered during the system level phase.

A second model that discusses the design process related to MSS is developed by Hanson (2012). As opposed to the design process described by Johansson (2006) stretching over several tiers in the supply chain, the suggested process by Hanson (2012) is delimited to the in-plant MSS. A vital part of the design process is how to choose the most appropriate material feeding principle between kitting and continuous supply, which is an issue that hasn’t been considered in detail in preceding models. The proposed model is illustrated in Figure 8 and consists of five distinct phases.

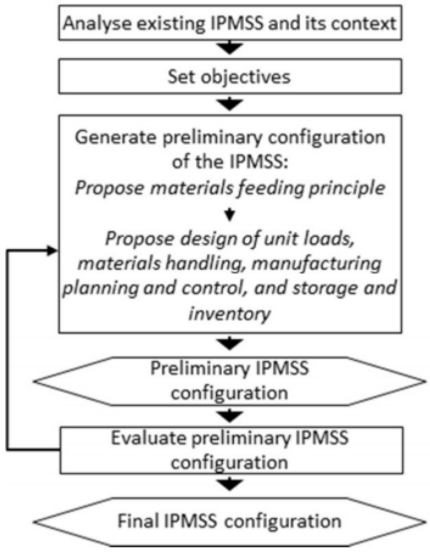

Figure 8. *The suggested outline of a design process for an in-plant materials supply system (IPMSS) (Hanson, 2012)*

The first step is to analyze the existing in-plant material system and its context (Hanson, 2012). Based on the analyses and strategic considerations of the company, objectives of how the in-plant MSS should perform will be decided. These objectives can be expressed in terms of priorities between different performance areas suggested by Hanson (2012). The third phase is the generation of a preliminary configuration of the in-plant MSS. It starts with deciding whether kitting or continuous supply is more suitable to use, and the selection should support the set objectives for the supply system. The selection of material feeding principle is followed by the conceptual design of the remaining parts of the configuration of the in-plant MSS (Hanson, 2012).

The two models are describing the design process for different kinds of MSS. Johansson (2006) are focusing on MSS stretching over several supply chain tiers, and Hanson (2012) narrows down the scope to the in-plant system. Even though the two MSS somehow differ there are some similarities in the design processes. Both models are initiated by setting up objectives for how the future state of the MSS should work. In the model developed by Hanson (2012) the configuration phase is iterative in its nature where the choice of material feeding principle has a higher priority compared to the remaining areas in the configuration. A similar pattern is shown in Johansson's (2006) model where decisions about the material feeding principle are taken before the detailed design is carried out.

Even though both models handle the design of MSS in different forms none of the processes fully covers the MSS from the suppliers until the point of use. How this process will be designed will be further discussed in chapter 5, where the framework is presented.

3.9 Total Cost of Ownership

In order to measure and evaluate a logistic system's performance it is important to identify the existing logistics- and capital costs of the system. The logistics costs can be defined for a single process, an organization, for a whole supply chain or network of companies. When considering the process of procurement of material from the suppliers, it necessary to include all costs associated with the MSS (Jonsson and Mattsson, 2005). To effectively managing logistics processes, the total cost concept is an appropriate approach to utilize. The goal of the organization should be to reduce the total cost of logistics activities, rather than focusing on reducing the costs for each activity separately (Ellram and Siferd, 1998). For example, if a company buys in large quantities, the supplier may be willing to give volume discounts which instead leads to higher inventory carrying costs and obsolescence risks (Oskarsson et al.,. 2006). A purchasing decision may not only affect the buying company but also the costs of the supplier, for example if the supplier needs to deliver smaller batches than what is economically to produce. In a close cooperating supplier relationship, it is necessary to equally share the risks and potential profits between the actors. In the concept of total cost, both direct costs and indirect costs are included. Examples of direct costs are the cost of the material, transport costs and customs fees. Administration costs for ordering and invoices, costs related to the material flows such as quality control, inventory, material handling, returnable packaging are examples of indirect costs (Jonsson and Mattsson, 2005).

4. VOLVO PRODUCTION SYSTEM AND VOLVO POWERTRAIN IN SKÖVDE

This section provides information on how the Volvo Production System (VPS) describes a MSS. The information is based on Volvo Technology (VPS Academy, 2008) education material. Furthermore, methods and tools developed by Skövde Powertrain will also be presented since these mainly originate from the VPS Academy. The chapter is concluded with supplementary information on MSS, obtained through interviews with representatives at Skövde Powertrain.

4.1 Introduction

Volvo's vision is to strive for:
"an organization where we continuously improve quality, delivery and productivity, in everything we do", (VPS Academy, 2008)

Everything starts from the bottom, from "The Volvo way", which is the base foundation that guides how values, culture and leadership supports everything Volvo do. This foundation support elements such as: teamwork, process stability, Built-In-Quality, Just-In-Time, continuous improvement and then the customer, as illustrated in Figure 9. Team work comprises everybody's commitment to improve the organization in order to achieve goals and objectives, by utilizing everyone's creativity, knowledge and experience. Process stability refers to stable processes in order to be able to eliminate waste and thereby create a predictable process which works efficiently. Process stability can be attained by having comprehension and deep knowledge of the operation. Built-In-Quality refers to never forward bad quality further in the process, which is a mindset that everyone has to carry. In this way, everything has to be correct from the beginning and nothing should go further before the fault is corrected (VPS Academy, 2008).

The Just-In-Time approach is to eliminate waste by doing what is needed, in the right quantity, that in a shortest possible time. This enables less inventory, one-piece flow and quicker fulfillment of customer demand. In order to be able to make continuous improvements, standardization must be attained and a clear vision where the company is going. These five elements above "the Volvo way" and under the customer represent the daily work of taking strategic decisions. Furthermore, these elements make it possible to achieve strategic objectives on the way to strive for operational excellence (VPS Academy, 2008).

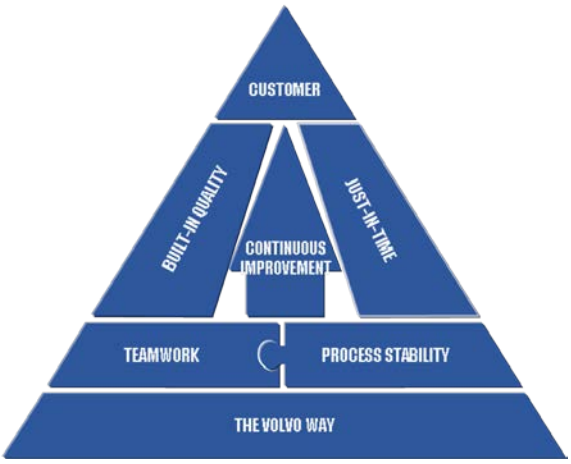

Figure 9. *Illustration of the Volvo Production System (VPS Academy, 2008)*

4.2 The material supply system

VPS Academy (2008) presents a number of tools and methods related to material supply to facilitate the creation of stable flows of well-presented material at the Point-of-Use material facade. Material supply is a part of the element Just-In-Time in VPS, see figure 9 above.

4.2.1 Design process

The main objective with the design of the MSS is to enable and create a continuous one piece flow, with no stagnations. To achieve a continuous flow, VPS Academy (2008) has introduced the lineback principle which means that the work with improvement should start with the line process and its operators and then continue upstream the supply chain see Figure 10.

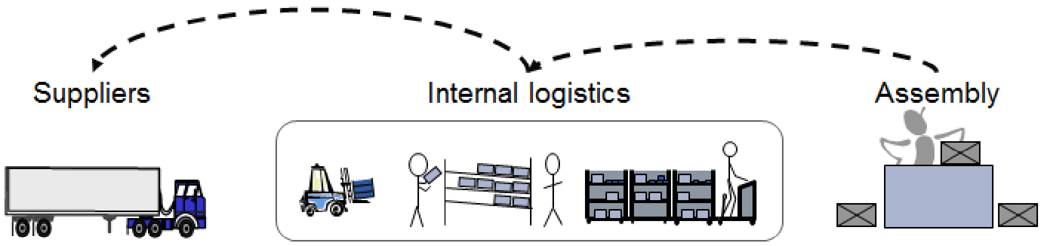

Figure 10. *The lineback principle (VPS Academy, 2008)*

As a result, it is suggested that the design process starts with improvements of the material presentation. The focus is on the operator to minimize non-value added activities. The second step concerns the internal logistics including the selection of material feeding principle and warehouse management. It is vital to develop material handling methods that facilitate materials availability, standardized work, leveling, takt and visualization. In the last step, decisions are made concerning the external logistics and the procurement process from the suppliers involving selection of suppliers and procurement methods. The presented steps in the design process will be further elaborated in the section below that describes the MSS six design areas (VPS Academy, 2008).

4.2.2 Material feeding and materials presentation

VPS Academy (2008) states that when selecting material feeding principle, each article must be assigned a distribution technique based on how the article is presented at the assembly line. The size, consumption rate and costs are factors that affect the evaluation of the articles. Volvo Powertrain (2013) has developed a decision matrix based on these factors for selecting an appropriate material feeding principle for individual articles. The matrix is presented in Figure 11, and includes the feeding principles: sequencing, direct supply, kitting, kanban and two bin system. The different zones in the matrix refer to a classification of the article based on their size, unit cost and commonality. For example, an AA article is characterized by a large size and being expensive at the same time. If the article also has an commonality that exceeds 75%, the article can be found in the upper right corner and should be supplied through a direct feeding principle.

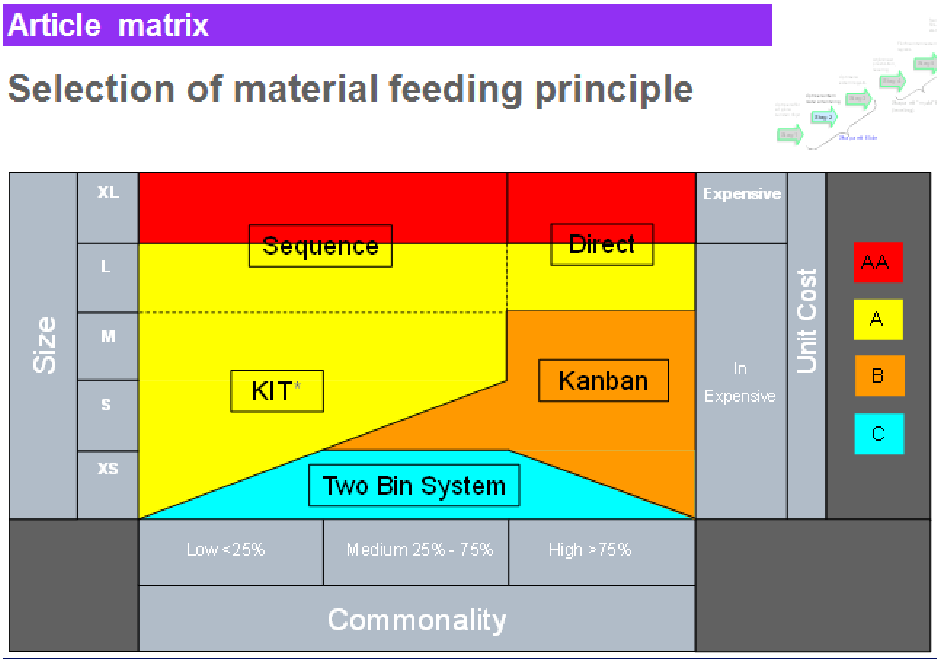

Figure 11. *Decision matrix according to Volvo Powertrain (2013), Skövde*

Through the selection of material feeding principle, the articles are moved from the supermarket or goods reception up to the Point-of-Use racks. The design of the material presentation is strongly affecting the operators working conditions and heavy and big parts needs to be presented in ergonomically friendly positions. Therefore, when designing the Point-of-Use racks the principle of "the golden zone area" can be a useful tool. The tool describes how to place different articles in the rack based on the weight-cost classification referred to the matrix in Figure 11 when selecting material feeding principle. For instance, an article that is expensive and has a large size is classified as an AA-article. In relation to the ergonomic context these parts should be presented in the center in front of the operator, as can be seen in Figure 12 (Volvo Powertrain, 2013). The remaining classification from B-D follows the same logic.

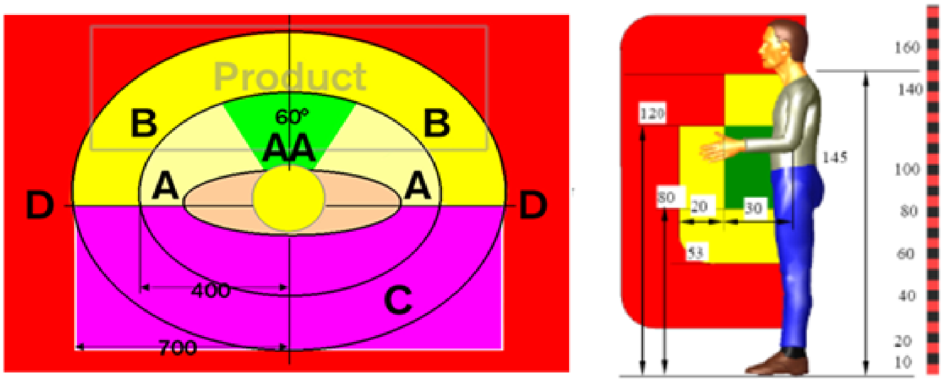

Figure 12. *The "Golden Zone" principle according to Volvo Powertrain (2013), Skövde*

4.2.3 Planning and control

When talking about different planning and controlling methods, one can distinguish between push based MRP-systems and pure pull systems. According to “the Volvo way” Volvo strives to extract all processes within a company to a pull system that only produces the right amount when needed in the shortest possible time. Thereby the most ideal and visional flow is a one-piece flow that eliminate all kind of inventory along the way. The pull system is an important element within the Just-In-Time approach that aims to deliver the correct parts, in the right quantity in the right place when needed. Furthermore the material must be presented in a way that enables efficient fetching of material for the operator (VPS Academy, 2008).

Furthermore, a supporting element to create a pull based flow is the Kanban approach, which enables communication between production elements when moving parts between them. Kanban can appear in various forms, such as: cards, containers, balls, lights, visually, electronically etc. Regardless of which form the kanban appears in the previous process will get the information regarding of the initiation conducted by the subsequent process (VPS Academy, 2008).

4.2.4 Transportation

Skövde Powertrain (2013) has divided the arrangement of transportation into two parts related to the internal- and external logistics. For both sections methods have been developed to facilitate the selection of the most adequate transportation procedure for different types of articles.

Internal logistics

Transportations in the internal logistics are related to how the articles are delivered either from the supermarket or goods receiving to the Point-of-Use racks at the assembly station. Examples of internal transportation modes are trains with pallets, cyclical trains, AGC and mixed trains. The decision of mode is dependent on the characteristics of the article regarding production volumes, cost and sizes and corresponds to the matrix that is used for selecting material feeding principle. In Figure 13 the same matrix is presented as in Figure 11, with the difference that instead a certain transportation mode is assigned for each zone. For instance, following from figure 13 articles that are big, expensive with high volumes should be supplied to Point-of-Use through direct deliveries which corresponds to the transportation mode “train with pallets” as seen in the upper corner zone in Figure 13 (Volvo Powertrain, 2013).

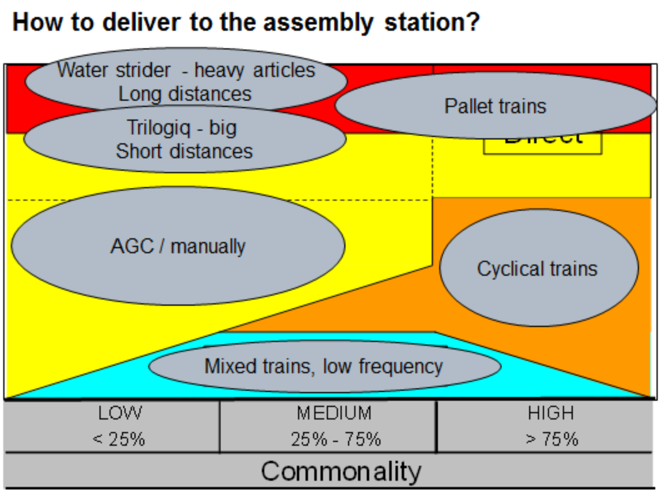

Figure 13. *Matrix for selecting the internal transportation mode, according to Volvo Powertrain (2013), Skövde*

External logistics
Skövde Powertrain (2013) describes that in order to make the external logistics more efficient it is vital to improve the relationships with the suppliers and the transportation system. The aim is to develop the transportation network by reducing parts inventory, increasing efficiency and connecting production and supply into a single flow. Skövde powertrain (2013) also lists six types of improvements that can be applied to develop the external transportation network:

- usage of milk runs
- mixed loads i.e. reduce the number of suppliers and instead increase the delivery quantities from the remaining suppliers.
- mixed transportation by consolidating items from suppliers that provides smaller quantities with major suppliers' in their vicinities
- utilize standardized packaging for enhanced stack ability
- Apply direct flows to avoid warehousing
- Efficient goods receiving location and process improvement

4.2.5 Storage
When designing the MSS, the VPS Academy (2008) states that the main focus should be on creating a continuous flow without stagnation. The production processes should be located close to each other to reduce the transportation, inventory levels and lead times. If continuous flow cannot be achieved and buffers are needed these should be managed by the principle of First-In-First-Out (FIFO). By adopting FIFO lanes a better inventory control can be obtained together with increased flexibility of the manufacturing process. Other benefits with FIFO are that the stored parts are ensured to not become obsolete and that quality problems are not built into the inventory. A second method to store parts is through a supermarket which also enhances the flexibility of the manufacturing process. According to VPS Academy (2008) the size of the supermarket depends on the reliability and changeover ability of the production process and should hold at least one piece of every part variant.

4.2.6 Packaging
To improve the materials handling and enabling continuous flows, VPS Academy (2008) emphasizes the usage of small containers. There are several potential benefits by using small containers instead of pallets such as reduced requirements for space and storage levels and lower costs and handling for repacking of pallets into small containers. Moreover, a better part presentation at the assembly line can be achieved due to smaller packaging resulting in better ergonomics for the operators (Skövde Powertrain, 2013). However, when it is impossible to implement smaller packaging and replenishment trains, forklifts and pallet trains are two alternatives that should be used. VPS Academy (2008) suggests that when pallets must be implemented, the material flows need to be controlled by a true 2-bin system.

The transition from pallets to small containers may also affect the external and supplier logistics in different forms. VPS Academy (2008) mentions three potential outcomes regarding the supplier context:

- higher packaging costs
- small impact on transportation costs

- possible change of part price

From the visit at Volvo Powertrain in Skövde, the changeover process from tree pallets to plastic blue boxes could easily be conducted. Representatives from Powertrain in Skövde claims that about 80 percent of all suppliers accepted the changeover without any problems, and in some cases the changeover derived in process improvements for the supplier. However, the rest of the 20 percent were able to make the changeover but required extra charges for that process, for about 1 to 50 percent more in the total parts price. In one case Volvo Powertrain could experience too much in extra expenses in relation to the part price which forced the company to accept the usual packaging instead. However, representatives from the company furthermore expressed the importance of balancing the packaging cost in relation to handling and transportation cost to reach the optimum, but at the same time provide the best possible solution for the parts presentation at the line (Weinö 2013).

4.2.7 Materials handling

VPS Academy (2008) states that the main goal of internal logistics is to reduce the work in process and present materials efficiently and ergonomically for the operator in the golden zone, see section 4.2.2, with minimal material handling. The reduction of materials handling is related to all actions that concerns the supply of material from the supermarket to the assembly line. It is necessary to choose the most appropriate transportation method and material feeding principle for each article in order to minimize the materials handling.

Volvo Powertrain (2013) lists seven points to facilitate the reduction of materials handling:

- eliminate vertical lifts of articles
- reduce the usage of forklifts
- reduce the number of lifting equipment
- eliminate transporters
- use standardized packaging and reduce the package sizes
- eliminate the usage of wood and cardboard boxes
- transport batches in as small quantities as possible

4.2.8 Landed cost approach

Volvo CE in Hallsberg uses the “Landed Cost” approach to calculate the total cost of ownership from the supplier to the Point-of-Use. Thereby the Total Cost of Ownership will be replaced by Landed Cost within this thesis. The consisting elements within the landed cost approach are:

- Packaging
- Part price
- Customs
- Transportation
- Administration
- Third party cost
- Material handling
- Risks

5. DEVELOPMENT OF THE DESIGN PROCESS FOR THE MATERIAL SUPPLY SYSTEM FROM THE SUPPLIERS TO THE POINT-OF-USE

The chapter will present the developed framework in relation to the purpose of this thesis. The framework is derived from the literature and empirical study that aims to show how to analyze and improve a current MSS of any setting from the suppliers to the Point-of-Use of an assembly station. The framework functions as a step-to-step guide for designing the material- and information flows in order to fulfill the objectives of the MSS with a TCO evaluation.

