CHALMERS
UNIVERSITY OF TECHNOLOGY

Impact of disposable packaging in automotive production

Master's Thesis in the Master's Programme
Supply Chain Management

ANNA BLOMBERG

GABRIELLA HALLAMS

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017
Report No. E 2017:080

MASTER'S THESIS E 2017:080

Impact of disposable packaging in automotive production

Master's Thesis in the Master's Thesis in the Master's *Programme*

Supply Chain Management

ANNA BLOMBERG
GABRIELLA HALLAMS

Tutor, Chalmers: Robin Hansson
Tutor, Volvo LS: Joel Larsson
Christel Säljö

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Impact of disposable packaging in automotive production
ANNA BLOMBERG
GABRIELLA HALLAMS

Master's Thesis E 2017:080

Department of Technology Management and Economics
Division of Supply and Operations Management
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

Cover:
A disposable cardboard pallet from Papyrus Supplies (in the size of L4) at a kitting station in Volvo Group's production.

Chalmers Reproservice
Gothenburg, Sweden 2017

Impact of disposable packaging in automotive production

Master's Thesis in the Master's program Supply Chain Management

ANNA BLOMBERG
GABRIELLA HALLAMS
Department of Technology Management and Economics
Division of Supply and Operations Management
Chalmers University of Technology

Abstract

Studies shows that the future packaging trends in the automotive industry are turning towards an increased usage of disposable packaging in longer distance flows. Accordingly, Volvo Group has initiated a project called *Next Generation Packaging* with the objective to harmonize and standardize the Volvo Group's packaging pool. However, there are concerns that disposable packaging material (often cardboard) will have a negative impact on the material handling, scrapping or recycling, and the level of cleanliness inside production plants, thus affecting the production quality.

The aim of this thesis is to study the effects of an increased usage of disposable packaging in the Volvo Group's receiving plant from goods receiving to point of use to waste handling, and to identify potential problems that arise from replacing the returnable packaging with disposable alternatives. The total scope for the project *Next Generation Packaging* is global, but the master thesis is limited in terms of geographical location and the main focus is on the production plant in Tuve. The report will further be limited to the packaging alternatives that *Next Generation Packaging* is reviewing, which are disposable boxes and pallets in cardboard provided by Papyrus Supplies.

In order to fulfil the aim and answer the research questions, an extensive part of the study was to understand and to map the current state of Volvo Group's internal logistics processes by conducting a Material Flow Mapping. The flows decided to follow were two pallet flows and four box flows. The six flows together covered all logistics processes that the disposable packaging needed to be tested in, in order to ensure endurance and applicability before a possible implementation.

To evaluate the packaging performance, the disposable packaging alternative provided by Papyrus Supplies have been analysed from four different packaging requirements: the protective perspective, the handling efficiency perspective, the ergonomic perspective, and the information perspective. The main conclusions made from analysing the disposable packaging based on these four perspectives are that the disposable packaging solutions could, in the rough, be handled in the same internal logistics processes up to the handling and collection of empty packaging. The breakdown of empty cardboard packaging does require new processes, as well as space and locations for handling of empty packaging.

Keywords: Disposable packaging, Returnable packaging, Packaging requirements, Packaging evaluation, Internal logistics, Material Flow Mapping

Acknowledgements

This Master thesis has been conducted in cooperation with Volvo Group Logistics Services and the Division of Technology Management and Economics at Chalmers University of Technology.

First, we would like to thank our examiner Robin Hansson from Chalmers and our supervisor Joel Larsson from Volvo Group Logistics Services. The advice and support you have given us have been extremely helpful. The meetings with you have both been very giving as well as highly motivating. Furthermore, we would like to thank both of you for letting us take part of your knowledge and experience.

We would also like to thank employees at Volvo Group Trucks Operations who has helped us during the whole time working with our thesis. Special thanks to Jonas Hansson and Magnus Schulke for your helpfulness and support.

Thank you!

Anna and Gabriella

Abbreviations and definitions

CBU	– Completely Built-Up
FiFo	– First-in-First-out
GTO	– Volvo Group Truck Operations
Knocked-down production	– Semi produced vehicles and parts sent from Volvo plant to local assembly factory, not necessarily owned by Volvo, for finalization
L-pallet	– The most commonly used type of wood packaging within Volvo
MFM	– Material Flow Mapping
Pallet	– Pallet base unit with pallet collar/-s or sleeve
Pallet base unit	– Flat wooden transport structure that supports goods
Pallet collar	– Supporting material on pallets, part of L-packaging
PoU	– Point of use
POW	– Pallet-On-Wheels
VCC	– Volvo Car Corporation
V-EMB	– Volvo Standard Packaging
VGLS	– Volvo Group Logistics Services
750	– Volvo Standard Packaging. Blue plastic box with the dimension 400x300x200 and a volume of 15.7 litres
780	– Volvo Standard Packaging. Blue plastic box with dimension 600x400x200 and a volume of 36.6 litres

Table of contents

List of Figures

List of Tables

1 INTRODUCTION

The following chapter introduces the reader to the subject of this study. First, the background is presented which gives the reader information about the studied area and the case company. The background is followed by the aim, delimitations and the thesis structure.

1.1 Background

The traditional view on packaging is that it enables protection during shipping and storing, where a redundant level of protection will result in unnecessarily high costs and an insufficient level of protection will result in a lack of quality (Gourdin, 2001). The prevailing view is that packaging is a critical factor in the supply chain and influence both the efficiency in distribution and the effectiveness of the entire system (Chan et al. 2005). Thus, the packaging system should therefore be integrated and regarded as an important part of the supply chain (Lumsden, 2006). Furthermore, Pålsson et al. (2013) argue that the choice of packaging system will impact both the economic and the environmental performance of a supply chain. Twede and Parsons (1997) explain that packaging highly influence the logistical productivity as it impacts the cost level of every activity in the logistics chain. Due to this widespread impact on every activity, there is no other component in the logistics chain that is exposed to as many requirements as packaging (Dominic et al., 2000). For instance, the unit sizes of the packages will have an impact on the storage and transport costs due to density, stackability and fill rates, and handling costs are reliant on unit loading techniques (Twede and Parsons, 1997). The packaging identification system, such as barcodes or labels, will influence the performance and level of inventory control, and the packaging design will directly affect the unpacking costs and the ability to reuse or recycle the material (ibid.). The objective behind the packaging should be to ensure safe product delivery to the user in good condition, and at a minimum overall cost (Paine, 1981).

Packaging is usually divided in disposable, or one way, packaging and returnable, or reusable, packaging (Kroon and Vrijens, 1995). Disposable packaging is usually discarded after one use, whereas returnable packaging by definition should be able to be used a number of times before it is discarded (ibid.). There are a number of studies concerning returnable packaging systems that suggest that effective reverse logistics can enable operational benefits, such as more efficient materials handling, improved fill rates and reduce the needed amounts of packaging material, as well as improve the environmental impact of packaging (e.g., Vijayvargy and Agarwal, 2013; Witt, 1999; Twede and Clarke, 2004). Several other studies argue for the economic and financial benefits of returnable packaging (e.g., Mollenkopf et al., 2005; Twede, 1999; Richey et al., 2004). However, Pålsson et al. (2013) claim that the empirical evidence for these claims are somewhat shortcoming since there is a lack of comparisons between disposable and returnable packaging systems which include both the economic and environmental consequences. At an industry or company level, the environmental objectives must be weighed against economic objectives as there often is a trade-off between these objectives to be considered (Enarsson, 1998).

Odette Sweden AB (2013) states that the future packaging trends in the automotive industry are turning towards “right-sized” packages, an increased usage of disposable packaging in longer distance flows, and an increased use of product specific packaging in the packaging pools. Accordingly, Volvo Group has initiated a project called *Next*

Generation Packaging with the objective to harmonize and standardize the Volvo Group's packaging pool. The project has two main themes; to align the returnable packaging pool by reducing the different types of packaging sizes, and to replace the returnable packaging with disposable packaging in flows with a long-distance repositioning of empty packaging to avoid the complexity of using a returnable packaging system. The desired end effects are an increased turnover in the packaging pool and less tied up capital in packaging.

Volvo Group's footprint is global with production facilities in Americas, Europe and Asia as well as knocked- down production facilities in various places across the globe. Furthermore, the products have a wide spread including trucks (of different brands), engines and transmissions, construction equipment, buses, marine and industrial engines. Given the range of location and products, the production facilities all have different prerequisites and requirements. At the same time, there are concerns that disposable packaging material (often cardboard) will have a negative impact on the material handling, scrapping or recycling, and the level of cleanliness inside production plants, thus affecting the production quality.

Within Volvo Group, there is no standardization or consensus on how to work with disposable packaging and today there is not one common view on whether disposable packaging is a valid alternative to returnable packaging. In order to investigate the effectiveness of the logistics activities in a plant with regard to the packaging requirements, Chan et al. (2005) defines five key perspectives to examine; the protective perspective, the handling efficiency perspective, the ergonomic perspective, the information perspective and the environmental perspective. The research does only include the first four perspectives, since the environmental aspects will be investigated with the supply chain as a foundation instead of a single plant. Every internal logistics process affected by a change in packaging will be analysed against these four perspectives. This master thesis supports Volvo Group's review regarding an increase in the use of disposable packaging as an alternative to returnable packaging, by evaluating the compatibility of disposable packaging to the factory processes. Ensuring no interference with production is a prerequisite before an implementation is possible and determines the proceedings of the project *Next Generation Packaging*.

1.2 Aim

The aim is to identify the effects of an increased usage of disposable packaging in the Volvo Group's receiving plant, from goods receiving to point of use to waste handling. The thesis further discusses aspects that ought to be addressed before an implementation of disposable packaging is possible.

1.3 Delimitations

The full evaluation of disposable packaging versus returnable packaging in terms of cost and environmental impact is not part of the scope. This is instead handled by Volvo Group's own project, *Next Generation Packaging,* to enable a supply chain perspective. The total scope for the project *Next Generation Packaging* is global, but the master thesis is limited in terms of geographical location. The main focus is on the production plant in Tuve, see Figure 1.1.

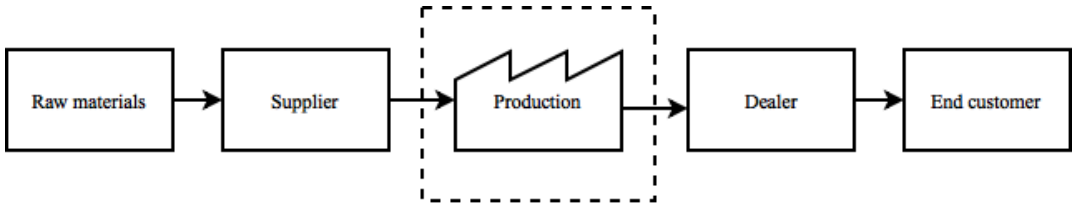


Figure 1.1. The limitation of the master thesis to the production plant in Tuve.

The report is further limited to the packaging alternatives that *Next Generation Packaging* is reviewing, which are disposable boxes and pallets in cardboard provided by Papyrus Supplies. This means that no further investigations regarding what other alternatives of disposable packaging that exist on the market will be performed.

Boxes can either be stored locally or in an automated storage at Volvo Group factories. However, an automated box storage does only exist in Tuve and not in any of the other Volvo Group factories. The automated box storage is furthermore not compatible with the disposable packaging provided by Papyrus Supplies and consequently, the automated storage for boxes is not part of the study.