5.1 The framework

When designing a MSS it has been defined that there are 6 different design areas to consider; material feeding principle, storage and inventory, transportation, materials handling, packaging and manufacturing planning and control. Both Hanson (2012) and VPS Academy (2008) indicate that the material feeding principles constitute a central element of any MSS. The view is supported by Johansson (2006) and it is appropriate that the selection of material feeding principle should be established before designing the remaining parts of the MSS.

In section 3.2.4, previous literature on the selection of material feeding principle was presented. It became clear that the selection procedure is associated with a considerable complexity since the choice of material feeding principle can affect both a multiple of the performance areas (see section 3.2.6) and because of the interrelations between the material feeding principle and the configurations- and contexts of the in-plant and inbound MSS. In order to consider all performance areas and interrelations, Hanson (2012) suggests that a structured process would be useful when designing an in-plant MSS as illustrated in Figure 8. Since the scope of this thesis covers the in-plant MSS, the foundation of Hanson's model is applicable. However, since the thesis also includes the inbound MSS, covering the suppliers, the model is extended and modified in order to fulfill the purpose of the thesis. The developed framework or design process is presented in Figure 14.

Following from the suggested model developed by Hanson (2012), the first step of the framework is to review how the existing system is functioning. The analysis should not only cover the configuration and the context of the in-plant MSS as proposed by Hanson (2012), but should also include the configuration and context of the inbound MSS. Based on this analysis, objectives is set for how the future MSS should perform. The third step includes the generation of a preliminary configuration of the MSS. As pointed out in the section above and according to the "lineback principle" derived from VPS Academy (2008) and described in 4.2.1, the process should be initiated with the selection of material feeding principle followed by the design of the in-plant MSS and eventually the inbound MSS. The aim with the "principle" is to create a continuous material flow but also to minimize the non-value added activities in the assembly station. Since the configuration step is divided into three separate phases it is important to focus on the overall performance of the MSS and not the performance of the individual sections. One example of sub optimization was given in section 3.2.4, discussing that companies may purchase big batches of a component since the supplier may offer a low unit price, but instead the materials handling and space requirement increases. Following the procedure of the presented design processes in chapter 3.8 by Hanson (2012) and Johansson (2006), the configuration of the MSS should be defined gradually during an iterative process. In the iterative process the suggested preliminary configuration of the MSS needs to be evaluated in comparison with the set objectives.

The process should also include an estimation of the Landed Cost of the configuration to measure the efficiency of the system and ensure that no sub optimizations occur along the MSS. The design process and its constituent sections are further described in section 5.2 - 5.6.

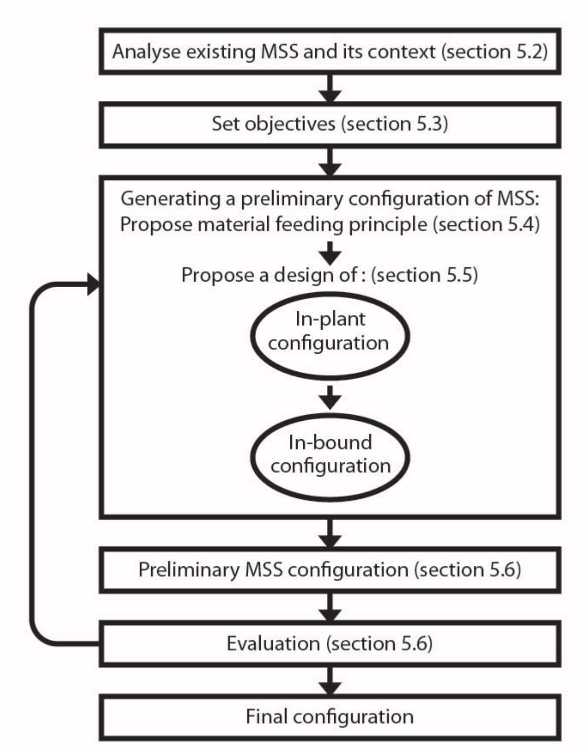

Figure 14. *The proposed framework for designing the inbound and in-plant MSS*

5.2 Analyze the existing MSS and its context

In the system analysis section an analysis regarding the configuration of the in-plant and inbound MSS has to be carried but also for the associated contextual factors. When analyzing the configuration one must make an analysis regarding the design areas:

- Transportation: Both externally and internally
- Packaging: which packaging that are in use today
- Planning and control: with concentration of material planning
- Material handling
- Material feeding principles
- Inventories

As the starting point of the analysis it is useful to identify the current material- and information flows from the suppliers to the Point-of-Use with a value stream map (VSM) and material flow map (MFM). The mapping can be made for individual material flows or for consolidated material flows that includes individual articles with similar characteristics. Through the VSM and MFM, a basic overview of the transportation, planning and control, material handling and inventories areas can be achieved. To obtain the overall view of the configuration, information on packaging and material feeding principles needs to be complemented.

The second part of the analysis includes the contextual factors in relation to the inbound and the in-plant MSS. In section 3.2.5 the contexts were defined as; everything that is not part of the configuration but that can still affect the performance of the MSS. The supplier related factors are associated with the inbound MSS and the part- and product, production and layout related factors are connected to the in-plant MSS. In the section all relevant aspects for each context were outlined, e.g. the production related factors refers to the number of product models, production volumes of the models and production rates. In Table 2 the findings from section 3.2.5 is presented, and the table can be seen as an appropriate guideline when collecting data and information about the context of an MSS. The columns are assigned for each context and the rows below states the related information that is needed to be analyzed.

Table 2. *The relevant aspects in relation to the three contexts*

Production related factors	*Part- and product related factors*	*Supplier related factors*
Range of product models	Size	Location of suppliers
Production volumes of the product models	Weight	The distribution of how the articles are supplied from each supplier
Production rate	Volume	
	Number of part variants included in the models	

5.3 Objectives

With the analysis as an input, the next stage in the design process is to choose the major objectives for how the future system should perform. When choosing the objectives, the most important objectives parameters should be selected for the most preferable material feeding principle setting. The rest of the un-prioritized performances should be considered when designing the remaining parts of the system. In the literature (see chapter 3.2.6) eight different performance areas has been found, listed below, however local objectives related to the specific environment of the plant might also be considered.

- Man-hour Consumption
- Product Quality and Assembly Support
- Inventory levels and space requirement
- Flexibility
- Control and visibility
- Product throughput time
- Ergonomics
- Investment cost

5.4 Material feeding principles - the selection process

This section will describe how to select the material feeding principle for one assembly station and will therefore define the individual material feeding configuration. The selection process starts by defining the overall setting of the assembly station by looking at the volumes and variants that each station produces. When the overall setting is set for the station, the framework will narrow down the material feeding section to an individual level for each part. The reason for this sequenced order can be explained that the material feeding selection should start from the overall view and then be further directed to a more detailed level, to gain an appropriate structure of the approach. This in order to comprehend a whole view of the material feeding selection. However, the whole approach to select the most preferable material feeding principle follows four sequenced steps and is illustrated in Figure 15:

1. Production related factors - volume and variant analysis
2. Product and part related factors
    a. Analyze the supplier related factors regarding the possibility for kitting back in the chain
    b. closely related to packaging
3. Sort out sequencing articles regarding to either size or weight (referring to chapter 3.2.5).
4. Final configuration of the material feeding selection.

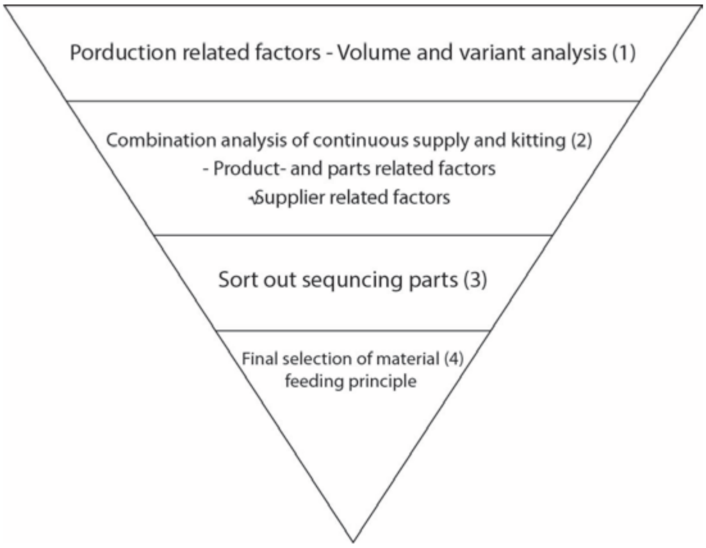

Figure 15. *Process for selecting the material feeding principle*

1. Volume and variant analysis - Production related factors

By using the analysis of the production related factors a preliminary material feeding setting can be presented. In this case production related factors are the central element, i.e. the volume and product model variants that an assembly station produces. The Figure 16 below illustrates a matrix that gives an initial glance whether only kitting or continuous supply is relevant or either a combination of both of them.

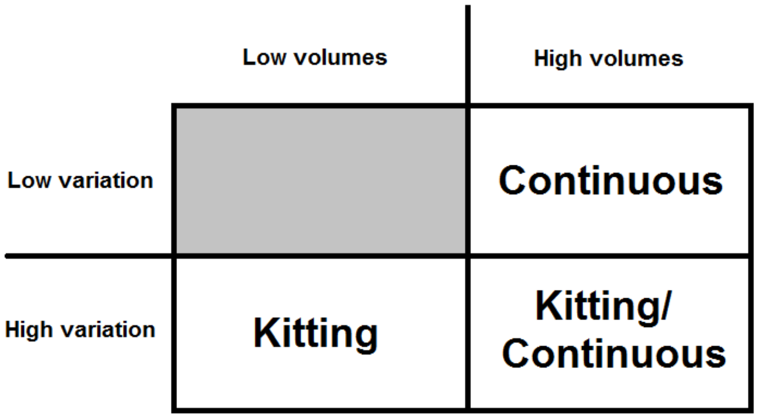

Figure 16. *Illustrations the matrix that is considering production related factors for selecting the material feeding principle*

In order to use this matrix data as production volumes and product variants for the station are essential to know. Local condition decides whether a station produces in high/low volumes and low/high variation. Three different scenarios can be carried out, where only one can be selected:

- When a station produces products of low number of variants in high volumes continuous supply is the more preferable material feeding principle.
    - However, it is still necessary to see if there are many parts in each model. Even though a model is only produced in a few variants, the model can include several part variants and in this case step 2 is necessary, this based on local conditions.
- When the station produces of high number of variants in low volumes kitting is more preferable.
- When the station produces products of high variation in high volumes a combination of kitting and continuous is current.

Regardless of what scenario that is selected it is still necessary to use the production related factors to propose an overview form the highest level within this framework. In order to make the final choice of material feeding principle step 2 includes the analysis of the parts- and product and supplier related factors.

2. Combination analysis of continuous supply and kitting

- *Parts- product- and supplier related factors*

At this stage all the prioritized performance measures will be analyzed regarding of the context and the configuration, this through carrying out all advantages and disadvantages in relation to each material feeding principle. These steps are:

- Firstly, use the prioritized objectives
- Secondly, then carry out all the benefits and disadvantages of each objective/performance in relation to the context and configuration.
- Thirdly, make a final analysis and see whether continuous supply can't be used due to decreased performance, i.e. only use kitting when continuous supply can't be questioned for instance through an more efficient parts presentation. Moreover, continuous supply should be used in the greatest extent and kitting when performance of continuous supply can't be attained. Consider supplier related factors when deciding whether kitting or continuous supply is more preferable.
- Fourthly, define the final proportion of kitting and continuous supply.

3. Sort out sequencing parts
In this step all heavy or large articles should be sorted out (see Figure 17) from articles that last on kitting in step 2. Follow this order:

- Firstly, one has to choose which of these two parameters; weight and size (see chapter 3.2.5) that should sort out all sequencing articles.
- Secondly, define all large, heavy or valuable (depending of the first step) articles by setting a limit regarding of when the article becomes large or heavy. These parts that can't be kitted due to high weight or large size should be investigated regarding of sequencing. The limit for whether the article is heavy/light, large/small or low/high value is decided upon local conditions.

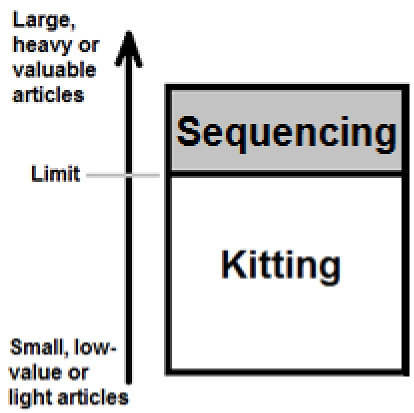

Figure 17. *The matrix consists of the material feeding principle kitting and which of the kit articles that should be investigated regarding of sequencing*

4. Final selection of material feeding principle
In this stage the proposed configuration should be presented after an iterative process of deciding the proportions of kitting, continuous supply and sequencing.

5.5 Define the rest of the MSS configuration
After the material feeding principle is selected the rest of the MSS needs to be designed, which includes both a proposal of the in-plant and inbound configuration. The theoretical design processes presented in chapter 3.8 does not outline the order for how the configurations should be arranged however VPS Academy suggests the lineback principle. According to the principle, the material feeding principle selection is followed by the design of the internal and then the external logistics. Following from the definitions of the MSS in chapter 3.1 it can be reckoned that the internal logistics corresponds to the in-plant configuration and the external logistics equals to the inbound MSS. Hence, the in-plant supply system should be designed before the inbound MSS. In order to construct the configurations, the previously described design areas need to be considered; transportation, packaging, planning and control, materials handling and inventory and storage.

5.6 Preliminary configuration and evaluation of landed cost calculations
As described above, the final configuration should be build up through an iterative process where the design areas are gradually constructed.

In the iterative process the proposed configuration needs to be evaluated in relation to the prioritized performance areas. To be able to compare the efficiency of the two systems and avoid sub optimizations landed cost calculations (see chapter 4.2.8) needs to be evaluated. As a result of the iterative process, the final configuration will be accomplished.

6. CURRENT STATE AT VOLVO CONSTRUCTION EQUIPTMENT IN HALLSBERG

This section will describe the current state of the MSS that has been approached at Volvo Construction Equipment in Hallsberg. The section starts from the supplier and stretches to Point-of-Use in the stage of the plate lining process. Furthermore, the current state section is within the first stage of the framework, i.e. analyzing the existing system (see section 5.2).

6.1 Contextual factors that affect the material supply system of Volvo CE in Hallsberg

Chapter 6.1 will describe factors that have an impact on the MSS of Volvo CE in Hallsberg. However, when looking at which material feeding principle that is the most suitable for a certain context not only the MSS configuration should be considered. Thereby a description of contextual factors will be conducted within this section. These factors may have a major impact on whether kitting, continuous or sequence supply is more favorable in a certain context. The contextual factors are production related and part and product related, which belongs to the in-plant related factors. Furthermore, there is a third factor, abbreviated as supplier related factors that will be described together with the section supplier situation and transportation network in chapter 6.2.1. The supplier related factors only cover the inbound section as elaborated within the theory (chapter 3.2.5). Hence production related factors and product and -part related factors will be described in this section, this together with the five different stations. Before the two contextual related factors are elaborated an introducing section will describe the overview concerning the plate lining process.

6.1.2 Introduction

When starting to look over the layout concerning the plate lining process, there are five stations that should be considered in this description. All these stations work independently from each other, but are dedicated for a certain product type, i.e. loaders, excavators and dumpers. Figure 18 illustrates how the layout looks like over the plate lining process, where the main inventory is located above the five stations in the figure. The two green marked stations weld produces for loaders, the only blue marked station produces for "excavators", whilst the two stations rightmost produces for "dumpers".

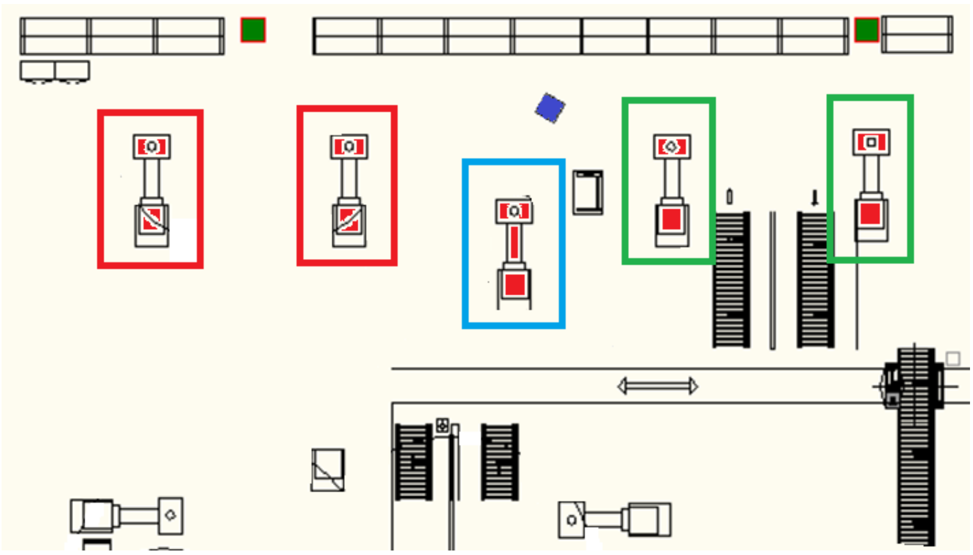

Figure 18. *Overview of the plate lining process area*

When looking at the layout regarding the stations, large products is welded and the space is limited for other activities, i.e. the space becomes narrow. Furthermore, there is no more space for more articles in the main stock and Volvo CE has started to outsource some material handling activities to a terminal. Since Volvo is planning for introducing of new models in the production the total number of articles will grow even more which can be seen as unsustainable in the future, this in a perspective of area and even capital tied up in the buffer.

Volvo CE plans to increase their production from current XXXX units to XXXX units by year 2015, which is the scope of the thesis. New models in the production and higher volumes cannot be fitted into the plate lining process area, and not even into the rest of the plant. The current situation forces the company to outsource the material handling process to an external actor in order to mitigate the growing buffers. Thereby the material handling has to be performed in a close off-site location, which further increase the transportation distances “automatically”. This option seems to be the most relevant in this case since Volvo is not able at the moment to establish an own logistics center due to the high fixed cost. However, this strategic issue should thereby be considered when the MSS of Volvo CE will be designed, as stated in the theory section, chapter 3.2.4.

6.1.2 Production-related factors

To extend the current situation, production related factors such as volumes and variants of the stations will be extended in this section. To start, there are as mentioned three major cab models, but each of these can be exploded to several variants of each model. When looking at the two “loader” stations, these stations produce 3 different “loader” types and in total “loaders” have 21 articles except from the cab frameworks. “Excavators” has only two different variants deriving from the excavator cab group, the vandal model and the usual model, and there are only some corner pieces that change the setting. In total “Excavators” have 24 different articles except from the cab framework. Regarding the “dumper” model there is today two models that in total consist of 20 articles except from the cab frameworks. In addition, there is no common parts numbers between dumpers, loaders or either excavators, and hence these cabs use its own material. However, every main cab model within each cab group has common articles and articles that vary between the models, which are illustrated in Figure 19. Volumes and BOM-structures between all main models and variants are illustrated in Appendix A.

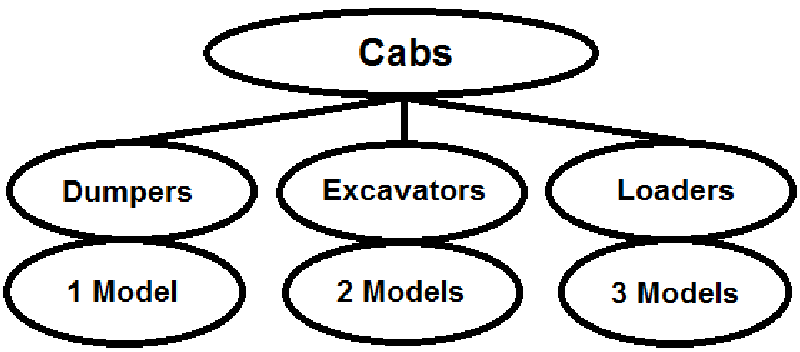

Figure 19. *The different cab variants for each cab type*

To add, what has been mentioned within this section regarding of number of models, these are not valid for the reality since this only concerns the set within the production. In the reality the loader station has seven models, the excavator two models and lastly the dumper that has two different models (see Table 3 below).