1.4 Thesis structure

In order to give the reader a more comprehensive picture of the report, the thesis structure is presented in this section. A brief description of each chapter's content will be presented in order to facilitate for the reader to search for specific information.

Chapter 1 - Introduction
The first chapter presents the thesis background and the problem definition. The aim of the thesis is then presented followed by the delimitations of the study. Finally, the structure of the thesis is presented.

Chapter 2 - Theoretical framework
The second chapter presents the theoretical framework used for the report. The theoretical framework will work as a foundation for Chapter 4 as well as the discussion of the thesis.

Chapter 3 - Methodology
The third chapter firstly describes the thesis research approach and thereafter the data collection process. Lastly, the data analysis procedure of the study is presented.

Chapter 4 - Identification of effects
In the fourth chapter, the empirical findings from the Volvo Group are disclosed according to the factory stations and the four different packaging requirement perspectives described in Chapter 2. Advantages and disadvantages with disposable and returnable packaging, as well as a grading of the effects are presented. Finally, a benchmark study performed at Volvo Car Corporation is presented in the closing subchapter.

Chapter 5 - Discussion
The first subchapter in Chapter 5 is based upon the second and fourth chapter, and both discusses the packaging from a general perspective and suggests different ways to handle the handling and breakdown of empty packaging. Furthermore, the second subchapter discusses aspects outside the scope that are considered highly relevant to consider before implementing a change in packaging, such as the importance of having a supply chain perspective, a proper area of usage, and managing the attitudes from people involved.

Chapter 6 - Conclusion
In the sixth chapter, the conclusion of this thesis is presented. The objective of the conclusion is to fulfil the aim.

2 THEORETICAL FRAMEWORK

This chapter will first present some general theory about packaging and various types of packaging, in terms of disposable and returnable packaging, in order to get an overview of the subject. The theoretical framework will then continue to explain different packaging requirements that can be used to evaluate packaging performance and quality.

2.1 Packaging

Paine (1981) defined packaging to have four fundamental functions; protecting, containing, preserving and communicating the enclosed goods. In addition to this, Robertson (1990) and Lockamy (1995) claim that packaging also functions as apportionment and unitization of the product. Hise and McNeal (1988) further add that the packaging should be designed to enable stackability.

2.1.1 Returnable packaging

Returnable packaging is by definition, according to Kroon and Vrijens (1995), packaging that can be used several times before it is discarded. Returnable packaging may vary both in regard to unit load and material. Typically, returnable packaging is made of steel, wood or various plastic materials and the most common unit loads are containers, pallets or boxes.

Returnable packaging requires a high initial investment cost in boxes, pallets, or containers (Twede and Clarke, 2004). It also brings additional transportation costs since it has to be shipped back to its origin after usage. To be able to reuse the returnable packaging, the packaging should be designed to be safe and being able to withstand the multiple shipping, refilling and reuse by the producer, consumer, or retailer (Johnson, 2008). The reusing extends the material's useful life and may result in an increased return for the material input, which conserves resources by a decreased demand for new materials and less processing energy requirements (Johnson, 2008). Nevertheless, a returnable packaging system require cleaning, maintenance, storage and sometimes transportation which demands resources and administration of the packaging (Kroon and Vrijens, 1995).

Within a return system for packaging, it is important that all parties work together in order to maximize the return flows and avoid waste (Bowersox et al., 2013). When deciding whether a use of returnable packaging is suitable or not, Bowersox et al., (2013) recommends a number of factors you should have in mind; the volume of goods, cost for return transportation, cost for disposable packaging, impact on the handling and damages of the packaging, and costs for administration and maintenance of the returnable packaging.

An issue with returnable packaging is the difficulty with reverse logistics, that is, when the packaging has been used for bringing goods from a sender to a recipient, the packaging is transported as an empty package to the next sender to complete the cycle (Kroon and Vrijens, 1995). Another issue is that returnable packaging does not always return for reuse due to difficult to control or diverging flows, and, where in some cases, the cost of investigating the whereabouts of lost packaging units could be higher than the value of the packages (McKerrow, 1996). Thus, a returnable packaging system puts

high demand on infrastructural consideration to handle the sorting and return of empty returnable packaging and sometimes requires incentives to return the packages (Johnson, 2008).

2.1.2 Disposable packaging

The most common denominator for disposable packaging is that it can only be used once before it is discarded (Kroon and Vrijens, 1994). According to Dominic et al. (2000), using disposable packaging generates large amount of excess waste which contributes to scarcity of raw materials and creates a need for efficient waste management. Since disposable packaging often is made of cardboard or wood, it is vulnerable to weather damage. On the other hand, one main advantage of disposable packaging is that it is made of lightweight material which is good from an ergonomic point of view (Azzi et al., 2012). Other advantages with disposable packaging are the inexpensiveness of the material, the usefulness in one time shipments overseas and the recyclability of the material.

2.1.3 Comparison between returnable and disposable packaging

Coyle et al. (1996) explain that one of the most important factors when choosing packaging is the physical characteristics of the product, for instance dimensions, weight and type of material. Other key factors are the logistics aspects, such as mode of transport, material handling equipment, and the duration in storage. The choice of packaging further affects the information to be distributed in terms of labels and barcodes (Coyle et al., 1996).

When comparing returnable packaging and disposable packaging, the waste handling, the recycling process and the reuse of the packaging differ significantly (Pålsson et al., 2013). It is impossible to determine whether disposable packaging or returnable packaging is the best choice from an environmental and cost point of view since the benefits depends on the packages external and internal environment e.g. the product, distribution channels and market (Bowersox et al., 2013). Furthermore, Bowersox et al. (2013) state that in general, it is preferable to use returnable packaging in flows where the turnover rate is high, the geographical transportation distance is short and when the flow consists of large volumes without any major variations.