Table 3. *The number of actual models for the dumpers, excavators and loaders*

Loader Types	Excavator Types	Dumper Types
L60 F	Standard	A25-40
L70-90 F	Vandal	A25-40 F/G
L60-90 G/H		
L110-120 F		
L110-120 G/H		
L350 F		

6.1.3 Product and part related factors
Regarding the product and part related factors; these can be found in Appendix B. The information covers the weight and measurements of each article.

6.2 Material supply system of Volvo CE
This section describes the parts that comprise the MSS as described in the theoretical part. Firstly, the planning and control part will be described in order to grasp the whole picture of the running MSS since it is one of the major parts when making the material flow map. Thereafter, the remaining parts of the MSS such as transportation, material handling, material feeding principle, packaging and inventory and storage will be elaborated in relation to the material flows from the suppliers to the Point-of-Use. The flows covered by the in-bound configuration, as defined in section 3.2.4, is denoted as the inbound flows and the flows related to the in-plant configuration is denoted as the in-plant flows. The description of the current state ends with an explaining of the inventory situation at Volvo CE and the operator in focus. Basically, this section starts by describing the inbound situation of how the flows go from the supplier until the goods receiving of Volvo CE alternatively the terminal. After this stage different flows will be described regarding of their characteristics. These flows stretch from the goods receiving until that the material reaches the storage and will be characterized regarding of typical characteristics it possess. Lastly, a description of the storage located beside of the plate lining process regarding of the upper rack storage and Point-of-Use inventory will be carried out, this together with the operator in focus. Hence, the MSS section will be described in three major sub-sections as illustrated in Figure 20.

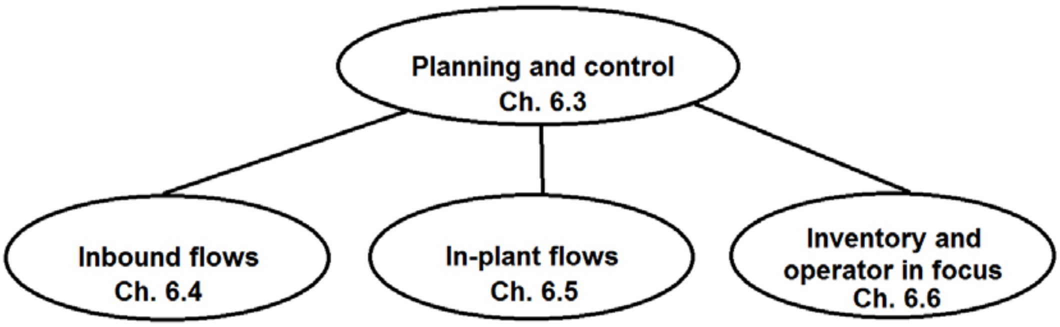

Figure 20. *The structure of the current state in relation to the MSS*

6.3 Planning and control

The planning and control section will describe the external information flows that appear when material is needed until it arrives to Volvo CE in Hallsberg. But basically, the material planning and control is conducted through the material planning department that mainly justify orders derived from delivery schedules and forecasts that Volvo CE send to their suppliers, see Figure 21 below. Volvo CE is sending forecasts every week to their suppliers in order to update the predicted need. As a confirmation from the suppliers the material planning department receives a delivery plan which consists of mainly the delivery date, quantities, material included in the order etc. But material planners at Volvo CE are even in charge of doing transport planning and securing deliveries. To their help they use MRP software (SAP), a business system to initiate schedules and then justify these when they stand out from the demand. These schedules are generated forecasts that counts in data from previous months, which is a strength plan derived from project plans of higher level. When it comes to the practical way of establishing contracts and negotiate with suppliers the purchasing department are delegated that responsibility.

Basically, everything derives from the customers of Volvo CE which send their schedules to production control of Volvo CE in Hallsberg. Through this information Volvo CE in Hallsberg can plan their daily production of cabs in the plate lining process as well the supply of material.

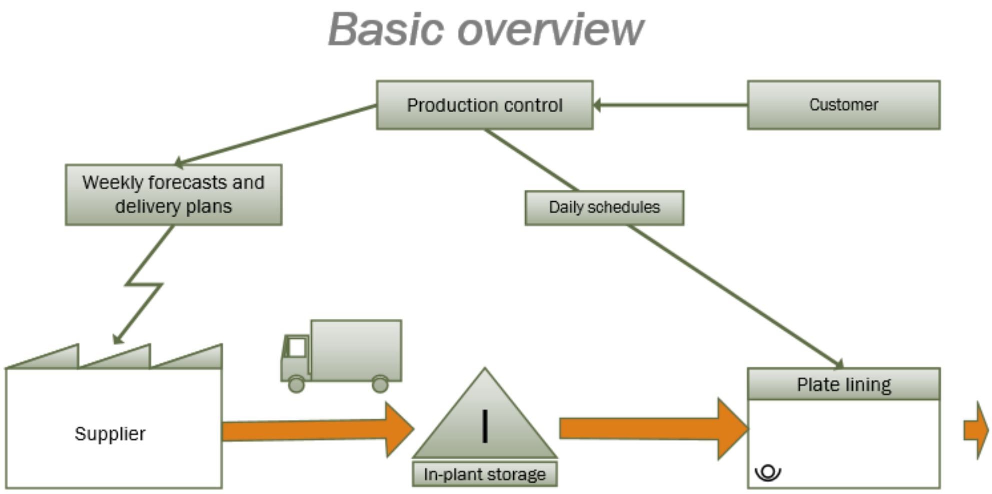

Figure 21. *Illustrates a basic overview of the information sent to suppliers and the plate lining process derived from the customer*

The business software is an important element for the material planning department since it holds all the necessary information. In this way the material planner can get warnings regarding of stocks that runs out or over stocking and thereby plan new deliveries of material to Volvo CE. Hence the planning process can be seen as a push process managed by a MRP-system where the customer demand doesn't straightly influence the material supplies to the company. The MRP-system creates schedules and forecasts by initiating BOM-structures of the demand derived from the customer side. Furthermore, when bad saldo reporting occurs in the company, extra deliveries is needed to take in action to be able to cope with low or even runned out stocks. Thereby the company focuses much on to get accuracy in the saldo reporting.

On the contrary, all material located in the hub is automatically replenished to Volvo CE through the common IT system with Volvo CE that initiates the replenishment. This happens through a reorder point signs that material is needed at the plate lining process. The information is sent to hub and the hub prepares the material for next possible delivery to Volvo CE. Hence, flows before the hub is controlled by a MRP-system whilst the flow from the hub to Volvo CE is a pull flow. A system keeps track on current stock levels for each material that goes under the automatic replenishment approach. Hence, the saldo within the system doesn't correspond to how much there is currently in stock, due to the automatic control of inventory. The automatic replenishment will be more elaborated within the hub flow section, chapter 6.5.1.

6.4 Inbound logistics - Supplier situation and transportation network

Firstly, if taking a look at the supplier situation, Volvo CE as the main part supplies material from different suppliers from different locations. Today, Volvo CE supplies 53 different articles from 13 different suppliers (See Table 4) for the plate lining process which is located within Sweden, Europe and Asia. When looking at geographical areas, the European suppliers originate from Sweden, Poland, Estonia, Hungary and Germany and the Asian supplier comes from South Korea, see Figure 22 for proportional numbers sourced from different parts of the world. Furthermore, the Swedish suppliers are pointed out in Figure 23.

Thereby different locations influence the lead time in different ways and hence, quantities that the company must supply to cover the accompanying uncertainties. Since the supplier related factors influence the choice whether kitting and continuous supply is more preferable in a certain context this section will be an interrelated part for the three other contextual factors as mentioned in chapter 6.1. Hence this section covers the third contextual factor, namely supplier related factors.

Table 4. *The table consists of all the suppliers concerning the plate lining process together with statistics of the number of articles that derives from each supplier. Furthermore, the table shows how many different stations that each supplier supplies with material*

Supplier	Country	Number of articles	Number of stations
Supplier 1	SE	12	2
Supplier 2	SE	1	1
Supplier 3	EE	7	2
Supplier 4	SE	5	3
Supplier 5	KR	2	2
Supplier 6	SE	1	1
Supplier 7	PL	8	2
Supplier 8	SE	6	2
Supplier 9	SE	1	1
Supplier 10	SE	4	1
Supplier 11	DE	1	1
Supplier 12	SE	3	1
Supplier 13	HU	2	1
13	**6**	**53**	

Figure 22. *The supplier proportion for each supplier area*

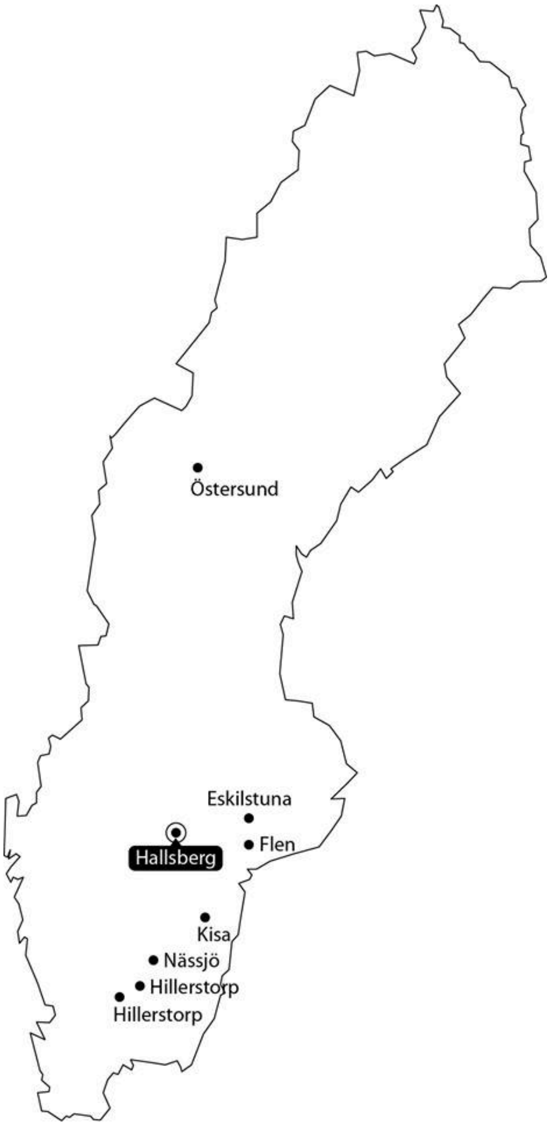

Figure 23. *The geographical locations of the Swedish suppliers*

Furthermore even implications regarding of suppliers ability to quickly serve Volvo with material arises, this since many of the suppliers can be defined as small and thereby these are not willing to keep inventories of finished goods. These small companies mainly start to produce material for Volvo when the order is initiated. Volvo CE uses Volvo Logistics to manage their transportations, this since the huge network that Volvo Logistics possess over. Volvo Logistics by itself uses third part hauliers such as Schenker, DHL etc. to transport goods whilst Volvo Logistics keeps track on administrative duties. The suppliers order one day before departure of the goods to a system called Atlas that is in hands of Volvo Logistics. Thereby transport hauliers will be requested to take care of the transportation of material to Volvo CE in Hallsberg. In this case Volvo Logistics handle contracts with hauliers and administrate the transportation network as whole.

When looking at the European area regarding the transportation network Volvo Logistics uses its extensive network of consolidation centers that allocate material to different locations. Initially the haulier collect material through milk runs along a route to then further cross-dock material to new locations in these consolidation centers or namely hubs. From European suppliers the lead time is from 2 - 19 days, from order to delivery.
Regarding deliveries that comes from South Korea the lead time is significantly longer and are about 78 days, from order to delivery. In relation to the transportation network in Europe the material takes a route with a ship from the supplier in Korea to Gothenburg in Sweden. This has forced the company to buy larger quantities in order to be able to cope with the uncertainty it cause. However, when the goods are received in Gothenburg it stays there for another week due to customs and inspection, before the material is sent by truck to the hub in Hallsberg. The hub called the Hallsbergsterminal will be more elaborated in the section of the hub flow. The other material flows related to the European and Swedish suppliers are delivered to the goods reception area at entry 1 or 2. If the goods are unloaded at the entry 1, a forklift truck transports the goods to entry 2 by driving on the outside of the plant.

6.5 In-plant flows - Layout and type of flows

The in-plant flow section clarifies the layout of the company and the flows that runs through the factory, from the receiving area until Point-of-Use, i.e. the in-plant flows that strength from the goods receiving until the storage of the plate lining process. One can hence distinguish between four flows that typically has been categorized regarding of their characteristics, these are: the hub-flow, internal flow and the two external flows originating directly from the suppliers divided in pallet respectively cardboard flows.

- *Hub-flows*: these flows come from the supplier and goes through the hub. The hub keeps track on the material until Volvo CE replenish the material to the plate lining inventory or Point-of-Use. All hub flows go through entry 2, see Figure 24, and are transported within pallets. Some pallets can consist of cardboard boxes which straightly goes to the Point-of-Use inventory, whilst pallets with only material will be stored in the company or straightly go to Point-of-Use if the need is urgent. In this flow only L and H pallets are in use, consisting of only one collar.
- *Internal flow*: these flows that comes from the internal production of material. This material is produced within the Volvo CE factory in Hallsberg.
- *External flow of material in cardboard boxes*: These cardboard boxes are transported in pallets and come straightly from suppliers. All pallets consisting

of cardboard boxes will go through entry 1, as illustrated in Figure 24. Hence these pallets consist of cardboard boxes that will be handled and stored in in the cardboard box storage within Volvo CE.

- *External flow of material in pallets*: regarding pallets with pure material, these pallets goes into entry 2, see Figure 24. External flows through this entry have different kind of pallets regarding of sizes in length and wideness, and even the height regulated through the number of collars. In this flow L, F and H pallets are in use and can be equipped with 1 to 5 collars.

As one can see in Figure 24 flows can either go through entry 1 or 2. All external flows goes always to the blue marked quadrant in Figure 24. At this stage the material will be divided regarding of if pallets consists of pure material or cardboard boxes. On the contrary, hub-flows comes straightly from the hub and will go through entry 2, as illustrated in Figure 24 as the black marked flow from the hub. Internal flows are not pointed out on this map since it derives from internal processes within the company.

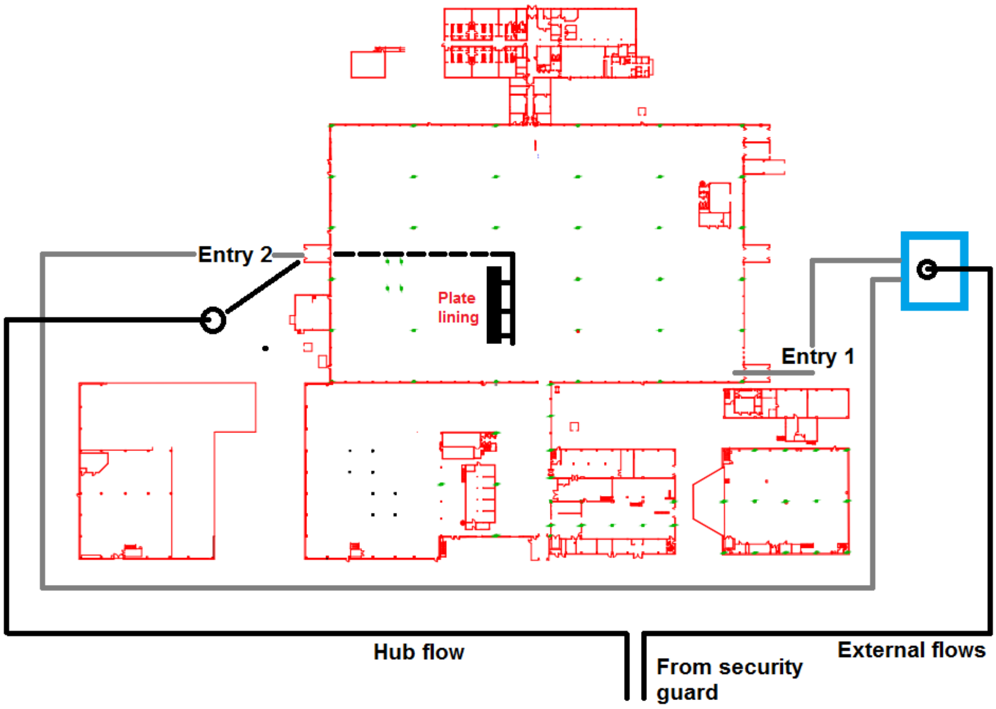

Figure 24. *The four material flows into Volvo CE*

Furthermore, Table 5 illustrates statistics of the numbers of different flows that lead to every station within the plate lining department.

Table 5. *Illustrates proportions of the articles flows that go for each cab type station*

Different flows - statistics		
Flows	**Number of flows**	**Percentage**
Hub	14	21,54
Internal (exclusive cab frameworks)	12	18,46
External Pallet	14	21,54
External Cardboard	25	38,46
Totalt	**65**	100,00

Loader	
Hub	1
Internal (exclusive cab frameworks)	5
External Pallet	11
External Cardboard	4

Dumper	
Hub	11
Internal (exclusive cab frameworks)	6
External Pallet	2
External Cardboard	1

Excavator	
Hub	2
Internal (exclusive cab frameworks)	1
External Pallet	1
External Cardboard	20

Information flows in relation to goods receiving
This information flow section will elaborate the information when the material goes through the different flows within the in-plant part. Regarding the registration of received material within the external flows concerning both cardboard boxes and pallets, the truck driver puts over documents for the goods reception. When the goods reception gets the documents they report the goods as in-plant material ready for consumption. When the outer forklift then further check the goods and find something that doesn't correspond to the delivery note reporting afterwards to the material planner can be conducted. However, when the material get registered in-plant status, indoor-forklifts can take care of the material and put it on a specific location. All the information can be accessed through a computer that every indoor-truck is equipped with.

When the driver of the indoor-truck see that material are available to be picked up, the forklift driver get a message on the screen regarding the assignment. After the pickup of material the forklift driver assign the material on a specific location and register the location in the computer. To add, the whole company uses the same ICT technology to communicate, which enable a common platform to work within. Regarding the information flows that comprise the hub, the same system is used even there and the same procedure of registering material is conducted. In this case the hub will be an included part of the in-plant material supply. Furthermore, the material doesn't need to be registered twice when it reaches Volvo CE.

6.5.1 Hub-flow

The hub-flow characterizes the flows that go through the terminal "Hallsbergs Terminal" before it is supplied to Volvo CE in Hallsberg. Today there are two suppliers that send material to the hub before it arrives at the plate lining process. The suppliers are the Korean company XXXX XXXX, where the transportation until the hub has been elaborated earlier in chapter 6.4 and the supplier XXXX XXXX. The picture below illustrates a conducted value stream map with the hub flow from the supplier to Point-of-Use, see figure 25.

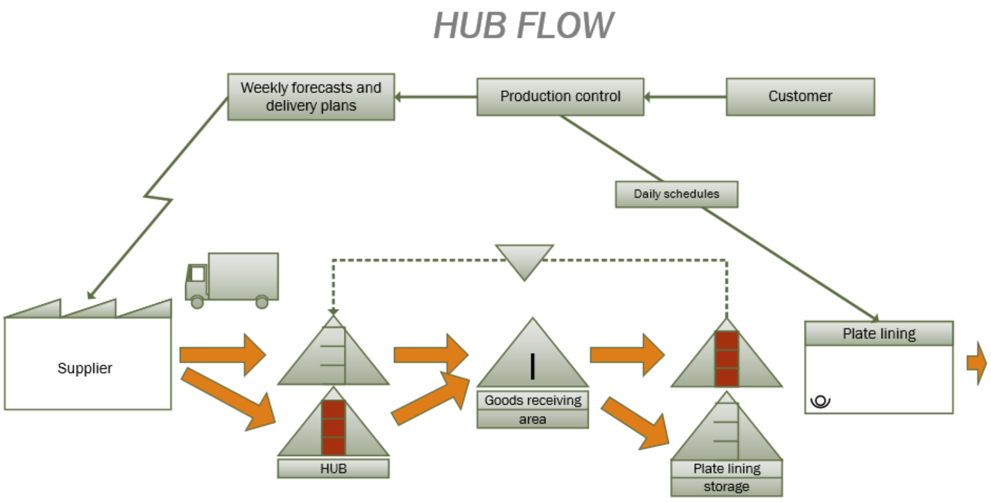

Figure 25. *Value stream map covering the hub flow*

Hallsbergs Terminal
The Hallsbergsterminal is one of the biggest terminals in the Nordic countries and possesses a central position in Sweden. This makes the Hallsbergsterminal strategically important for many actors and has great abilities to connect many locations. The Hallsbergterminal can handle all types of unit loads, and thereby the Hallsbergterminal is a combi terminal. Today, the terminal even possesses great connection with the port of Gothenburg and hence, the terminal can be used for the dry port concept. Furthermore, the Hallsbergsterminal is able to kit, sequence, assemble, re-package, control, transport, store and even administer goods (Hallsbergsterminalen, 2013).

Motivation for outsourcing
The company has started to outsource their inventories to the Hallsbergsterminal due to the lack of space and hence, the Hallsbergsterminal takes care of keeping inventory and materials handling for the whole company. The situation of Volvo CE has been concerned since material was forced to be stored in tents outside of the company, which is not sustainable due to occurring corrosion on the material. The company wanted as well transforms the current high fixed cost to a lower variable cost that gets higher when more material gets outsourced. Today Volvo CE has a possession of 500 pallet slots at Hallsbergsterminal.

Hallsbergsterminal in short
However, when Volvo CE needs material the Hallsbergsterminal prepares the goods and Volvo picks up the material with their own truck and trailer on regular time intervals. The truck goes four times every weekday and departure the following times from the Hallsbergsterminal: 7:30, 10:30, 12:30 and 15:00. The Hallsbergterminal is located about five kilometers away from Volvo CE and the material is ordered from Volvo CE automatically through the information system when the material reaches a certain saldo level. The system functions thereby as a re-order point system.

Receiving of goods and buffer storage

To describe the actions that occurs, the material arrive firstly from the supplier to the hub with a truck from either the Port of Gothenburg (Supplier: XXXX XXXX) or Östersund (Supplier: XXXX XXXX). However, the material that comes through the Port of Gothenburg concerns everything supplied from Korea. The material will then be transported to Volvo Arendal Logistics Center where the material will be handled over to pallets from the container. Regarding the flow that comes from Östersund these goes straightly through the transportation network of Volvo Logistics to the Hallsbergsterminal. When the truck arrives with material to the hub dedicated for the plate lining process, the material will be registered as in-plant status in the information system. As mentioned earlier the procedure to register material is performed in the same way as the material that arrives at Volvo CE. Then after a forklift unload the truck and place it on the ground near beside of the truck. Then the forklift driver takes the material to the assigned arrival area inside of terminal. Thereafter depending on if the material is packaged in pallets or in cardboard boxes, all pallets will be stored in racks whilst cardboard boxes in the supermarket.

Order picking and dispatch Area at the hub

When the goods are initiated from Volvo CE through the scanning or automatic replenishment system, the material will be picked regarding the order list. The forklift driver collects all needed pallets from the racks and picks cardboard boxes from the supermarket storage. Since the hub and Volvo CE uses the same IT-system, the forklift driver gets all the necessary information from Volvo CE and the forklift driver can see all the missions on the screen initiated from the replenishment system. Furthermore, all the picked material will be placed on the dispatch area and before it will be loaded on the truck, the material will be registered and labels on pallets can thereafter be stapled. Then the truck driver arrives and signs all the documents, and thereafter the forklift starts to load the truck with the picked material.

Goods receiving at Volvo CE

When the truck from the terminal arrives it takes the road to the second entry as illustrated in Figure 23. Thereafter the material is unloaded beside the truck and then the truck leaves. All material coming from the hub has a yellow label that indicates that the material is from the hub. If the label has a background with “urgent”, the material has to be quickly delivered to the line. Moreover, the truck that arrives is always nearly empty, just some few pallets every time. This since the route from the hub has only been in charge for some months. To add, stops in the production affects the quantities that the truck carries and can thereby be empty since the transportation follows a fixed time table.

Freight area located next to the inside of the second entry

When the material is unloaded on the receiving area, the forklift transports the material to the receiving area inside of the plant, see Figure 26. At this stage, the material waits for indoor-trucks to place the material in the storage. However, the receiving area inside the plant causes trouble for both people and forklifts. This since the area is assigned for people to walk, but even are in use as a receiving area for goods. In this area both outdoor-forklifts and indoor-forklifts operate at the same time, which makes the handling problematic due to the small area. Furthermore, the area can be seen as risky since people use this as a gate to walk and thereby the risk for accidents increases. To add, some serious accidents has never happen since forklift drivers and people around are aware of the situation, but it has happen smaller accidents several times.

Figure 26. *The goods receiving area inside entry 2*

Furthermore, when the material then has to be picked by the indoor-forklift it must firstly be sorted, this since pallets has to go to different locations in the company. When the forklift finds right pallets, the forklift transport the material to the main storage located next to the plate lining process area. The material will be stored in a dedicated place upwards in the rack or either straightly be presented for the stations, this depending on how urgent the need is. However, material that comes into cardboard boxes will be opened up and will be emptied of material when the forklift driver Point-of-Users over the material in grey plastic boxes at the Point-of-Use stage. Since the risk for cardboard boxes to catch fire near the welding stations.

6.5.2 Internal flow

Internal flows are flows that come from internal processes in the company. These internal processes use to bend plates or weld several articles to one article dedicated for the plate lining process. Today, 12 parts of 65 in total come from internal processes see Figure 27 for internal flows. Many of these articles derive from subassemblies in welding stations that supplies material from external suppliers. These articles will not be covered in this thesis, only the complete main articles that are supplied from these stations will be considered.

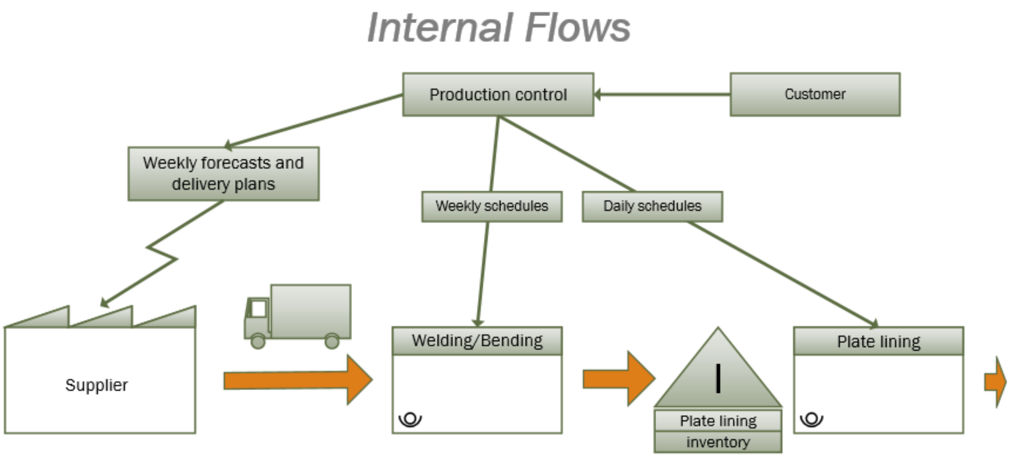

Figure 27. *The material flow map shows the internal flows*

Furthermore, some stations produce articles after weekly schedules except from the cab frameworks that are planned daily. When producing the cab frameworks, which are the main house for the cab, it derives from an internal process that kits a set of articles to then be welded together into a finished cab framework. There are in total 10 different cab frameworks from this process. Material that is produced on a weekly basis can be stored either in a upper rack or straightly be presented at Point-of-Use. On the contrary, some internal processes produce material regarding of the current need at the plate lining process. The material supply to the plate lining process is initiated through a two-bin system that is visually controlled. When one of the packages becomes empty a new package is supplied to the stations. Hence, the process is not controlled by the MRP-system and can be characterized as a pull system. The problem arises when the assigned place for the packaging is empty or when two packaging of goods is at the line at the same time.

However, material that is produced internally comes in high quantities, which give a rise for more inventories at the plate lining stations. The problem arises due to the ability for the internal stations to quickly change the current setup; thereby the long setup time decreases the flexibility to make changeovers in the production. This forces internal production stations to produce in larger batches than is currently needed in the plate lining process.

6.5.3 External flows

This section will describe external flows that do not go through the hub. In this way the material goes straightly from the suppliers to Volvo CE in Hallsberg, but this flow will be distinguished in two flows: external flows in cardboard boxes respectively external flow in pallets. The reason behind this has to do with their characteristics regarding of different approaches to handle material when it arrives at Volvo CE in Hallsberg. Basically, before the material arrives to Volvo CE the procedure for both flows is the same, but then after these flows differs to each other due to where flows enter the company.

Goods receiving area

From the roads the truck enter Volvo CE by passing the security depot and then further to the receiving area where the truck stops under the tent. The receiving area is located about 100 meters from the first entry stated in the map, see Figure 24. The truck driver goes to the goods reception and hand in necessary documents and the goods will be registered. Then an assigned forklift comes to unload the truck of all pallets and places these just behind the truck. The forklift driver check the number of pallets and give the acceptance to the truck to leave when everything correspond to what’s written in the delivery note.

Then after when all the pallets are lifted off on the ground the sorting process is started. The sorting process mainly consists of sorting all the pallets in right stacks and turns the pallets in right position. Then the forklift driver goes to the goods reception to get white pallet flags to stick on each pallet. On each flag there is information about material numbers, locations, properties for the material etc. In this case, these paper flags can drop off from the pallet or easily be damaged, this especially when the weather conditions is bad. However, pallets are under this session moved and turned 2-3 times before the pallet is in the right stack.

The reason for stacking pallets in right stacks is because the load from the truck is going to different locations in the company. From these three stacking groups, two of them concern the plate lining process, which corresponds to these two different flows mentioned in this section, i.e. the pallet flow respectively the cardboard box flow. Pallets will then be transported by forklift to the other side of the company and then in through the second entry. The flow consisting of cardboard boxes that will be transported to the first entry, marked in Figure 24.

Cardboard boxes

When these cardboard boxes loaded in pallets come in through the first entry, it goes through a conveyor. At this stage the forklift must justify the number of pallets that can go through the conveyor (See Figure 28), this since the height of the gap prevent the whole stack to be fed at the same time. But even that pallet has to be fed one by one, so the operator inside the first entry can handle the incoming goods. In each pallet concerning the plate lining process material can be kept in boxes or otherwise outspread in the pallet. If the material is outspread in the pallet, the material has to be repacked in new cardboard boxes. In total there go 25 parts through the first entry that concerns the plate lining process. The flow map of the external cardboard boxes is illustrated in Figure 29.

Figure 28. *Photos from both outside and inside of the plant on the conveyor at entry 1*

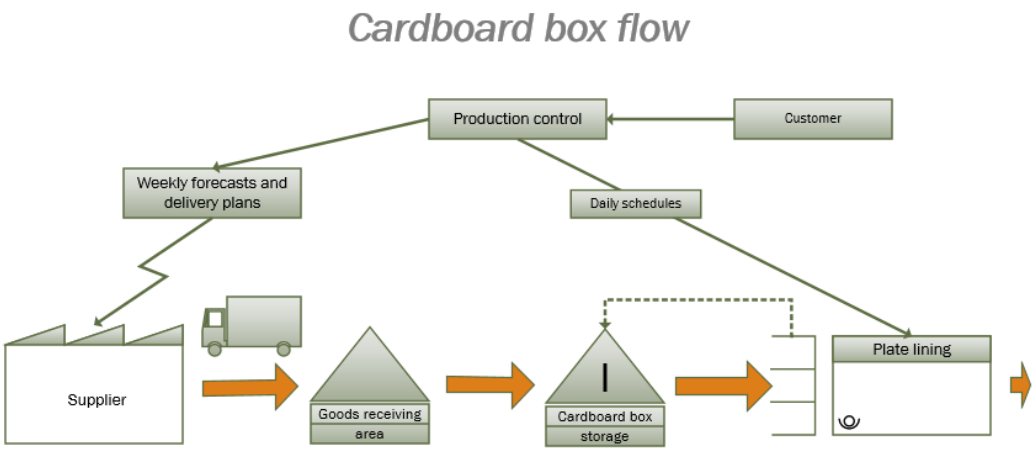

Figure 29. *The flow map illustrating the material that goes through the cardboard flow*

Thereafter all the small cardboard boxes will be stored in a paternoster stock containing of only cardboard boxes, see Figure 30. When an initiation from the plate lining process arrives regarding a need for replenishment, a forklift picks up the material from the paternoster stock and transports these until the inventory of plate lining. Here the forklift driver Point-of-User the material from the cardboard boxes into existing grey plastic boxes at the Point-of-Use inventory, where the material flow then ends. The situation may differ if the material is needed straightly in the plate lining process, hence the material will bypass the storing point in the paternoster stock.

Figure 30. *The paternoster stock where all the cardboard boxes will be stored when these comes straightly from the supplier.*

Pallets

Regarding the pallets, these come from the goods receiving area and in total there are 14 parts that follow this flow. But in relation to the cardboard boxes pallets goes into the second entry instead and thereby the flow differ in that sense. But anyway, pallets from the receiving area on the other side of the company will be transported through the second entry and to the receiving area inside of the plant. This area is the same area as elaborated in the hub flow section, where both people and trucks shares the area. One can hence add that goods from two different flows share the area.

But anyway, the transportation that takes the material from the good receiving area to the receiving area inside of the second entrance is performed by a forklift. This implies that the forklift has to go all the way from the other side to pick goods, and this has to be performed several times since the forklift only can carry a limited amount of pallets. Sometimes the goods even will be placed outside beside of the second entry, which implies more material handling since it will be carried into the receiving area then further. This especially occurs when the receiving area inside of the second entry is full.

Furthermore, in the receiving area inside of the second entry the goods will be rearranged since the goods will go to different locations. Number of vertical lifts that the forklift performs is 2-3 times per pallet. When all the pallets are stacked in right order everything adept the plate lining process will be transported for storage in the upper racks or straightly for presentation in the stage of Point-of-Use. Furthermore, pallets for external flows have no dedicated place, which implies that pallets can be stored on other places in the company depending on the availability of empty places in the main storage.

6.5.4 Vertical lifts from all flows

From all the flows the number of vertical lifts performed by a forklift has been counted in order to be able to calculate the material handling cost for each flow, see Table 6. However, every flow has been narrowed down on a packaging level to really see where the differences in material handling occur.

Table 6. *The number of vertical lifts for each flow*

HUB-FLOWS (Current state)

From	CB	L1 in GB	L1	H1		
Truck and trailer -->	2	2	2	2	CB =	Cardboard Box
Goods receving area (Inside of Entry 2) -->	1	2	2	1	GB =	Grey Box
Upper pallet rack -->	0	26	2	2		
Total:	3	30	6	5		

EXTERNAL PALLET FLOWS (Current state)

From	L1	L1 in GB	L2 in GB	L4	H1
Truck and trailer -->	1	1	1	1	1
Goods receiving area (Tent) -->	5	5	5	4	4
Beside goods receiving area (Tent) -->	1	1	1	1	1
Outside Entry 2 -->	1	1	1	1	1
Goods receving area (Inside of Entry 2) -->	3	3	3	2	1
Upper pallet rack -->	2	26	26	2	2
Total:	13	37	37	11	10

EXTERNAL CARDBOARDBOX FLOW (Current state)

From	CB
Truck and trailer -->	1
Goods receiving area (Tent) -->	2
Conveyor -->	2
Paternoster stock -->	1
	6

Internal Flows (Current state)

From	F2	Wagon	L1	L2	G2	H2	L1 in GB	L2 in GB
Upper pallet rack -->	3	3	3	3	3	3	29	29

6.6 Material storage and Point-of-Use presentation

This section will describe the flows that end up in the upper rack of the storage or goes straightly to the Point-of-Use storage. The upper rack is the buffer storage to the Point-of-Use storage, which will be replenished when the operator order more material.

Thereby, the upper rack storage will be explained first and then lastly the Point-of-Use storage which is the material presented for the operator. Both the upper rack and Point-of-Use inventory is located in the same racking. The dimension of the whole racking is measured to 21.24 meters in length, about 12 meters in height and 1.2 meters wide, see the Point-of-Use storage in the Figure 31 and 32.

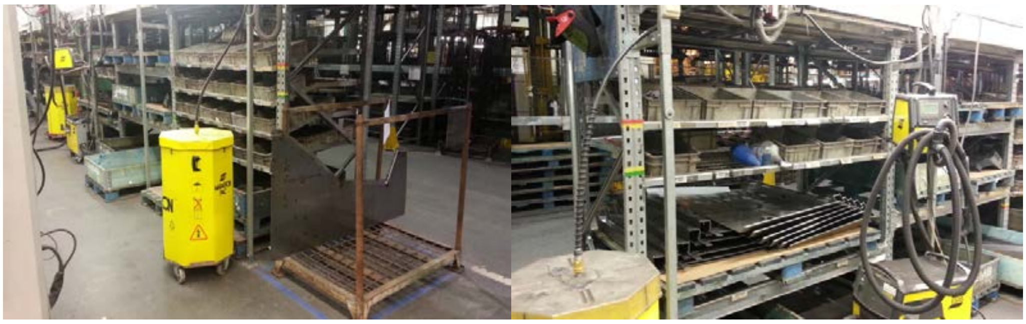

Figure 31. *The Point-of-Use storage for the excavator and dumper stations*

Figure 32. *The Point-of-Use storage (upper part of the racking) from a backside view, whilst the lower part is the backside of the Point-of-Use storage.*

6.6.1 Upper rack storage

When the material comes into the plate lining department, it will mainly go to the upper rack, but can even go straightly to the Point-of-use inventory depending on the demand. However, material in cardboard boxes goes straightly into the Point-of-Use storage and will not be stored in the upper racks. But this section will describe the state of the upper rack storing, and only pallets from external flows and from the hub flow will be stored in the upper rack.

When the forklift arrives with pallets, the stack with pallets will be placed on the ground and the forklift places each pallet in the upper rack one by one. Each pallet that is lifted up in one place will be registered in the system regarding of which location it possess. Some specific part numbers have their dedicated slots in the upper racks, whether the remaining part numbers are placed where there is a free slot. When the forklift lift up pallets, many of the pallets has to be lifted up highly, this implies both unstable and risky lift processes. Today the whole racking reaches nearly up to the roof and it demands carefully handling of heavy pallets up in the racks by the forklift driver. The same situation can be experienced when the forklift has to lift down pallets to replenish the Point-of-Use inventory.

Regarding the material stored upwards in the racks, it is mostly material dedicated for the plate lining process. But even material for other departments is stored up in the rack, which can force the forklift driver to choose other locations in the company to store material intended for the plate lining process. However, the material storage in total keeps lot of inventory and disturbs the sight over the plate lining process area. However, all the stations within the plate lining process use only continuous supply as material feeding principle.

6.6.2 Point-of-use storage

The Point-of-use storage presents the material for the five different stations, and every station hold its own section of material. Since “dumpers” and “loaders” uses two stations each, decentralized storages with identical material is presented for these cab types several times in the Point-of-Use inventory. The middle station that produces for the excavator has only material presented once in the Point-of-Use storage. This section will explain the Point-of-Use storage regarding of the three major cab types, i.e. “excavator”, “dumper” and “loaders”.

Basically, all the material stored in the Point-of-Use inventory is stored in pallets and grey plastic boxes, except from sequenced material delivered from internal processes. Material that comes through internal flows comes through internal conveyors (welded cab frameworks) and sequenced wagons consisting of plates, see Figure 33.

Figure 33. *The wagon consisting of plates*

In this case, large and medium sized material is kept in pallets and wagons, whilst smaller parts are mostly presented in grey plastic boxes, see Figure 34. Typically, larger articles are positioned at floor or at next level in the racking, whilst smaller and medium sized parts the level above the larger.

Figure 34. *Grey boxes containing small- and medium sized parts at the excavator station*

Regarding the middle station that produces for the excavator, the operator picks small parts from the Point-of-Use inventory and kits them on a rolling table, this in order to get the material closer to the assembly station, see Figure 35. The distance from the Point-of-Use inventory to the station is about 2,5 meters away, if comparing to the other stations which is located about 1,5 meters away. This indicates clearly that the operator prefers closer material presentation for the station. However, the operator claims that the table acts as a quality assurance since all the material on the table has to be consumed during the welding operation. Hence, the table assures that the operator does not forget material to weld or picking the wrong parts.