Skjøtt-Larsen et al. (2007) argue that, if returnable packaging is used outside of a closed distribution system, usually a deposit is needed in order to limit losses of the packaging, and that shrinkage or loss of returnable packaging should be added to the packaging costs. Furthermore, cleaning, return transports and administration are other costs that returnable packaging need to be accounted for and there are environmental aspects, such as emissions from and fill rates in the reverse logistics, that has to be considered when using returnable packaging. According to Skjøtt-Larsen et al. (2007), returnable packaging is heavier and rarely as volume effective as disposable packaging.

2.2 Packaging requirements

This section firstly describes and explains packaging requirements according to four perspectives, presented by Chan et al. (2005); the protective perspective, the handling efficiency perspective, the ergonomic perspective and the information perspective. After presenting theory about the requirement perspectives, trade-offs that may arise between these different perspectives are discussed.

2.2.1 The protective perspective

A basic function of packaging is to protect the goods from the outside environment during production, material handling, transportation, and storage (Chan et al, 2005; Twede and Parsons, 1997; Coyle et al., 1996). External factors that may impact the goods can be physical strains, such as shocks, vibrations, or compressive forces, but also other types of strains, such as the effects of heat and cold, moisture, corrosion, or theft (Twede and Parsons, 1997; Coyle et al., 1996). The protective perspective includes assuring arrival of goods to the user according to an agreed upon and pre-defined condition. The crucial performance measure in the protective perspective is strength and how the packaging will withstand the impacts, vibration, stacking and handling (Twede and Clarke, 2004). Insufficient protection and damaged goods can lead to destruction of the added value from production, additional costs in the form of replacement orders, additional administrative costs, and a loss in goodwill due to the delays (Coyle et al., 1996). However, the degree of product protection must be economically viable and depends on the product value and fragility, as more protection often equals higher costs (Chan et al., 2005).

2.2.2 The handling efficiency perspective

The handling efficiency perspective regards the convenience and handleability during internal and external distribution (Chan et al., 2005). Internally, the packaging should be adjusted to fit the production and integrated in the production and refilling system (ibid.). Externally, the packaging should ease handling, transportation, storing and information (Chan et al., 2005). Packaging have a large impact on the handling process and packages that are inconvenient to handle may cause workload disorders and product damage (Chan et al., 2005). The usage of standardized measurements can bring benefits in more efficient material handling with standardized equipment, increased volume utilization in transports and storage, and a better possibility to mix different product types in certain spaces (Twede and Parsons, 1997). The packaging sizes should be designed to apportioning the product into a desirable size, weight, and amount, with a consideration to the level of tied-up capital (Chan et al., 2005).

2.2.3 The ergonomic perspective

Ergonomics means adapting work activities to the workers in order to prevent risks of accidents and poor health (Arbetsmiljöverket, 2016). There are three ergonomic aspects to consider when planning and organizing the work; the physical, the organizational and the mental aspects of the work environment. Ergonomics is often linked to productivity, and the importance of integrating ergonomics aspects when improving activities within the company is stressed by several authors (Battini et al., 2011; Azzi et al, 2012). It is necessary to consider issues connected to ergonomic in packaging design, such as the opening of the package, the picking or emptying process, and the

handling procedures, both to improve productivity but also the workers' health (Rosenau et al., 1996; Hellström and Saghir, 2007; Olsmats, 2000). Manual lifting and handling of various industrial packages are most often required in industrial production, which can result in debilitating injuries due to activities such as bending, lifting or repetitive motions (Azzi et al., 2012). Azzi et al. (2012) further stress that the logistic and production system should be designed with an ergonomic aspect in mind, in order to reduce or eliminate work injuries. However, in certain cases, e.g. manual warehouses, picking areas or manually assembly lines, it is not possible to avoid work that requires to be handled manually by the operators (Azzi et al., 2012). Therefore, the design of the packaging need to compass the ergonomic requirements in terms of weight limits, optimal handholds and reach requirements (Rosenau et al., 1996).

2.2.4 The information perspective

An important packaging function is to distribute information and to represent the product it carries throughout the chain of distribution (Chan et al., 2005). Identification of the goods can be done with for example barcodes and RFID, and included information can be origin, manufacturer, product, amount, and part number (Bowersox et al., 2013; Coyle et al., 1996). Chan et al. (2005) explain that there are high costs involved in the handling of incorrect products, goods damaged by incorrect handling, and reclamation of secondary or tertiary packaging. Information regarding handling instructions, such as temperature restrictions, stacking directives or information about dangerous goods, should be mediated by the packaging in a clear and efficient manner (Chan et al., 2005). In international environments, the effectiveness and efficiency of the information flow along the whole supply chain can be improved by the use of unambiguous and easily understood symbols or coding (Chan et al., 2005).

2.2.5 Trade-offs between the four perspectives

When designing a packaging, it is clear that compromises need to be made between the various packaging functions and requirements, and the role of the packaging needs to be considered within a systematic approach (Azzi et al., 2012). There are often interdependencies between different aspects, e.g. ergonomics issues might drive for designing smaller packages which bring higher material consumption, and an increase of the packaging's protective level might reduce the risk of damaging the products related to handling, but may in contrast cause unnecessary waste and costs. Mollenkopf et al. (2005) emphasizes how changes in one perspective might cause the entire system to change due to the interactions between the different requirements.

Innovation in packaging might drive positive interactions and create synergies among different perspectives (García-Arca et al., 2006; Gustafsson et al., 2005; Rundh, 2005). As an example, improving the space utilization in transports brings lower costs as well as environmental benefits.

2.3 Management and handling of packaging waste

According to Golinska (2013), studies regarding forward logistics, including development, production, sales, and consumption of products are prominent and advanced, whereas studies on reverse logistics, and the elements of collection, transportation, recycling, and reuse of wastes, are falling short. Nevertheless, companies are nowadays obliged to take responsibility for their waste, and this creates a need for efficient handling of the company waste (Golinska, 2013). Nyström (2006) claims that waste can be seen as a hidden resource and that analysing the waste can be economically rewarding for a company. Every package that is discarded, has once been purchased and transported to the company, and there is a, sometimes significant, cost for the waste disposal service. Thus, if reducing the amount of waste, there may be savings to both the purchase and the disposal cost (Nyström, 2006).