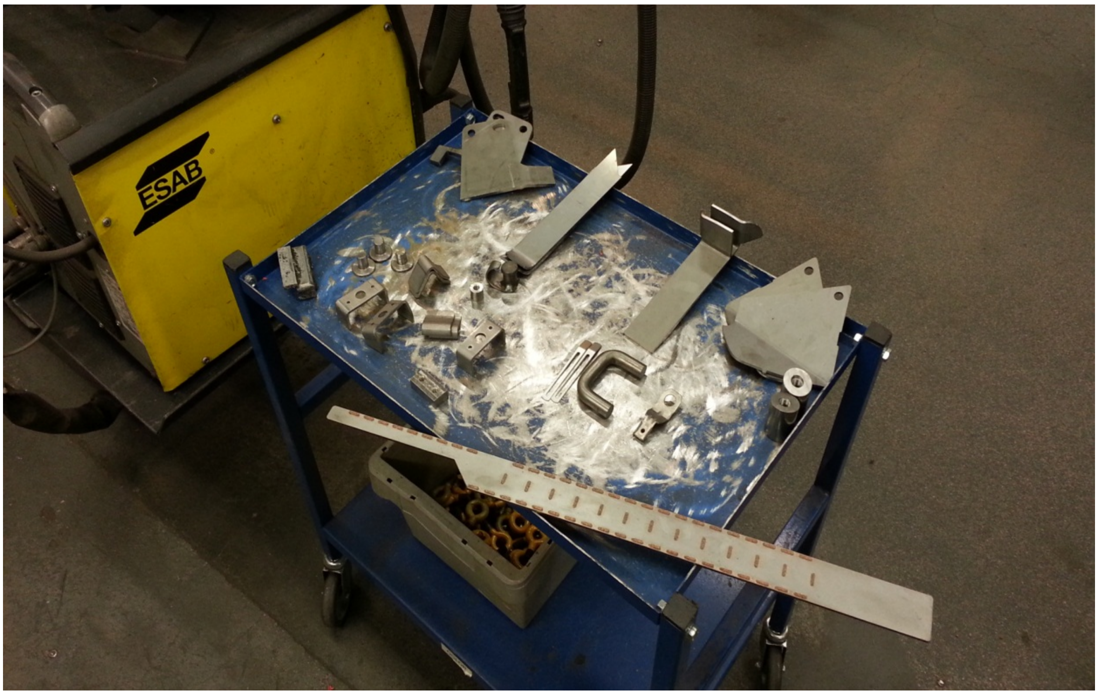

Figure 35. *The kitting table belonging to the excavator station*

When looking at the Point-of-Use inventory considering all the sections, one can clearly conclude that the storage is messy. Many of the pallets, except from the containing material, contains crap, tools, fixtures, helmets, clothes etc., but even other material than the dedicated material. Furthermore, lot of empty grey plastic boxes are still remaining in the Point-of-Use inventory and takes unnecessary space. Many times the operator look through many of the empty boxes for material and throw these around in the storage place, which makes it even more messy, see Figure 36 and 37. Furthermore, obsolete material is still remaining in the Point-of-Use inventory and lot of welding equipment that is in the way for the operator.

Figure 36. *Examples of the current parts presentation*

Figure 37. *Illustrating the messy conditions at Point-of-Use.*

When looking into the pallets, these are not even full and they consist of material that is not needed at the moment. The same can be said about the stock in the Point-of-Use, where lot of the material is not needed at the moment and thereby unnecessary storing is a fact. Many of the pallets that come to the plate lining process from suppliers are not even full and hence lot of air is transported. Lot of the material are stored at several places which takes up a lot of space since many of the articles could easily be placed in the middle. By placing the material in the middle of two stations, both of the stations can be supplied with the same pallet. Furthermore, when the pallet or grey box of one station run out of material, the operator walks to the section of the second station to fetch material. This implies that the operator first has to go to his own section to seek for material and then further go to the second section if the pallet or the grey box is empty. This implication occurs only in stations for “dumpers” and “loaders”, since the material appears more than one time. It can be obvious that the material tied up in the inventory is not needed, just the parts that are needed and safety stocks to be able to cope with the risks.

However, great illustrations of the problematic regarding the distance to fetch material can be seen in the “loader” station, where operators create their own bins to put material into, see Figure 38. This occurs often when same material must be carried several times from the Point-of-Use inventory. But this phenomenon is more obvious in the middle station as mentioned earlier. In this case the material storage is replenished with material, but then handled by the operator once more, before it is fetched again.

Figure 38. *The operators at the loader station have made their own bin to reduce the walking distance*

One more thing to add is when the operator fetches several parts of the same type, the operator usually places the rest of the parts near beside on a table or on the shelf on the Point-of-Use inventory. Sometimes the material can be forgotten on the shelf or on the table, which increases the loss of material. Regarding forgotten material quality problems occurs due to parts that the operator has forgotten to weld. But quality problems in general appear when the operator weld wrong parts on the cab framework. When talking with the welding operators at the plate lining process no quality problems in association with MSS occurs often.

Regarding return packaging that occurs when pallets becomes empty, the forklift comes to take the empty pallet when new material has to be replenished at the racking. When the forklift then has released the empty pallet from the racking, it goes either to the goods receiving area inside of the plant (entry 2) or straightly to the end destination of the Volvo CE plant, i.e. the trailer outside of entry 2. All the empty pallets at the goods receiving area inside of the plant, will then further be loaded on the trailer outside of the entry. This causes problems since the space limitations on the goods receiving area inside of the plant are used for even incoming material as well a walking way for people. Furthermore, when the trailer becomes filled with pallets of different sizes, a truck drives the pallets to an packaging pool managed by XXXX some kilometers away. Pallets with collars loaded into the trailer are not degraded which derives in lot of air transported and the fill rate is thereby low. Furthermore other packaging types appearing in the storage of the plate lining process such as grey plastic boxes and wagons from internal process are handled differently. Grey boxes are still remaining into the Point-of-Use inventory since these are only filled with material from cardboard boxes. Regarding packaging derived from internal flows will be carried back automatically when a new wagon with new material arrives to the Point-of-Use inventory. To summarize the return packaging findings concerning the internal flow is still prevail in the company, whilst pallets from external and the hub flow will be sent back to the packaging pool. All the carbordboxes from the cardboard box flow and the hub flow will not be used again.

6.6.3 Ergonomical conditions - with focus on the operator

When looking at the more ergonomical conflicts that occurs in the plate lining process when the operator fetch material, many times the heavy parts can be seen as the most critical in this sense. The problem occurs mainly when the operator fetch heavy parts and have to lift it, this complicates since operators experience problems with their arms and backs. The fact is that operators mainly have problems with their back, this since heavier parts are more located on the ground. There is no direct supporting lift accessory that helps the operator to lift the heavy parts. Thereby the operator must firstly be placed on a narrow position to grab the part with both hands, to then position the part again before the real lift can be performed.

When the operator picks medium or small size articles from pallets, these pallets are located between two shelf levels. This makes it harder to get out the part from the gap, see Figure 39.

Figure 39. *Highlighting the gap between the parts rack and the pallets*

Furthermore, when the pallet starts to become emptier, the operator must strengthen the arm to grab the part from the furthest. In this case the operator can by accident hit his head in one of the pallet corners over. This can be solved temporarily by letting a forklift push the pallet from backward position into the plate lining process direction, see Figure 40. This problem is more exhausting when the pallet is located on a low position.

Figure 40. *At some times the pallets must be pushed further to be able to fetch material easily*

Moreover, welding equipment stands in the way, which complicates the procedure to fetch parts from the Point-of-Use inventory. The operators have given some suggestions regarding of how to solve these problems. But anyway, as mentioned in the previous section the material must be located much closer to the welding station in some cases. However, the layout needs to be rearranged since it causes narrowness to fetch material within the welding area. Welding equipment and computers stands in the way for the operators when walking to the Point-of-Use storage to fetch material.

7 ANALYSIS

This section continues the first step of the framework, see section 5.2, and will cover the analysis of the current state section regarding of the context, inbound flows, in-plant flows and the state at the plate lining inventory with the operator in focus. Furthermore, objectives will be set in order to support the framework of the choice of material feeding principles for each welding station. These objectives are derived in accordance with the management of Volvo CE and strategic considerations. After the choice of material feeding principle the rest of the system will be proposed a future configuration. In the end, a final future state proposal for Volvo CE regarding the plate lining process will be presented.

7.1 Analysis of the current state

The analysis of the current state section will comprise of the current configuration and the surrounding context that affects the MSS. Thereby the system will be analyzed regarding of the contexts, inbound flows, in-plant flows and the state at the plate lining inventory with the operator in focus. The three last mentioned components of this section correspond to the configuration proposed in the current state section. Furthermore, the analysis of the current state is still in the analysis part (stage 1) of the existing system in the framework.

7.1.1 The context of the material supply system

Since the context affects the current MSS, production related factors, product and part related factors and finally supplier related factors will be analyzed.

To start with the *production related factors* these comprises the different variants and the number of articles that appears within the context. The more variants the more articles will be required at the plate lining area which implies different consumption rates for variable articles. Since kitting is more preferable for articles that possess variable status, it is relevant to look if the different welding stations produce single or several product types. When the data was narrowed down it resulted in three different part sets for loaders, two for excavators and one for the dumper. As the result shows the loader stations has more part numbers than the two other models. The excavator station in the middle possesses over two part sets where one of the models is barely produced and hence these parts possess a slower consumption rate. Thereby parts can be categorized as dedicated for all variants and variable between the different variants.

Furthermore, regarding *product and part related factors* these comprise the characteristics of the articles concerned at the plate lining process. When looking at the sizes, values and weights of articles one can clearly state that articles that gets larger becomes heavier since the material for the welded parts are metal. Hence weight can be seen as a factor that affects the choice of material feeding principle, as stated in chapter 3.2.5.

As seen in Table 2, the *supplier related factors* covers the geographical locations of the suppliers and how the parts intended for one station is distributed among the suppliers. The supplier related factors are closely interrelated to how the parts are packaged at the suppliers. As stated in section 3.2.5, if kitting will be used then it can be viable to examine if kitting can be exercised already at the supplier stage. This option is only practicable if the major parts of the parts are supplied by the same supplier or it can effectively be arranged between some suppliers, see chapter 3.2.5 within section supplier related factors. Following from Appendix C, it is observed that all three stations have several parts that are supplied from the same supplier. For example, concerning the dumper 79% of the parts are supplied from "XXXX XXXX XXXX" and for the loader station "XXXX XXXX XXXX" supplies 38% of the parts. When evaluating the selection of material feeding principle and design the MSS, this information is relevant to consider.

7.1.1 Inbound flows

Regarding of the inbound flow that comprises from the supplier to the goods receivement of Volvo CE in Hallsberg or the Hallsbergs Terminal, the whole network is arranged by Volvo Logistics and operated by external hauliers. Since Volvo CE purchases 56 articles from 13 suppliers from 6 different countries, different lead times will affect the material supply to Volvo CE. This occurs when suppliers are located far away from the plant, which implies that the company must purchase larger quantities. The situation for the Korean supplier XXXXXXXX differs from the other suppliers, since the supplier is located in Asia and the material has to be transported by boat. The transportation lead time is over 40 days excluded from the time for administrative duties, which implies that Volvo CE must cover up with larger inventories. To add, one of the parts supplied from XXXX XXXX is valued as the most expensive article among all the articles purchased to the plate lining process. This implies that Volvo CE must cover up with expensive articles since the lead time due to the transportation mode results in larger quantities. The rest of the European suppliers have relatively short lead times and Volvo CE does not need to cover up too much, whilst the Swedish suppliers only need one day of shipping. The problem that arises is that Volvo CE purchases too large quantities but this derives in better prices for only the parts. Instead, the company needs to pay for activities related to store the material. On the contrary, the problem lies more in the ability for suppliers to produce and stock finished goods.

7.1.2 In-plant flows

The in-plant flows section will comprise an analysis regarding the four different flows categorized in the current state section, i.e. the hub flow, the external cardboard box flow, the external pallet flow and finally the internal flows derived from internal production.

External flows

When looking at these flows that goes along the pathway of cardboard boxes and pallets, one can clearly state that the material handling along the way creates unnecessary decoupling between the Point-of-Use and the goods receiving point. All the flows that comes straight from the suppliers arrives first at the goods receiving area, where the unloading and sorting operation takes up too much forklift work. When the forklift unloads the truck and trailer and then sorts all the pallets in different stacks regarding of locations, it requires 4 vertical lifts for the pallet flow and 2 vertical lifts for the cardboard box flow. This results in two different stacks with pallets that will go the pallet flow path respectively pallets that follow the cardboard box flow path.

This can for instance be illustrated when the cardboard box flow has to be handled again before the pallet is fed into the conveyor at entry 1. Furthermore, when the handling process inside of entry 1 is performed another storing process is conducted, into the paternoster stock. When the material is needed at the Point-of-Use a forklift pick up the right material from the paternoster stock and drives it to the Point-of-Use storage. When the forklift arrives with the material the forklift driver must take the grey plastic box from the rack and pour over material from the cardboard box into the grey plastic box. Regarding the flow that follows that the path of pallets the forklift takes the material from the goods receiving area and drives it about 20 meters away to another storage area where the goods can be located for many hours. The goods have then to be transported to the other side of the company to entry 2. This process has to be

performed several times which adds even more unnecessary material handling along the way. The material will then be located outside of entry 2 before it is transported inside of the entry 2 to the goods receiving area. The material can then be standing at the narrow goods receiving area for many hours before a forklift is assigned to take care of the goods. When an assigned forklift comes to load the upper rack or the Point-of-Use storage at the plate lining process it must firstly sort the material once again to be able to take right pallets. In this way all this handling operations requires lot of unnecessary material handling from forklifts and it is not strange that both indoor and outdoor forklift causes lot of traffic inside of the company.
What can be concluded from these two external flows is that the man-hours of the forklifts may be reduced and which also causes trouble inside the plant for both people and the material handling in general. By looking over how many times the material must be handled along the way before the material can be presented to the operator, one can clearly state that lot of the unnecessary material handling can be eliminated. All the interruptions through the decoupling along the flow create unnecessary storing points and the company needs cover up with more inventory than what is needed, which goes align with the theory in chapter 3.7.

The hub flow
Regarding the hub flow the material must first go through the Hallsbergs Terminal before the goods is sent to Volvo CE. This solution has been in use since the beginning of 2013 and one can clearly state that the material handling within Volvo CE has been reduced, see table 5 for differences. Instead the material handling can be performed at the terminal instead of being processed through the complex system of Volvo CE. Through this solution Volvo CE has been able to change the current high fixed cost to a lower variable cost since the terminal only charges Volvo CE for each pallet that is handled and send to the plant. As a result, Volvo CE has been able to reduce the stock on hand in the factory. When the truck arrives at Volvo CE the material is transported to the goods receiving area inside of entry 2. One problem that occurs is that the material can be standing at the goods receiving area for a long time. Then the forklift comes to pick up the material and transport it to either the upper rack or the Point-of-Use inventory.

When pallets from the terminal is transported to Volvo CE and then lifted up in the upper rack, the function of the terminal can be seen as not fully utilized. This since these pallets could still be stored at the terminal instead, but in the case of Volvo CE an additional material handling is required when the pallet must be lifted down again. In this case Volvo CE replenishes too much material from the terminal what’s actually needed in the plate lining process. Furthermore, pallets classified as urgent can be lifted up in the upper rack and hence this can be seen as strange since these pallets should straightly be presented in the Point-of-Use inventory. Regarding the cardboard boxes, the same procedure is performed as in the cardboard box flow when the material has to be poured over to grey plastic boxes. This additional handling can thereby be seen as waste.

Internal flows
Regarding the internal flows that derive from internal processes within the company, too large batches are replenished from these processes. Many times material that is presented at the line derived from internal processes can cover up the production by several weeks and for the worst case several months, for instance the big plate for the loader model L350 that is barely consumed. The reason is the inability for internal

processes to produce smaller batches due to the setup time. Some articles are produced after weekly schedules set by the material planning department and some articles are produced after kanban. However, the kanban approach seems to not work out correctly since the assigned place for the wagon consisting of material can be empty and operators need to shout out when material is needed. Sometimes there is two wagons of material instead of one, which means that the internal production probably produces more than needed and hence doesn't follow any replenishment signal.

7.1.3 Inventory at the plate lining process and operator in focus

When examining the inventory stage of the plate lining process the inventory can be divided in two different sections as abbreviated in the current state section, upper rack respectively the Point-of-Use storage. The upper rack consists of mainly heavy pallets that the forklift driver must lift up, which in a safety aspect is dangerous if something happen. Furthermore, all the material in the upper part of the rack indicates that the flow from the supplier until the Point-of-Use seems to be not greatly connected and hence decoupled several times, according to the theory within chapter 3.8. However, the material that comes into the company that concerns the external flows of pallets is not always stored in the upper rack of the plate lining process, but in some other place. This since these flows has no dedicated place in the racks. However, this causes problems since the forklift has to go and get these from another racking and hence the visual control of material is not optimal. Thereby, material can be spread out all over the welding department of Volvo CE, which decreases the visual control, but the situation prevails different for material coming through the terminal. This since all the pallets coming through the terminal has a dedicated place in the racking system. To add in this context, pallets from other departments within Volvo CE can be stored in the plate lining inventory which causes a complex situation for the whole welding department when pallets are outspread all over the places.

Furthermore when looking at the connection between the upper rack and the Point-of-Use inventory, the upper part acts as a buffer zone for the Point-of-Use inventory. When one pallet or grey plastic box becomes short of material the assigned forklift must lift down the pallet and refill the Point-of-Use inventory. When the forklifts change pallets from the racking, two vertical lifts in total are conducted. But the situation is different when grey plastic boxes must be filled up. Thereby, the assigned forklift driver must every time lift down the pallet and take material from it and then lift the pallet up again to the upper part of the rack. Hence several of the pallets dedicated to be transferred over to grey plastic boxes will be less than full. On average every pallet that will fill up grey plastic boxes will be lifted up and down 26 times, which causes lot of unnecessary material handling. Furthermore, in many cases the material is presented twice for both the loader and dumper station. This causes more inventories since the material has to be presented twice, even though the material can be presented once. When talking with operators from the plate lining process regarding the twice presented material they claims that the material can be presented once without any doubts of affecting performance concerning fetching of parts. Thereby, it still prevail questions about why material is presented twice when it easily could be presented once. One logical answer could be closer material fetching. When the material runs out for one station, it occurs that the operator walks to another station to fetch material. In this case, material is not available for the operator and hence unnecessary walking from the other side of the second station must be conducted. When talking with operators regarding this problem the replenishment approach is not robust at all. When the operator chooses to replenish material to the Point-of-Use inventory there is no confirmation from the computer if the material order is complete and gets transferred to a forklift driver. Thereby the operator must tell a forklift driver to lift down material from the upper part of the racking. This system to replenish material must be more robust and the goal for Volvo CE regarding the plate lining process is that the operator should not replenish the material. To add, in some cases a try out regarding automatic replenishments for some material at the plate lining process is conducted.

Regarding the distances when the operator fetches parts from the Point-of-Use inventory, the most attention comes from the middle station which produces excavators. The operator fetches parts from the Point-of-Use inventory and places these on the rolling kitting table. The reason for why the middle station uses a rolling kitting table is due to the longer distance between the Point-of-Use inventory and the welding station. Furthermore, when talking with the operator regarding of the more functional aspects of the kitting table, operators from the middle station claims that the kitting table acts as quality assurance regarding of fetching the right parts and not forgetting parts. However, as pointed out in the theory section the kitting process should be performed by the operator since it enable continuous improvement and higher quality of the kitting process. This since the operator is aware of the problems that occur if the kit is not complete at all. Furthermore, this problem even arises in the loader and dumper stations where the operator fetches several parts and places these on a closer area. This implies that some material should be presented closer to the operator. However, this derives in other problems when the operator forget to use these parts, this since many parts are outspread over the working areas. This can further derive in losses of material. Furthermore, all the obsolete material located in the Point-of-Use inventory takes up unnecessary space as well material intended for other internal process than the plate lining process. Moreover, the grey boxes and pallets presented in the Point-of-Use have often a low fill rate. This indicates that many of the pallets or plastic boxes take up lot of space in the Point-of-Use inventory and hence it should be able to present the material in smaller packaging.

Regarding the ergonomically conditions when the operator fetch material from the Point-of-Use storage the operator has no supporting tools to grab the parts. This relates to the heavier parts located on the lowest level and it is mostly very narrow for the operator to move within the limited area. A greater example can be illustrated at the excavator station where the larger heavier parts are presented in wagons, which make it easier to grab the large plate. This since the plates is presented in a vertical position and hence the operators don’t need to rotate the part. Regarding the lighter parts these are either presented in pallets or grey plastic boxes. When looking at the lighter parts presented in pallets these can be pretty hard to fetch due to the narrow gap between the racking and the pallet. Thereby the operator must carefully bring out the part between the gaps. Furthermore, when pallets consists of many small parts the pallet has to be pushed backwards of the racking by a forklift in order to be able to fetch parts from the part of the pallet. However, when looking at the grey plastic boxes the ergonomic is easier for the operator when fetching parts, but the situation is different for the total weight of some grey plastic boxes. The weight exceed the recommended weight for the boxes, the maximum weight of these boxes is twelve kilograms. Many of these grey boxes consist of more parts than the restricted limit, which makes the process to take off the old box and load a new box with material more unstable due to the heavy weight. Furthermore, when the flows doesn’t works properly it result in unnecessary storing within the plate lining process area and hence derives in further problems for the operator, such as bad working conditions due to the narrow area and not steady place due to lack of space, as elaborated within the current state section. Thereby these recommended restrictions should be considered in a future configuration of the future state.

Concluding analysis

To conclude the analysis in a whole view perspective one can clearly state the material handling along the way to serve the plate lining process can be reduced. Many times the material will be handled along the way from the goods receiving area until Point-of-Use which causes the need for unnecessary stocking at the storage within Volvo CE. Furthermore all the material can either enter Volvo CE through entry one or two which causes un-consolidated flows to the Point-of-Use storage. Firstly, the material within external flows must be handled on the other side of the company, which then will be transported by a forklift to the main side entry. This implies that material is not sorted before it arrives to Volvo CE, which even could be straightly transported to the right side if the material were sorted at a previous stage in the chain. However, the hub can show a better example where less material handling is needed, this since the material comes straightly to the right side and can hence be transported straightly to the goods receiving area within the company. As the statistics illustrates (see Table 5) regarding the hub flow, it is obvious that material handling along this flow takes up less resource due to less need for handling. If Volvo CE from the beginning ordered sorted pallets and these straightly goes to the right destination, probably the need for material handling and inventory would be less. If looking at the statistics through the cardboard box flow, the material handling along the way seems to be low. But, what that statistics illustrates is the number of vertical lifts performed by a forklift; the statistics does not unravel material handling of other mediums. Thereby it is vital to consider the material handling that is performed by other mediums. To conclude cardboard boxes needs less resources by forklifts, but requires resources by a dedicated station to stock cardboard boxes.

Furthermore, resources that Volvo CE already possesses over should be considered when the new MSS is designed. At the same stage of this thesis Volvo CE has started to use tugger trains (see Figure 41) for some certain stations and plans to increase the use continuously. The problem lays more in the area at the goods receiving area at entry two inside of the company that has been described as narrow for material handling. However, Volvo CE plans to build a roof outside of entry two to enable vehicles such as tugger trains to operate outside of entry two. This will further derive in possibilities to straightly catch tugger train wagons from the truck by a forklift regardless of weather conditions. Thereby, this project should analyze the current resources as well new resources that can be adapted to the context of Volvo CE.

Figure 41. *The tugger train that Volvo CE has started to use*

7.2 Objectives

In order to improve the existing MSS from the suppliers to the point-of- use, it is vital to identify how the future state should operate. In the literature study under section 3.2.6 eight performance areas within both assembly and materials supply were presented in relation to the selection of material feeding principle. As pointed out in the framework (chapter 5.3) for the design process (see section 4) it is necessary to set priorities between the different performance areas after the initial analysis of the existing system. The priorities should also reflect the future strategic considerations with increasing production volumes and part variants. After discussions with Volvo CE it was specified that the objective of the future MSS should reduce the required space and inventory levels of parts around the plate lining workstations and improve the ergonomics for the operators. Moreover, Volvo also has a general goal to reduce the number of forklifts hours by 50%, design a safe environment and that no wood pallets should be used at the Point-of-Use. Furthermore, the management stated that the operator should be released from the responsibility of replenishing material to the Point-of-Use inventory.

Space requirements

Following from the description of the current state there are two different storage types located in a rack presented at the workstations (see Figure 30 and 31). The lower part of the rack functions as a Point-of-Use storage where the operators fetches parts to weld on to the cab framework, and the upper part is a buffer to replenish the Point-of-Use storage. The total height of the upper rack reaches more than 10 meters in height and Volvo CE's goal is to relocate the buffer to an appropriate location, which consequently affects the design of the material feeding system.

The area dedicated for placing Point-of-Use racks and parts presentation are limited around the welding stations. When the number of part variants is expected to increase, it will put new requirements for how to arrange the material for the operator efficiently. The available space for each welding station is illustrated in Figure 18 and the suggested design should not exceed the measurements of the existing rack.

Ergonomics

Several ergonomic issues have been identified that deteriorates the operators' work environment. As described in the analysis for the current state, there are several heavy and cumbersome parts that are presented in an inappropriate manner for the operator which has caused body injuries in different forms. Therefore, Volvo CE has pronounced that the future design of the Point-of-Use racks needs to support the ergonomic situation for the operators and the golden zone principle should be considered, as stated within the VPS section in chapter 4.2.2.

7.3 Preliminary configuration of the MSS

In the third step of the framework a preliminary configuration of the MSS will be generated for Volvo CE in Hallsberg. The suggestion will be based on the required objectives set by the management and the analysis of the current system, but also the interrelation with the MSS context. Furthermore, it is necessary to focus on the efficiency of the total MSS from the suppliers to the Point-of-Use at the plate lining operation to reduce the risks for sub optimizations. Therefore, the suggested MSS will also be evaluated from a landed cost perspective. As been stated, the configuration of a MSS consists of six different design areas; material feeding principle, inventory and transportation and material handling, packaging and planning and control. The framework suggests that a material feeding principle should be proposed foremost, followed by designing the remaining parts of the configuration. It should also be noted that an iterative process have been undertaken in order to generate the proposal, however, solely the final result is presented in the report.

7.3.1 Material feeding principle choice

After the analysis of the current state of Volvo CE, the management has chosen to focus on the two objective areas: reduced space requirements around the plate lining stations and improved ergonomics for the operators. If the selection of material feeding principle only considers the set objectives, it can be realized from section 3.2.6 that kitting may be preferable for all three plate lining stations. According to the theory the space requirements at the assembly stations can be reduced by kitting since the inventories are moved upstream compared to continuous supply. Similarly, the ergonomics can be improved through kitting since space-efficient parts presentation can enable parts being presented closer to the operator.

However, in the plate lining process the three different welding stations are dedicated specifically for the loader, the excavator and the dumper. Since the three models differs with respect to the parts to be welded on to the cab frameworks and has different contextual factors that was outlined in 6.1, the selection of material feeding principle will be further analyzed individually for the three stations. The analysis follows section 5.4 that describes the procedure for selecting a material feeding principle.

Loader station

The first approach in the analysis is to study the production volumes and the number of product models the assembly station is producing annually, followed from section 5.4 and step 1. At the station there are 3 variants of part combinations that are to be welded on to the loader cab framework. All loader models use nearly the same part combinations with a few exceptions. The L250 and L350 require different types of floor plates in comparison with the models L60 - L120, and the L350 needs another three parts to be welded on. These three additional components are smaller in size and can be fitted into gray boxes. Since all models from L60 - L350 can be processed in any of the two welding stations the total volume of welded cab frameworks for one station equals the sum of the individual number of cab frameworks, resulting in a total annual volume at XXXX cab frameworks representing a proportion of 46% of the current production volume. Following from the definition in this report, 3 variants of part combinations is considered as low variation and that XXXX welded cab frameworks is considered to be a high production volume for the Volvo CE plant. By applying the matrix displayed in Figure 16, to determine the material feeding principle, it can be seen that initially continuous supply is preferable for the loader station as illustrated in Figure 42. Regarding of the local conditions for the loader station within the context three models has been seen as variation in some degree. Hence, the loader reaches the limit for combination of kitting/ continuous supply, which implies that kitting can be used to some extent.

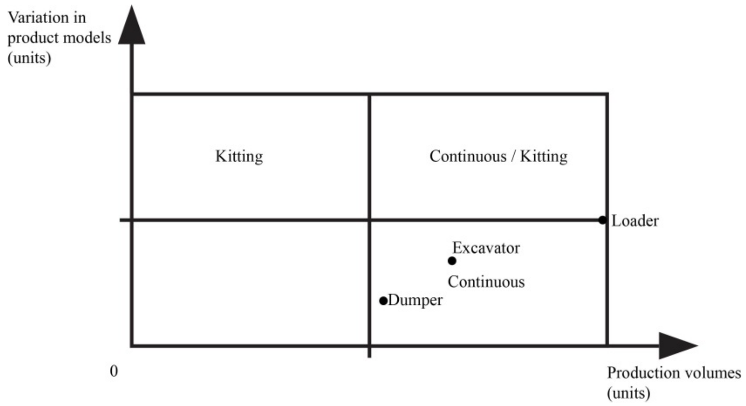

Figure 42. *Local conditions on the initial selection of material feeding principle*

In the next step in the analysis (section 5.4 and step 2) it is necessary to investigate whether a continuous supply design can attain the set objectives, especially since the theory suggests that kitting is preferable, by considering the parts and product context and the current configuration. The total amount of loader parts are 21 different part numbers including both externally purchased and internally processed parts. The measurements and sizes differs greatly between the parts ranging from the smallest weld nut with a weight of 0.01kg up to the floor plate that weighs 14,9 kg with a length of 1,3 meters.

In the current material feeding configuration, continuous supply is used and the bigger parts are mainly presented in standard euro pallets in forms of L1, F1 or H1 and smaller parts in grey boxes. The Point-of-Use racks intended for the two loader stations measures a total length of 9,25m, width of 1,00m and height 2,09m. Through the analysis of the current state and interviews with plate lining operators and truck drivers, relatively high volumes of inventory in the Point-of-Use storage have been observed. For example, there are standard L-pallets containing handles with a quantity of 100 parts that corresponds a run out time of about 4 days when full production rate is assumed. Equivalently, there are grey boxes that are replenished by the truck driver containing parts that can be used for 6-7 days. There are two main reasons for keeping big unit loads in the Point-of-Use racks. Firstly, by purchasing higher quantities per order from the suppliers the unit price per part can be lowered. Secondly, it is cheaper to produce the internal parts in bigger batches which lower the costs related to the setup times for the machines. However, when examining the measurements of the parts the main proportion can also be fitted into smaller types of packages such as blue boxes, i.e. possibilities for down-sizing. This is especially suitable for the smaller parts that are packed in grey boxes. It has also been recognized that in some cases there is only a single grey box presented in the Point-of-Use racks and hereby the full depth of the racks is not utilized. Therefore, one suggestion is to re-pack all the components that is currently presented in grey boxes into small sized boxes and use a replenishment system with several blue boxes in one line. The result is that the same amount can be stored in the component racks but that utilizes less space.

From a supplier network perspective, it can be seen that 6 parts are supplied from XXXX in Sollentuna. All of these parts are “handles” and stored in EU-pallets in the Point-of-Use rack. Since 1 of each handle is needed to be welded on for any of the loaders, 6 pallets are presented on the left side of welding station and 6 on the right side. The storage of the “handle” pallets occupies a large volume in the Point-of-Use racks and it is notable that the handles in the pallets on the right side, is moved by the operators themselves to a more central position to reduce the walking times as explained in 6.6.2. The quantity of handles in each pallet is between 75-120 items corresponding to a run out time to about 2 days. In agreement with the welding operators, it would be more beneficial to consolidate the two pallets with the same part numbers into one pallet regarding the space utilization and then place the pallet in a central position. By supplying both welding stations from solely one rack position will increase the fetching times and walking distances slightly. But this will not affect the total cycle time substantially since the operators have time to prepare all parts during the inspection procedure, after all parts have been welded on to the cab framework. To further reduce the space occupation of the six pallets, benefits can be achieved through presenting the handles in a smaller rack where each handle hangs in hooks instead of being presented by the consolidated pallet. However, this solution can be seen as beneficial since this firstly reduces the inventory at the Point-of-Use stage and secondly benefits the future solution to store larger quantities in the hub. Hence Volvo CE can purchase quantities in the range of the Economical Order Quantity which will be used within this thesis for all articles bought. On the contrary, keeping lower inventory levels at Point-of-Use results in a higher replenishment frequency, which derives in more transportation within the plant.

Among the parts for the loaders, the floor panels are the biggest parts and are presented in F3 pallets. This step refers to the third step in the framework within material feeding selection (see chapter 5.4). The floor panels are heavy and currently they are not presented in the golden zone for the operator which results in ergonomic issues. With the future suggestion through restructuring and downsizing, a great amount of space will be released and the pallets with floors can be placed in an ergonomically position for the operators. Since the floor panels weigh on average 17kg it is beneficial to place the pallets on a rolling wagon with a certain amount that is replenished from internal stations.

Lastly, to reduce the space requirement in the Point-of-Use racks and to facilitate the welding process it was suggested by the operators to move some of the smaller parts to a rack in the area between the two conveyors, as showed in Figure 43. Furthermore, the relocation will also improve the ergonomics since a higher proportion of the parts can be presented in the golden zone for the operator. However this step can be seen as a more layout related issue, which enables better ergonomics for the operators.

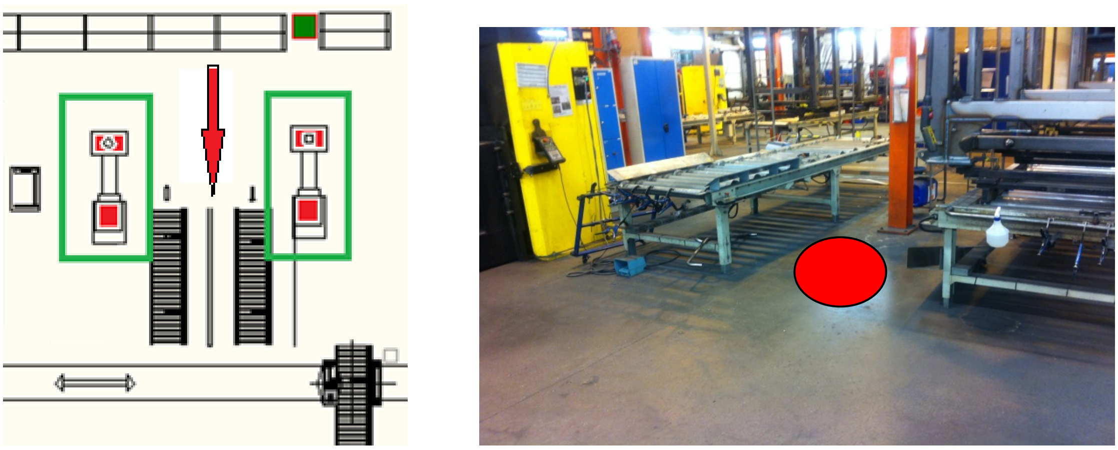

Figure 43. *It was suggested by the operators to move packages containing smaller parts to the conveyor area*

The flexibility can also be improved by introducing smaller component racks that are portable and easy to arrange. When the racks are flexible, they can be moved more closely to the welding object but also facilitate when the space beneath the racks needs to be cleaned. The final proposed design may hence cover up the increasing volumes and variants in the future since many of boxes and pallets can be downsized by a factor of a half. The expected future increases in production volumes by 10-25% and increased number of part variants can be absorbed by the suggested material feeding principle design that decreased the space utilization.

In this case, it can be seen that the objectives can be achieved through continuous supply utilizing an efficient parts presentation. Hereby, it is not necessary to use the more costly material feeding principles of kitting or sequencing to satisfy the requirements, and in the analysis process section 5.4 the step 3 can be avoided. Only in one case the sequencing will be used for a heavy plate that is consumed in average two times per week. It can in this case be unnecessary to keep a bunch of material displayed at the line, which takes up unnecessary space. The proposed design will both improve the ergonomics and reduce the space requirements in the Point-of-Use racks.

To conclude from the selection of material feeding principle for the loader station all the articles will be supplied through continuous supply, except from one article that will be supplied through sequencing. However, the bigger parts last on the sequencing area within the matrix but seem to be material that is consumed often, except from one article. Hence, these bigger parts will be feed through the principle of continuous supply and the rarely consumed article will be supplied through sequencing. Furthermore, the part with the characteristics of being long in the length, i.e. concerning parts supplied from XXXX. As these articles were insufficient to supply individually through kitting due to the increased cost, these can be supplied through continuous supply if using right the right packaging. Those articles will be supplied through one common pallet instead of individual pallets for them all. The material feeding principle and packaging type for each article are illustrated within the table in Appendix D.

Excavator station

The excavator model has 2 variants of part sets that weld on to the cab framework. The most common model is the “standard” type and the modified type is “vandal”. The difference between the two models are that the parts required for the standard type are also welded on to the “vandal”, but the “vandal” further requires an additional 7 parts. The Bom-structure for each model is found in appendix A. The total annual production volumes of the two types are XXXX units, which are considered to be high. On the other hand, the variation of models is low and hereby it can be seen from Figure 41 that continuous supply is preferable when considering the production context in the first step in the material feeding selection within the framework (see chapter 5.4).

The total number of parts is 24 part numbers whereas 7 of these are allocated for the “vandal”, as mentioned above. The major proportion of the parts is smaller details, and 22 out of the 24 parts are stored in grey boxes. The remaining parts is a “panel” which measures a length of 1,5m, width 4 and a thickness of 5 cm and is stored in a moveable trolley and a sill plate that is stored in the racks intended for the dumpers. The current parts presentation is illustrated in Appendix E.

The range with part numbers can be considered relatively high and according to the theory kitting may be a viable option. When there are a lot of details to choose from the fetching times can be increased as well as the quality can be affected negatively if the operator picks a wrong part or forget parts to weld on. However, as described in the current state the operators prepare the small parts by picking the needed parts from the Point-of-Use racks and puts them on the rolling table, see Figure 35. The picking can be seen as a variant of a kit preparation which reduces the fetching times and walking distances. It is also beneficial that the operators themselves prepare the kits to ensure that all required parts are available on the table resulting in a quality check. As in the case of the loader station, the operators have time to prepare the material during the inspection control of the cab frameworks is performed and hereby will not affect the cycle time.

Even though the number of parts is high, the existing material feeding principle and parts presentation is satisfying the space requirements due to the characteristics of the parts. Therefore, no substantial changes of the material feeding principle are considered to be needed. According to the operators, the ergonomics is also adequate since the most parts are easily handled. If following the approach within the framework to choose the most preferable material feeding principle, the performance can still be achieved through use of continuous supply. The only part that is somewhat unmanageable is the panel due to its heavy weight and large size; therefore it would be preferable to store the panel in an vertically adjustable trolley to facilitate the material handling. The investigation regarding of the heavy article last on continuous supply since it were always consumed at the station and therefore needed to be supplied through continuous supply, this if following step three within the framework (chapter 5.4). Furthermore, it has been observed that the fill rate in the grey boxes are in general very low and that only a single grey box is presented in the racks for each article, see Figures 44 and 45.

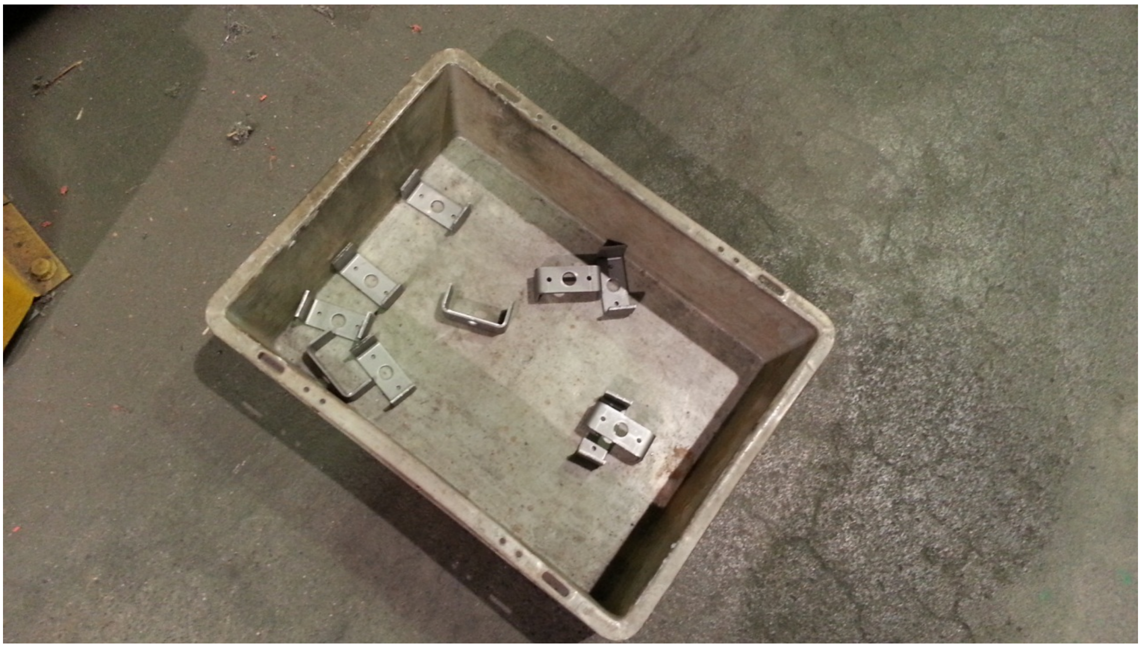

Figure 44. *Example of the low fill rate in the grey box*

Figure 45. *Second example that illustrates the low fill rates in the grey boxes*

On average there are 8-10 parts in every grey box meaning that the run out time is around 8-10 hours due to the long cycle time of the welding operations. The parts presentation of those smaller parts can hereby be improved by changing the grey boxes and instead store the parts in blue boxes of smaller sizes. Since the width and height is smaller than the grey boxes the whole Point-of-Use racks can be reduced in size, increasing the fill rate in the blue boxes and at the same time keep the same quantity of parts units. The suppliers that supplies material for the excavator is spread out all over in Sweden but also in Europe, hence there is no obvious advantageous to consolidate materials from the suppliers.