Companies should strive to have both economically and environmentally sustainable waste management systems (White et al., 1995). The operating cost of the system must be to an acceptable level, at the time as keeping the emissions, energy, and non-recyclable waste as low as possible. White et al. (1995) state that there must be a holistic view on the waste management, due to the fact that all processes within the waste management system are interconnected. As an example, the collection and sorting method will affect the possibility to recover materials.

Levy (1993) recommends a quantitative prevention as well as a qualitative improvement of packaging waste, a maximization of the recovery of packaging waste, and a minimization of the final disposal of packaging waste, in order for companies to decrease their environmental impact from their use of packaging. Both disposable and returnable packaging solutions ought to be developed and manufactured with regards to resource efficiency by decreasing the amount of material required to manufacture the packaging (Dominic et al., 2000). The development and production of packaging should consider waste minimization by enabling recyclability, and the usage of dangerous substances should be avoided or minimized (Dominic et al., 2000). Furthermore, different packaging alternatives must be weighed against each other. On one hand, disposable packaging causes excess waste which has to be transported to a disposal centre, but on the other hand, returnable packaging has a need for maintenance, cleaning and reverse logistics (Dominic et al., 2000).

3 METHODOLOGY

The methodology describes how the thesis project was executed in order to fulfil the aim. Therefore, this chapter presents the arrangement of the study and the course of action that have been used during the project.

3.1 Research strategy

Considering that the aim of the study is to identify potential effects in a company's internal logistics processes due to an increased usage of disposable packaging, the assessment was made that an extensive part of the study was to understand and to map the current state of their logistics processes. Furthermore, this resulted in a need for a research strategy where new theory could iteratively be applied to the research in conjunction with insights that developed along the process. According to Patel & Davidson (2003), abduction is a way to execute research that unites the research strategies induction and deduction, where induction regards collecting and analysing data in order to formulate a hypothesis, and deduction formulates an hypothesis based on theory and develops a test to examine the hypothesis. Hence, the chosen research strategy of abduction, oscillates between the two different ways of relating literature to empirical findings, and allows the researcher to make new findings which leads to new literature studies, which in turn can be tested, during the research project (Patel & Davidson, 2003).

3.2 Data collection

The two main approaches of collecting data are qualitative and quantitative data collection (Bell and Nilsson, 2006). A study can combine the two ways and one approach does not exclude the other (ibid.). Bell and Nilsson (2006) describe that the quantitative data collection gathers facts and compare different grouping or formations of the collected data, whereas qualitative data collection emphasizes individual views before statistical connections. Eliasson (2013) claims that the qualitative approach is better suited when the problem is vaguely defined or difficult to understand, and thereby hard to quantify. Consequently, the data collection in this study has mostly been of qualitative nature.

Furthermore, the information that is collected can originate from either primary or secondary sources (Bell and Nilsson, 2006). The source is defined as primary if the information was gathered during an ongoing study in order to fulfil the study's aim, or defined as secondary if the information was gathered before the start of the study as an interpretation of a primary source (ibid). This research has mostly been based upon primary sources with interviews, observations, and activities on-site. However, the informative material provided by Volvo Group have been a mix of primary sources, for instance material from the larger project *Next Generation Packaging* which this thesis work is part of, and secondary sources, such as the documentation of Volvo Operations Concept.

3.2.1 Literature review

An initial literature review was conducted in order to create an appropriate foundation for the master thesis. The information from the literature review was mainly received from the database of Chalmers Library and Google Scholar, together with the following

keywords: disposable packaging, returnable packaging, packaging requirements, and internal logistics. Previous knowledge about the subjects in question has been obtained in master level courses at Chalmers University of Technology, such as Production Flow, Supply Chain Management, Lean Production, Project Management, and Sustainable Logistics. The literature review, together with previously obtained knowledge, worked as preparation for the empirical data collection. Furthermore, in this thesis project, the primary sources have shaped the work and have often led to a subsequent gathering of theory. Several changes have been made to the theoretical framework as new discoveries were found while gathering the empirical data.

3.2.2 Interviews and questionnaires

Information and opinions about an increased usage of disposable material and different aspects to consider have been gathered through interviews and questionnaires. Bryman et al. (2011) emphasise the need to avoid that the participants in the interviews and questionnaires experience an infringe on privacy or a lack of informed consent. Therefore, all participants were informed about what the purpose of the interview was, how the results were to be used and was given the option be anonymous and to review the work before it was published.

The interviews were conducted with people from different levels within the company, as well as various positions and departments, that possessed relevant knowledge or experience to the study. The interviewees were operators at the factory, local Logistics Technicians, regional Logistics Engineers, regional Packaging Development Project leaders, the regional team of Packaging Engineers, the regional Internal Logistics packaging team including their manager, and Ergonomic Experts. The interviewees were identified through a stakeholder mapping in collaboration with the supervisor from Volvo Group. The interview methodology chosen was semi-structured interviews, since this method allows the interviewer to be flexible, to rearrange questions and to ask follow-up questions which were not included in the interview template (Patel & Davidson, 2003). The interviews were based on some prepared questions according to the funnelling technique, where the starting questions were general but turned more and more specific towards the end question, as this is considered to increase the interviewee's motivation to partake (Patel & Davidson, 2003). See Appendix 1 and 2 for interview questions. However, the prepared sequence of questions was only used as guidance for the interviewers and rarely followed from start to finish. The interviewees were controlled in the aspects of keeping to the subject of investigation, but otherwise free to explain in their own words.