The suggested layout is found in Appendix F with a space reduction that covers the 25 % in increases of volumes and variants, which further satisfies the objectives and future demands. However, to conclude from the material feeding selection concerning the excavator station all the material will be supplied through continuous supply, even the larger part since this article is always consumed. The result from the material feeding selection regarding the excavator station can be found within the table in Appendix D.

Dumper station

Starting with the material feeding selection and the first step within the framework in chapter 5.4, the same set of welding parts is used for both cab frameworks in the plate lining station for dumpers. In the context of production the variety is low since there is only one set. The current production volume is XXXX cab frameworks annually, which can be considered as medium to high volumes. When considering the overview of the production environment it can be perceived that continuous supply would be the most appropriate feeding principle for the dumper station. This is also illustrated in Figure 41.

As been described for the loader and excavator station it is not sufficient to only consider the production context when making a selection of a material feeding principle, but also to revise the part- and product related factors, set as the second step within the material feeding selection chapter within the framework (see chapter 5.4). The total amount of part numbers presented at the loader station equals 20 different parts, which is the lowest number among the three welding stations. The characteristics of the parts are slightly different from the loader and excavator, and at the station small, medium and large sized parts can be found with various shapes.

The smallest part is a bracket with a weight of 20 grams and measures 35mm in length and the biggest part is the back door panel weighing 25 kg. Currently, continuous supply is used at the station where the small sized parts are stored in grey boxes whilst the bulky, medium and large sized components are stored in pallets. Since the space around the welding stations is limited it is difficult to present the pallets in an efficient way for the operators. For instance, some parts is located in another shelf on the side of the excavator station which forces the operator to fetch parts on another location than the own location. Thereby the welding station for the dumper positioned rightmost must walk through the narrow area to fetch some parts. Since many of the parts can be downsized from larger packaging to smaller ones kitting is not questionable in this case. However, if following the third step in the framework within chapter 5.4, large articles will be supplied through continuous supply since the consumption of the heavy plates is high. Thereby sequencing as material feeding principle for the heavy plate isn't questionable in this case. By only applying continuous supply with the suggested parts presentation it is estimated to reduce the space requirements with 25%, which will cover the future demands of production volumes and part variations. The reason is that many of the packaging currently displayed at the Point-of-Use storage can be changed too much smaller packages. The smaller parts that are stored in grey boxes can be put in smaller blue boxes and parts that are stored in full pallets can also be placed in blue boxes, when possible. Furthermore, material that should not be in the Point-of-use storage for the dumper station can be allocated to other locations. These two changes will cover up the planned increases of volumes and variants of 25 percent.

From the material feeding selection within the dumper station everything will be supplied through continuous supply. What has been experienced from the other two stations regarding of sequencing articles, large articles within the dumper station is always consumed for each cab welded. This heavy article will be supplied through a wagon where the material is presented horizontally. However, the result from the material feeding selection for the dumper station is illustrated within the table in Appendix D.

7.4 Design process

In this part the design process is conducted to define the rest of the MSS. This means that storage, material handling, transportation, packaging and planning and control should be defined through the decisions taken in the previous part, namely the input of material feeding selection. Since the material feeding selection is the central part when building a MSS everything starts from the output from this process. However, the design process will mainly start from an overview, i.e. structural changes from a flow view will firstly be conducted. Thereafter detailed suggestions will be proposed to this design process. The design process has however been approached regarding of the lineback principle but will be presented in a holistic view to give the reader a finished result due to the interrelated coordination between the inbound respectively in-plant section.

7.4.1 Structural changes

Since the flows comes into the company through two different entries as well goods received at different locations structural changes will be conducted to reduce the required material handling along the way due to the current structure. In this way, all the flows will be consolidated to be able to move the material along one common pathway into the company. This derives in less material handling since external flows of pallets arriving on the other side and the cardboard box flow can be totally eliminated (will be further elaborated in the design process section). All the flows will thereby go through entry two, which creates a more straight flow into the plate lining process, see Figure 46. Thereby only two different flows will be proposed in this setting in comparison to four in total when the current state is in action.

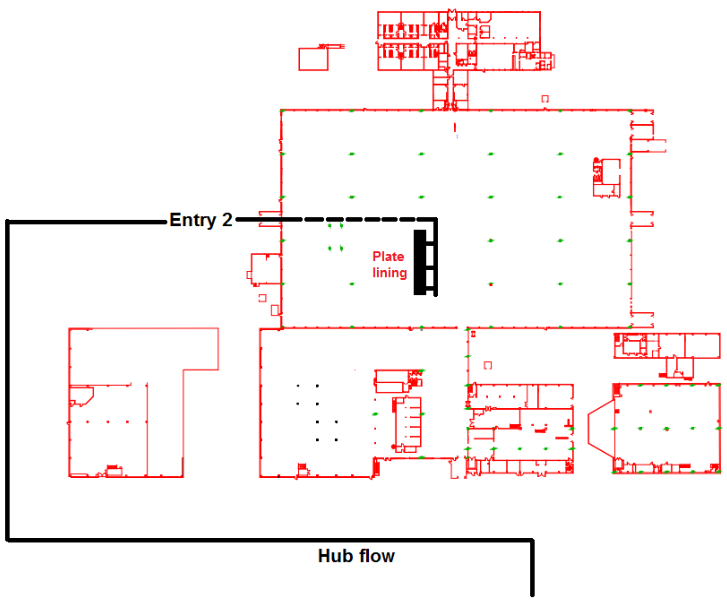

Figure 46. *The picture illustrates the future state with the main structural changes that should be conducted when this future state is implemented*

7.4.2 Inventory

The inventory within Volvo CE for the plate lining process should not be located at the Point-of-Use, this since the lead times exceeds the maximum inventory that can be carried at the plate lining process, if following the restriction to only store maximally material for two days. Thereby all the buffers intended for the plate lining process will be moved back in the chain to the hub Hallsbers Terminal. The decision to put back the inventory one step in the supply chain and not to the suppliers lies in suppliers like to keep inventories. Suppliers refuse to keep finished stock and this proposal hence has to consider this aspect when dealing with the current situation. However, benefits through this proposed inventory setting is the opportunities to consolidate all the material in one point and hence coordination issues can be attained when material has to be fed along one common pathway to Volvo CE. When consolidating the material in one point the material can be fed to the Point-of-Use on an one common occasion, instead of being supplied from many decentralized units at different times, which probably creates more traffic outside of entry two and within Volvo CE.

Regarding the Point-of-Use storage that serves the stations along the plate lining process, all the three cab sections will be provided with a supermarket each. If starting with the middle station that produces for excavators all the suggested material will be fed through continuous supply will be included within the supermarket (see Figure 47), whilst an external supermarket will provide articles that left on continuous supply but seems to be large in size.

Figure 47. *Example of a supermarket rack that can be used for the excavator station*

However, the stations that produce for loaders will be provided with a common supermarket that feeds both the station within loaders. Large parts that lefts on continuous supply will be provided beside of the middle supermarket. One smaller supermarket will be provided closer to the both stations, in order to provide smaller parts in order to be able to decrease the walking to the main supermarket.

Regarding the two dumper stations the layout put some restrictions to place the supermarket at an appropriate place to feed the both stations. The fundament restricts to put one common supermarket just between the two stations. Thereby it is suggested to put smaller supermarkets on each side of the fundament that provides with common material. Furthermore, the heavy plates coming from internal stations will be put in individual supermarket that supplies the both dumper stations with large parts. The proposed layout is shown in Figure 48.

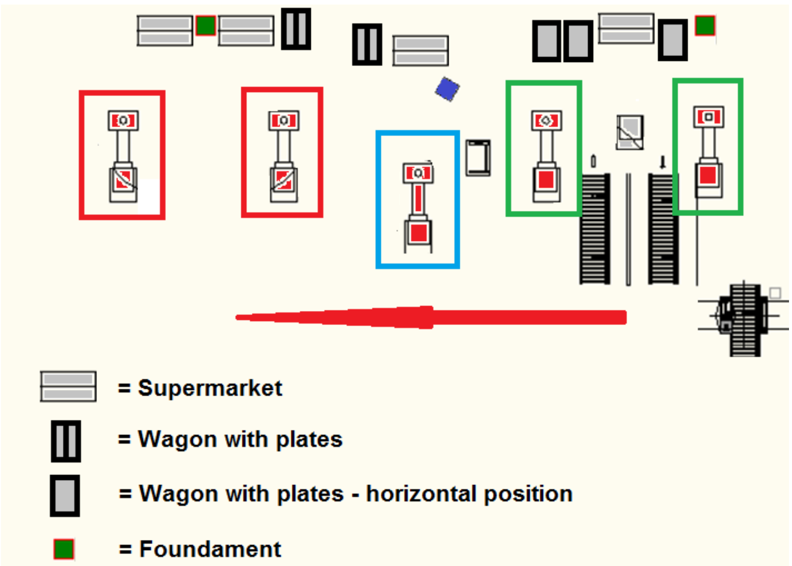

Figure 48. *The proposed layout for the plate lining department at Volvo CE in Hallsberg*

7.4.3 Transportation and material handling

The transportation and material handling from the supplier until the Point-of-Use will be changed in some extent, except from the current transportation from suppliers until the material is registered as in-plant. Only some suggestions regarding of recommendations for further investigations will be pointed out in this thesis. Since the transportation network doesn't has been approached in the same intensive manner as the rest of the MSS, the transportation has an indirect influence on the rest of the MSS that should be considered to optimize the whole setting. However, when looking over the in-plant transportation for the future state, all forklifts will be eliminated concerning the plate lining process, this due to the safety risk by using forklifts in spaces where people use to walk. All the supermarkets for the loader, dumper and excavator stations will be supplied through tugger trains that fill the stations with material. Internal plates will be picked up by the tugger train on the same route, which implies that the tugger train couple wagons from the internal stations. In this way the tugger train can supply all the material intended for the plate lining process. This alternative only alleges for the indoor forklifts, but doesn't affect forklifts operating outside of the plant. However, since the structural changes within the flows paves the way for less material handling, outdoor forklifts will only be used in conjunction with unloading of the truck and trailer, by lifting off tugger train wagons. From being using forklifts constantly this structural change eliminates all forklift use nearly by all, except from the unloading operations. This solution goes hand in hand with the safety thinking that "The Volvo Way" strives for. Furthermore, some internal processes located next close to the plate lining process should not be included within the tugger train route, this since the material can easily be rolled to the plate lining process instead. However, every time when the forklift lifts off tugger train wagons from the truck and trailer, only two vertical lifts is needed to be performed by the forklift. The rest is then solved by the tugger train and hence, many vertical lifts and material handling along the way can be eliminated. This implies that all the vertical lifts within the plant will be eliminated whilst only two lifts will be required when the unloading of the truck and trailer is conducted.

7.4.4 Packaging

Regarding the packaging of all the material at the plate lining process, the whole environment should be free from tree pallets and hence support the new proposed packaging system. In order to be able to re-change process all the material at the plate lining process has undergoing a downsizing. The procedure starts from the supplier, where the intention is to change all the pallets to plastic blue boxes and plastic pallets. From the visiting at Volvo Powertrain in Skövde, the changeover process may look like similar and the majority of the suppliers may be able to deliver their articles within the new system that is provided here. In the case of Volvo Powertrain, 80 percent of all suppliers were able to make the changeover without any problems and hence were not taking any extra charge. Since Volvo CE is only supplying material from 13 different suppliers concerning the plate lining process, there should not be larger problems to changeover to the new setting. However, this thesis will consider this problematic scenario and calculate the changeover process. Furthermore, those articles concerning the korean supplier will be repackaged from their initial package into blue boxes within Arendal Logistics Center, this due to the limited coverage of Volvo Logistics outside of Europe. By applying the blue box system provided by Volvo Logistics the previous return logistics setting can be eliminated. This implies that Volvo Logistics will provide the return logistics hereafter which eliminates the use of XXXX. Hence the return logistics can be covered within the same cost of packaging, instead of being two independent separate costs, i.e. packaging cost and return logistics cost.

Furthermore, by enabling the right packaging from the supplier stage no material handling in form of repackaging will be needed between the supplier and Volvo CE. Thereby, the material will only be stored at the terminal point and not repackaged. The proposed packaging for all the articles is illustrated in Appendix D. However, in order to be able to decide which packaging that is the most suitable for a certain article the coverage time has to be considered. The coverage time for the material at the plate lining process should not be more than 2 days and thereby it is important to choose the most suitable package to get high filling rates. Furthermore, the packaging has been chosen regarding of the features of each item to match the most appropriate package, and at the same time be able to handle the coverage time. Examples of packaging for the future proposal are illustrated in Figure 49.

Figure 49. *Examples of wagons and packaging that is proposed for the future state*

However the return packaging will take the same way as the tugger train where the tugger train driver collects all the empty blue boxes from the return shelf at the supermarket. These will be placed into the tugger train wagon which then will be transported back to the terminal. The terminal will cross-dock the empty packaging back to the packaging pool which is operated by Volvo Logistics. Volvo Logistics will then provide new and fresh packaging to all the suppliers.

7.4.5 Planning and control
When looking over the planning and the control over the future system, the current resources will be used to the largest extent, this since the scope of this thesis should not be exceeded. The idea is to keep the current MRP-system that replenishes material from the suppliers to the terminal, whilst everything between the terminal and Volvo CE should comprise of a pull system. In order to be able to create an environment where operators doesn't replenish material to the Point-of-use storage a kanban approach will be implemented between the terminal and Volvo CE. Every packaging at the Point-of-Use storage will correspond to one kanban card and thereby when the tugger train driver collects and scan the empty packaging and an initiation to the terminal will be sent through the system. When the initiation is received at the terminal, the terminal prepares the next route by picking all the needed material and sends it to Volvo CE through the internal transportation system between the terminal and Volvo CE. Furthermore, regarding the quantities that should be ordered from the supplier, the company should hence use the following Economic Order Quantities (EOQ) for material as stated in Appendix G. The Economic order has been calculated through the formula presented in the theory section within this thesis.

7.4.6 Further recommendations
Since this thesis does not comprise any setup time reduction on internal stations that produces articles for the plate lining process only further recommendations can be suggested. However, what is just required from the plate lining process is to decrease some of the articles batch sizes in order to be able to fit in the quantities within the maximum allowed coverage time. This can however be a hard task to perform since cost and production schedules must be considered if these kinds of changes have to be done.

As specified earlier the external transportation network will not undergo any major structural changes. Instead our proposal of recommendation is to look over the current setting regarding of the truck transportation of material from Gothenburg to Hallsberg should be investigated for a change to train transportation instead of truck transportation today, this concerning for the Korean supplier. In this way, more environmentally friendly solutions can be investigated to be obtained. Furthermore, the line between Korea and Gothenburg should be more investigated regarding of the transport mode since one article possess over a high value and the total lead time between these locations is over 60 days.

7.5 Proposed future state
In this section the future state is illustrated through flow maps conducted for the two remaining flows after the improvements. The two flows are illustrated in the figures below, the future state for the external flows (see Figure 50) respectively internal flows (see Figure 51). The proposed design for the parts presentation for each welding station is presented in Appendix F. Finally, the landed cost calculations for the present system respectively the future state is presented in Appendix H. It can be concluded that the proposed future state fulfills the objectives set in chapter 7.2, focusing on ergonomics and space requirements. By comparing the current parts presentation (Appendix E) with the proposal (Appendix H) it can be seen that the ergonomic conditions will be improved for the operator and the heaviest and big parts are presented in the golden zone. The required space utilization for the racks have been reduced by 42% on average and the expected increases in production volumes can hereby be absorbed by the new system. Furthermore, Appendix H shows that even though the volumes will increase by 25% until 2015 the cost for the proposed system will be reduced by 32,3% relatively the costs for the current system.

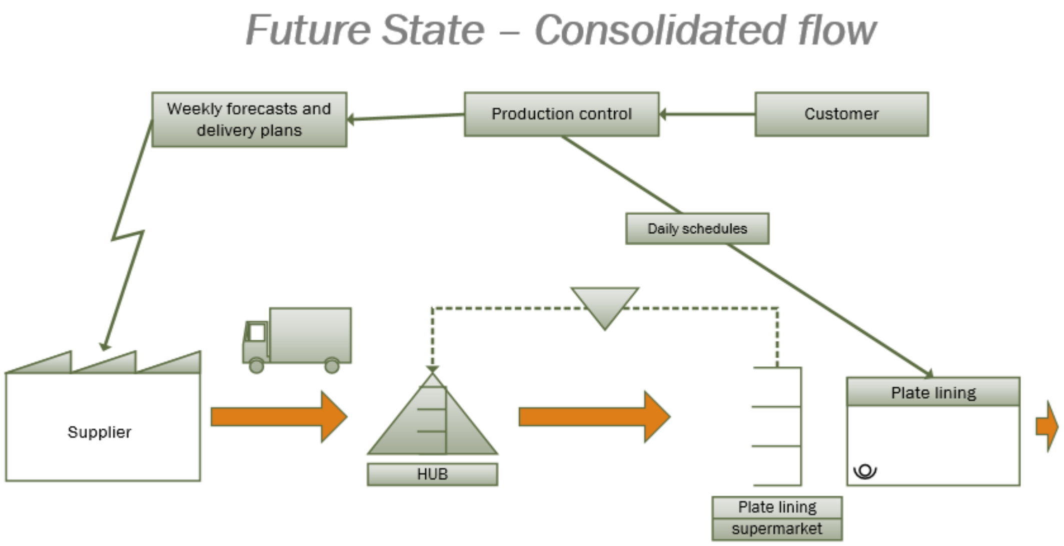

Figure 50. *Illustration of the future state for the all the external flows consolidated to one common flow*

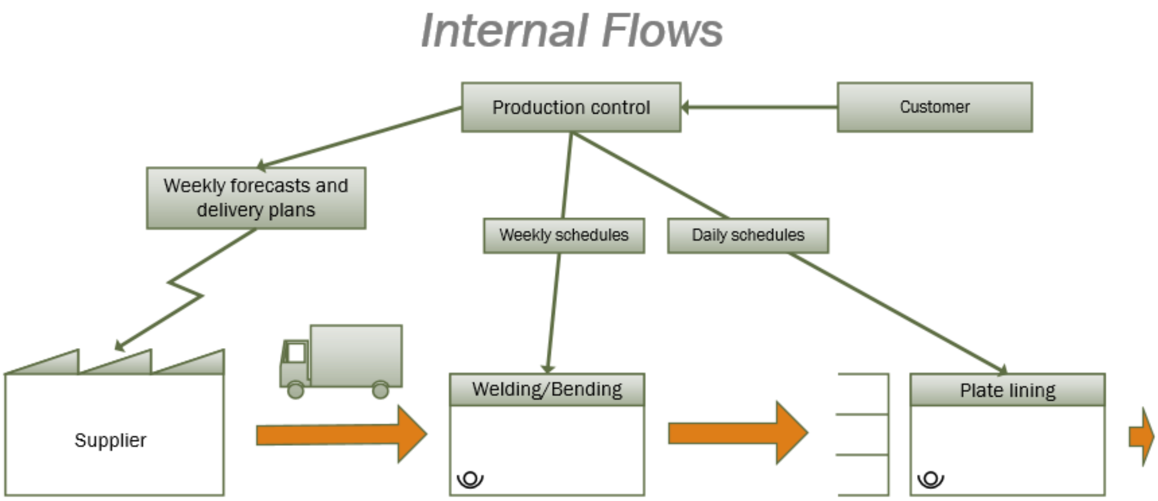

Figure 51. *Illustration of the future state for the internal flows*

8. CONCLUSION

In the conclusion section the result of the work will be elaborated in relation to the expected outcome. However, the purpose of this master thesis was to create a framework and then apply on the context of Volvo CE in Hallsberg. The framework resulted in an approach that shows sequential steps that has to be performed to design a complete MSS and hence, can be applied in various settings. In the case of Volvo CE in Hallsberg the framework was applied successfully and can thereby help them to supply the material in a more efficient way than earlier. Firstly, in order to be able to make these improvements objectives for the future state had to be set. This since the objectives defines the performances that the MSS must attain. From the process of set these strategic objectives, it last to put focus on decreasing the storage within the plate lining department and improve the ergonomic conditions for the operators. However, the solution has not been applied or tested in the reality but the analysis and the result from the analysis shows that Volvo CE will gain a more efficient and straight flow from suppliers if comparing to the previous setting. However, the developed framework for choosing the right material feeding principle and enabling an approach to build a future MSS uses to highlight the whole picture instead of sub optimizing individual entities, as many other assessment tools or frames doesn't consider.

The current buffering within the company and unnecessary stocking at the Point-of-Use storage does not fit within the future state and has moved upward in the supply chain to a hub. All the indoor forklifts concerning the plate lining process has been eliminated and instead being replaced by tugger trains that increases the safety within the company. No more unnecessary material handling within the company will be conducted and instead the company can focus on their core competence. All the pallets and grey boxes has been substituted with blue standardized Volvo plastic boxes and plastic pallets that derives from the supplier. In this case, the supplier will pack the material in the right packaging from the beginning. Internal stations supplies the plate lining process with their material within internal wagons. The operator don't need to take care of replenishing the material to the plate lining process and can instead focus on the welding process. However, the benefits of this solution will give Volvo CE in Hallsberg the opportunity to apply these suggestions in the reality. Furthermore, Volvo CE in Hallsberg can according to the cost calculations reduce the total cost by 41.6 % by changing over to the new Material Supply System by tomorrow. However, by including the stated increase of 25 % in volumes and variants Volvo CE can hence by 2015 reduce the total cost by 32.3 %.

Furthermore, to see whether this thesis has answered on the three research questions, the answers of all the questions will be concisely answered through referring to the actual chapter within this master thesis.

The first question was as following:
RQ1: "*What material feeding principle is preferable at the plate lining process for the each article?*".
What could be seen here is that the framework declared the material feeding principle of all the articles and has thereby answered the first research question. The result from the material feeding principle selection can be found within Appendix D. In this way the first question can be fully completed.

The second question was as following:
RQ2: "*How should the material flows from the suppliers to the goods receivement be arranged?*"
The research question number two has also been answered from the authors and what's presented within chapter 7.4.1 material flows from suppliers will be consolidated and stored at the hub. The hub then sends material to Volvo CE in Hallsberg when material is needed at fixed time spots.

The second question was as following:
RQ3: "*What material flows will go through the hub?*"
The third research question refers to which material that goes through the hub. Thereby, as the result showed from the future state only two different type of material flows was remaining, external flows respectively internal flows. All the external flows with material will go through the hub (see chapter 4.1), whilst the material within internal flows will still be replenished straightly from internal stations.

9. DISCUSSION AND FURTHER RESEARCH

The purpose of this master thesis was to develop a model for designing the MSS from the suppliers to the Point-Of-Use. The model is presented in chapter 5 and is considered to make a theoretical contribution since no previous literature was found on the specific subject. Furthermore, the validity of the framework was also tested through a case study on Volvo CE Hallsberg and the results were presented in chapter 7. However, even though a similar study has not been conducted previously this study can be validated by its relevance based on earlier research. Some smaller parts from different research papers have been tied together and appearing gaps could hence be filled by theories from other papers. Thereby several articles can be seen as constituent parts of this thesis and creates interrelated bridges from all the papers in one common thesis.

As described in section 3.2.4 and 3.2.5 the design process and selection of material feeding principle is a complex task. When developing the MSS it is necessary to consider and comprehend all interrelations between the configurations, contexts, performances and future strategic considerations. The framework will not specifically point out what methods to select and use within each design area, but will give guidance for identifying all relevant aspects in order to make appropriate decisions. The framework can be seen as a structured step-to-step guide that can facilitate the practitioner in the industry when developing the MSS.

The advantage with the framework is that the complexity associated with material feeding principle is considered. In many cases, previous theoretical and empirical models only handle a subset of the stated interrelations which can lead to non-optimal solutions. When designing the MSS stretching from the suppliers to the POS, it is also important to consider that all design areas are aligned with the same goal. In order to reduce the risk for a sub-optimized MSS; the framework emphasizes the importance of TCO.

The framework was applied and validated through the case study at Volvo CE. The considered MSS included material flows from 14 suppliers and 64 different parts that were supplied into the plate lining process. Due to the scope of the case study, it was needed to categorize the individual material flows in groups with similar characteristics. As a consequence, the suggested future system considered the general material flows and not the individual parts. Future research can include a more detail study for how each individual part should be supplied through the MSS from the suppliers.

Since the focus of the study has been on a general level, the individual design areas has not been elaborated in detail due to the limited time frame for the project. Hence, further research may include how the control and planning, transportation and storage part should be chosen in relation to the selected material feeding principle. Due to the weak appearance of earlier studies that used to concern this area no exact approach could be defined within this thesis. However, under this study it appeared that packaging could be very closely related to the choice of material feeding selection, this since the analyzed context together with the objectives could affect whether some articles could be provided within small blue boxes or forced to be kitted depending on the outcome of the performance. However, this relation has been an own perception of what could be closely related to the first approach within the design process, and maybe some kind of reasoning to an approach could be conducted to find a suitable approach where to start.

Furthermore, regarding the solution proposed for Volvo CE in Hallsberg the supplier situation can in some way prevent the wished future state since this thesis uses to not consider supplier related issues. Everything depends on the supplier situation and how Volvo CE can fulfill their own obligations regarding price and the suppliers ability to changeover to blue boxes. It is important to address that this thesis provides an optimal theoretical solution where the proposed solution isn't implemented in the reality. The way Volvo CE can influence the destiny of the decisions of suppliers is in this context restricted since Volvo CE doesn't possesses over the decision making at supplier stage. The transition from the behold of the supplier can be a complex issue until it reaches to a stage where Volvo CE can influence the outcome. Thereby, the terminal between the supplier and Volvo CE can be seen as the limit where Volvo can influence the outcome in their own way. However, to attain one piece flow advocated by Volvo Production System, the whole supply chain from the supplier stage until Volvo CE in Hallsberg must be coordinated. Today, this can be a complex issue to solve since the context changes from time to time in a dynamical marketplace.

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APPENDIX A - Production related factors

Has been removed due to confidential issues

Annual volumes

Has been removed due to confidential issues

BOM-structure Excavator

Has been removed due to confidential issues

BOM-structure Dumper

Has been removed due to confidential issues

BOM-structure Loader

Has been removed due to confidential issues

APPENDIX B - Product and part related factors

Has been removed due to confidential issues

APPENDIX C – Supplier related factors for each station

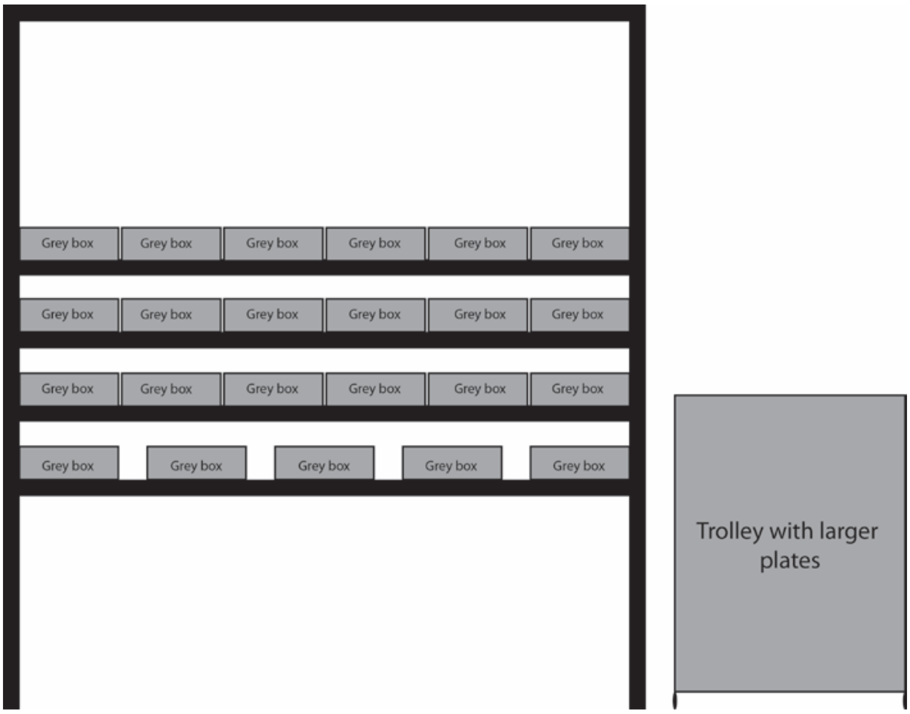
Has been removed due to confidential issues

APPENDIX D – Proposed material feeding principle and packaging

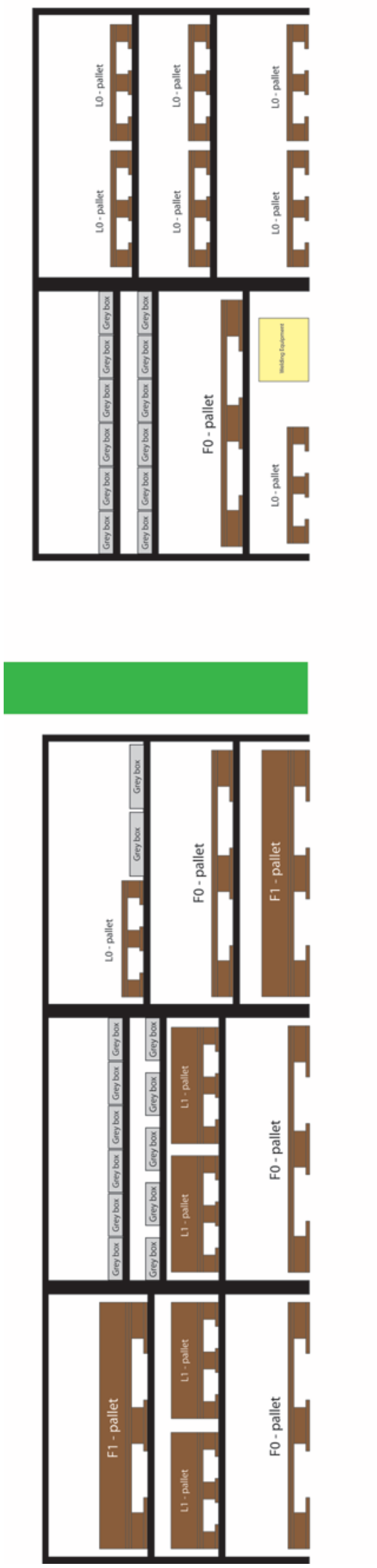
Has been removed due to confidential issues

APPENDIX E – Current parts presentation at the assembly stations

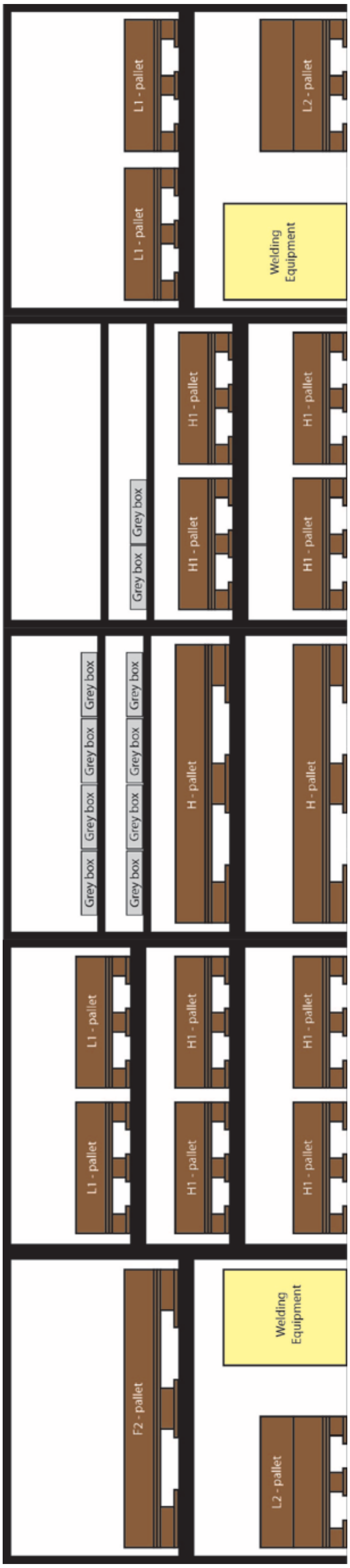
Excavator station



Dumper station

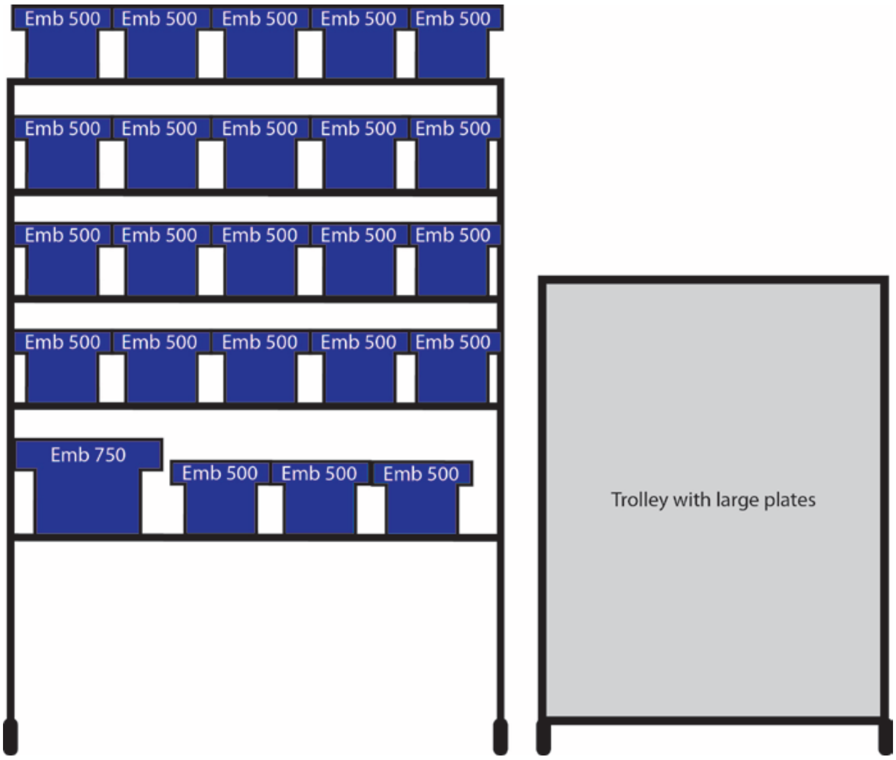


Loader station

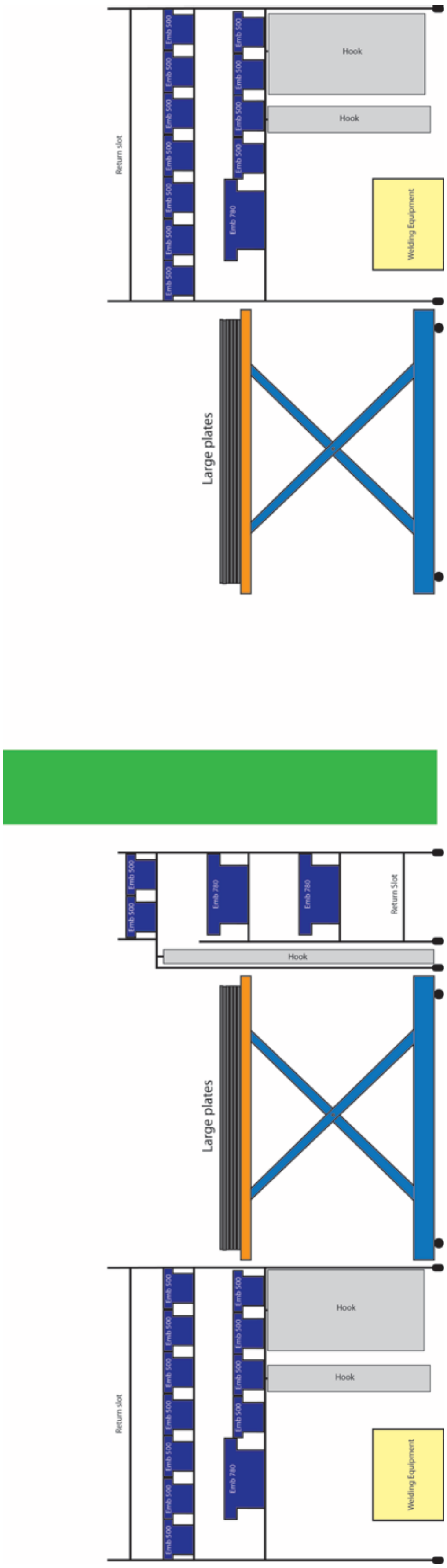


APPENDIX F – Suggested layout for the parts presentation

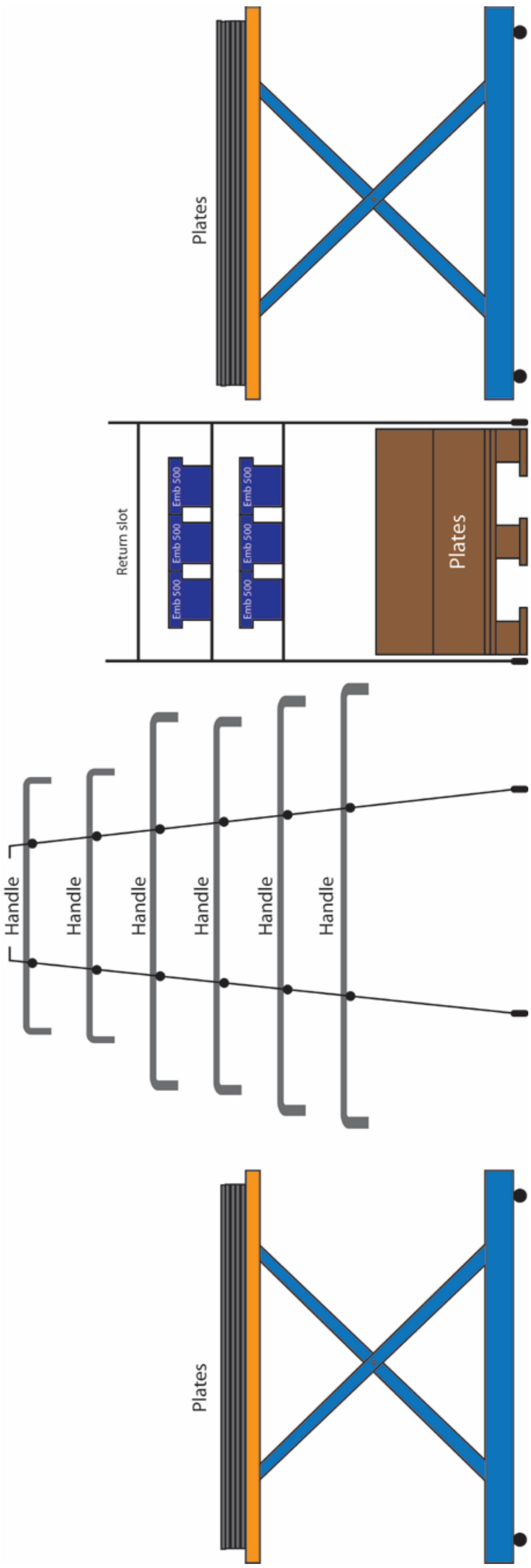
Excavator station



Dumper station



Loader station



APPENDIX G – Economic Order Quantity

Has been removed due to confidential issues

APPENDIX H – Landed Cost Calculations

Has been removed due to confidential issues