In order to get a broader view and reach out to more people while performing the tests, questionnaires were handed out as well. One questionnaire was sent out to a team of Packaging Engineers after they had participated in an ad-hoc evaluation of the disposable packaging, which was performed by the Packaging department but also functioned as input to the thesis work. The results of this questionnaire can be seen in Appendix 3, for pallets, and Appendix 4, for boxes. Another questionnaire, which can be seen in Appendix 5, was used during the test activities, which was primarily answered by the operators who are handling the packaging material on an everyday basis. These persons were considered to have relevant input, but not enough available time to attend an interview. The results of the questionnaire can be seen in Appendix 6.

3.2.3 Material Flow-Mapping

Value stream mapping is an important technique in lean manufacturing and a tool to identify waste and assess value adding and non-value adding activities in operations (Rother and Shook, 1999). The method is widely used in industrial settings but focuses on the flow of the value stream, i.e. all actions required to develop and bring a product from raw material to the customer (Rother and Shook, 1999). However, value stream mapping is not suitable to describe the materials supply processes, i.e. a large part of the internal logistics processes, since all those processes are regarded as non-value adding. In order to evaluate and describe materials supply processes and develop a foundation to improve them, Finnsgård et al. (2011) have developed an adaptation of value stream mapping, that is the Material Flow Mapping tool (MFM). This tool contains appropriate measurements to assess the performance of materials supply activities, which are defined as either handling, administrative, transportation or storage processes. The methodology of MFM involves the process steps of deciding the study object, scope and requirements, collecting data, compiling the collected data, analyzing video material, compiling the actual MFM, performing an HATS (i.e. Handling, Administration, Transportation, and Storage) analysis, and re-iterate to ensure validation of results (Finnsgård et al, 2011). According to the developers of this tool, Finnsgård et al. (2011, pp.3), MFM is:" an important contribution in describing the materials flow, making flows of necessary non-value adding activities visible and acts as the tool to support operational improvements".

The first step according to Finnsgård et al. (2011) is to decide on the scope of the mapping and the requirements from the end user. In this case, no self-evident end user could be identified as the packaging tests would extend beyond the operators, and the requirements was instead determined by Volvo Group. The requirements were to be able to test both disposable pallet and box solutions from Papyrus Supplies, which was already used by VCC, and to later on test them in the different processes. The decision was made to test the equivalents of the most commonly used V-EMB (standardized packaging types) at Volvo Group, i.e. the L-pallet, the 750 box and the 780 box, to which the amount of transactions can be seen if figure 3.1.

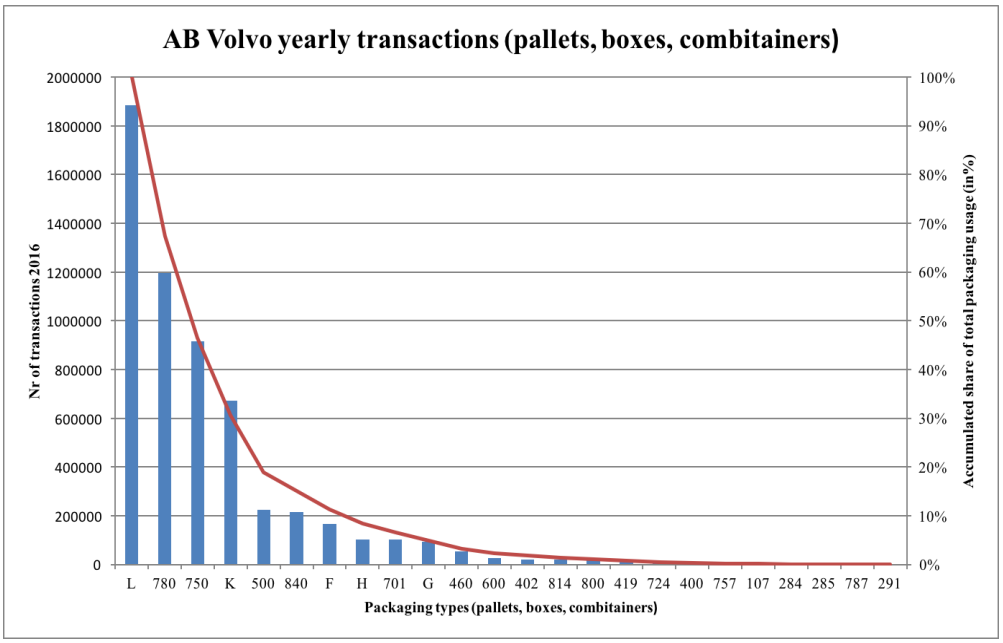


Figure 3.1. Volvo Group's amount of transactions for standard V-EMB packaging types 2016.

The specific part numbers, carried by the mentioned packaging types, for which flows to follow - from goods delivery to point of use to recycling - were decided together with the supervisor, a Logistics Engineer and a Packaging Engineer at Volvo Group. This resulted in two pallet flows, one for wiper panels which goes through a kitting station where there was a possibility to improve the ergonomics and one for a component to the dashboard in an internal sequencing area, for which with the cardboard packaging could enable a bigger pallet and more layers due to the sleeves. Four part numbers packaged in boxes were decided upon, where two were heavy (heavier than 10kg) and two were lightweight (lighter than 7kg), and two of them went to a pre-assembly station, one to a kitting station and one to the main line. This resulted in five different box flows to follow, since two of the part numbers had identical flows all the way from goods receiving to point of use. The five flows together covered all logistics processes that the disposable packaging needed to be tested in, in order to ensure endurance and applicability before a possible implementation.

Regarding data collection, Finnsgård et al. (2011) explains that one must decide whether to follow the flows upstream or downstream, where following the flows upstream is preferred in the VSM methodology to assure conformity to customer requirements. However, the decision was made to follow the flows downstream to ease the process and consume less time. The separate flows of the pallet components were followed one at a time, whereas the box flows were followed as one until the supermarket and thereafter in three different flows. Finnsgård et al. (2011) recommends following the components without interference and to record the flow by video to enable timestamps and repetitions. Due to a camera prohibition, no recordings could be done but duplicate and extensive notes were taken on all process steps. When there were any uncertainties, the operators were asked to explain the procedures in order to fill in the gaps.

The data collected was visualised in a schematic picture where the different process steps were shown and categorised as handling, administration, transportation, or storage according to the MFM process by Finnsgård et al. (2011). Since no video material was allowed, the notes taken during the data collection were compared and relevant data was compiled into the picture. A summary of the number of different process categories, i.e. a HATS analysis, followed. Both the summary and the schematic picture was conferred with the persons involved in deciding the flows.

3.2.4 Test activities

The literature study provided an understanding of different packaging requirements, and the material flow mappings were performed in order to create knowledge about the logistics processes. A combination of the literature study and the MFM:s created the foundation for the test activities, where the processes were tested with disposable packaging solutions according to the four packaging requirements developed from theory. The same five flows, that were studied and mapped in the MFM:s in their current state, were examined through test activities for every station that can be seen in Table 1 beneath. Goods of the chosen part numbers were placed in disposable packaging and the compatibility to the current processes, as were studied with returnable packaging, was evaluated. As in the current state MFM, all flows were followed downstream and the different pallet flows were followed individually after goods receiving but the box flows were followed as one flow until the supermarket and then divided into three

different flows. With the current state MFM and HATS analysis as a base, all processes in the tests that were affected by the change in packaging could be noted.

The supervisor, the Logistics Engineer and the Packaging Engineer at Volvo Group helped to map the different people that needed to be involved or informed at the different stations; goods receiving, automated storage, local storage, internal sequencing, Pallets-On-Wheels, kitting, supermarket, pre-assembly and the line. See Table 3.1 for more details about the tests at respective station. A questionnaire was developed to extract the opinions from involved persons at the different stations.

Table 3.1. The setup for the tests.

Station	Tests	V-EMB Equivalent
Goods receiving	Stackability test, Handling test	L4, L3
Automated storage	Compatibility test	L4 on slave pallet base unit
Local storage	Placement test, Handling test, Forklift mistreatment test	L4
Internal sequencing	Picking test	L4
Pallets-On-Wheels	Loading and unloading test	L4
Kitting	Picking test	L4, 780
Supermarket	Placement test, Handling test	780, 750
Pre-assembly	Picking test	780, 750
Line	Picking test	750
Handling and breakdown of empty packaging	Breakdown test, Disposal test and discussion	L4, L3, 750, 780

The stackability test was to ensure stackability of the disposable pallet even if the top pallet was not placed correctly on the corner lists (explained further in 4.2.2) and to evaluate the stackability during movement of the pallet stack. The different handling test were to determine the handleability of the disposable packaging solutions in the current processes, with current equipment, i.e. different trucks, and also by manual handling of the boxes in the supermarket. The placement tests were to investigate whether the disposable pallet base units could be stored in the storage shelves, as is optimized for V-EMB. The forklift mistreatment test investigated the fragility of the pallet base unit towards the spreading of forklift's forks, where the forks were spread outside their normal range. The loading and unloading on a POW unit was tested with the current equipment, and the picking from both disposable pallets and boxes were tested at different stations. Furthermore, the breakdown was tested though manual disassembly of the disposable solutions, whereas the disposal test was a simulation of possible future scenarios followed by a discussion of the suitability of the different alternatives.

3.2.5 Volvo Car Corporation Benchmark

To complement the observations made in the production facility at Volvo Group Trucks, benchmarking against Volvo Car Corporation (VCC) was executed in order to enable a comparative analysis. VCC was chosen because it is a company that operates in the same industry and have had similar problems that Volvo Group has now. Thus, benchmarking against VCC was regarded as likely to generate several applicable learnings. The comparison was based upon an interview with a logistics representative from VCC a walking tour in the production facility. A third MFM was not considered necessary to conduct since the expenditure of time was too high in proportion to the gain, and as their solution only was to inspire a solution for Volvo Group, not to be copied.

3.3 Data analysis

The literature and the collected data from the MFM:s, interviews, questionnaires, tests and the benchmark were combined and compiled in the chapter *'Identification of effects'* and the authors' own views on the test results as well as aspects outside the scope were revealed in the chapter *'Discussion'*. The aforementioned includes descriptions of the effects and different concerns. The magnitudes of the effects were estimated and summarized in the latter.

3.3.1 Identification of effects

During the test activities, observations were performed and all processes belonging to the different stations were tested. From this, the effects at each station were evaluated and categorized according to the four packaging perspectives from the theoretical framework. Both positive and negative effects of changing to disposable packaging could be identified, which were summarized in an overall evaluation of the disposable packaging. The overall evaluation is based on the advantages and disadvantages of the two packaging alternatives, disposable and returnable, and on an estimate grading of the effects in the internal logistics processes in Volvo Group factories.

3.3.2 Aspects of discussion

The categorization of effects at each station functioned as a foundation for a wider discussion of the packaging in accordance to the four perspectives. The results from the tests were combined with theory, and certain obstacles that Volvo Group needs to address before implementation, could be highlighted. Since there was no current process for handling and breakdown of empty disposable packaging and the test only was to investigate an adjusted alternative to the handling of V-EMB, the handling and breakdown of empty packaging needed to be further analysed in order to evaluate more options. Different handling processes for the empty disposable packaging, as suggestions from the master thesis students and based upon their overall learnings, and the implications of these were discussed.

Furthermore, the discussion chapter discloses aspects outside the scope of the thesis since these are regarded to have too big of an impact to be neglected. The last subchapter reveals the importance of having a supply chain perspective, conveys a proper area of usage for disposable packaging within Volvo Group which is the KD operations, and remarks that attitudes towards change should be managed.

3.4 Trustworthiness of the study

Four main areas are considered in order to obtain trustworthiness of the research; credibility, dependability, conformability and transferability (Bryman et al., 2011). This section describes these four areas.

3.4.1 Credibility

A risk with the abductive research approach, described by Bell and Nilsson (2006), is that the researcher might be affected by its own impressions or experiences, and that no studies is done unconditionally. This was noticed while performing the research, since the conducted interviews often tended towards the issues that was of highest interest to the interviewee. An additional risk might be that people recommend who to talk to depending on what opinions one might have, which has to be taken into consideration in order to avoid a biased truth. To preserve objectivity, the literature study, the material flow mapping and the test results were given more weight in the analysis than the interviews.

A negative effect of gathering data by distributing questionnaires is that supplementary questions cannot be set. Therefore, it is important to formulate the questions as clearly as possible and leave room for the respondents to leave any other comments. The questionnaire that was handed out during the test activities, which can be seen in Appendix 5, was arranged for the person that fills it in to agree to certain statements on a scale from "does not agree at all", grade 1, to "agrees completely", grade 5. This leaves a big risk of getting inaccurate results, as the intuitive way to rate a packaging, if not reading the instructions properly, might be according to an inclining scale from "bad" to "good". To increase the reliability and to ensure the quality of the study, the method of triangulation was used. This means that the examined information is viewed from different perspectives to identify convergence between different sources and to increase the understanding of the problems (Denscombe, 2009). Information that emerged from the test questionnaire was compared to information gathered from the interviews and the packaging evaluation questionnaire to mitigate these risks. Also, persons from different levels and departments were interviewed and answered the questionnaires, which further contributes to the different perspectives and thereby the reliability of the collected information.

3.4.2 Dependability

Regarding the aspect of dependability, Bryman et al. (2011) argues that the researcher should use an auditing approach, which means ensuring complete records such as fieldwork notes and interview transcripts. All interview notes taken by the two research members were compared afterwards to minimize the risk of faults or misinterpretations, and the interviews were recorded and replayed in case of information gaps.

Since the research team have had limited access to the factory, the quality of the study has been ensured through Volvo Group reviewing produced material. Drafts and mappings have been sent to concerned parties for control and approval. During the MFM:s, no video recording was allowed and thus, no video material was gathered. Nevertheless, the representation of the collected data in a schematic picture was verified by a Logistics Engineer with expertise in the Tuve factory's internal logistics processes.

Furthermore, the test activities were developed in consultation with the same Logistics Engineer, a Packaging Engineer and the Volvo Group supervisor.

3.4.3 Conformability

Bryman et al. (2011) describe conformability of a study as a study where the researchers have not allowed personal values. The conformability will increase since the study, which means all interviews and observations, were performed by two persons, and discussed afterwards, in order to ensure that the same view had been received.

3.4.4 Transferability

Since the study was performed on behalf of Volvo Group, its prime and most appropriate area of application is this company's specific situation. It is considered difficult to draw a conclusion whether if it is applicable in other industries or not. Still, the study conveys a methodology for how and in what ways a company may map the logistics processes, as well as a framework for evaluation of different packaging types. Hence, the research and the results might be interesting for other companies which are investigating packaging requirements or effects of different packaging types in internal logistics processes.

4 IDENTIFICATION OF EFFECTS

In this chapter, information gathered from the Material Flow Mappings will be presented along the results from the tests, questionnaires and interviews. The chapter will firstly describe Volvo Group's predefined packaging requirements. Thereafter, the chapter set-up is to present the pallet preconditions and the empirical findings in accordance to the sequence of the logistics processes for the two pallet flows, and after this present the box preconditions and the findings for the three box flows according to the same rationale. The test results are divided according to the four different packaging requirement perspectives described in the theoretical framework.

4.1 Volvo Group's overall packaging requirements

Volvo Group have defined their own basic packaging requirements that all packaging container must fulfil. The containers must ensure the quality of the part, i.e. that the part is clean, dry, and not exposed to dust, which correlates to the protective perspective. The containers must be stackable with a high filling rate when transported, must be easily picked up and taken out, and must support efficient handling, which counterpart is the handling efficiency perspective. The containers must satisfy ergonomic demands, which includes easily built-up and collapsed, lightweight, and safe, which is equivalent to the ergonomic perspective. Furthermore, what is not explicitly stated but still demands, is that all containers must be able to carry the standard label for the automotive industry, which corresponds to the informative perspective.

4.2 Pallet preconditions

With the requirement to test a pre-decided pallet solution that was used by VCC, two pallet flows were chosen. These represented the most common paths for pallets at the factory, but also brought the possibility of improvements for the specific carried part numbers. The first flow with wiper panels was chosen to investigate whether it could bring ergonomic benefits to the kitting station. The other flow with a component to the dashboard in an internal sequencing area was decided upon to see if the disposable solution could enable a bigger pallet and more layers due to the hatches on the pallet from Papyrus Supplies, which can be read more about in Chapter 4.2.2.

4.2.1 Returnable pallet

The standard Volvo Group returnable packaging, V-EMB, includes five different pallet sizes in the L-format and all L-pallets are composed of a wooden pallet and a number of pallet collars, see figure 4.1. The pallets generally also have a bottom sheet.

Figure 4.1. Volvo Group's standard wooden returnable pallet (without a lid) with different insert sheets inside.

All sizes have the same inner and outer length and width, 1178x773mm respectively 1225x820mm, but varies in height and therefore also in the weight of the empty pallet. The different pallet sizes are called L1, L2, L3, L4 and L5 where the letter L represents the format and the digit represent the height due to the number of pallet collars. Every collar corresponds to a height of approximately 195 mm. The total weight of the pallet and the carried goods is not allowed to exceed 1000 kg. The weight of an empty L3 pallet is 61 kg and an empty L4 pallet is 71 kg.

4.2.2 Disposable pallet

The disposable pallets from the packaging wholesaler Papyrus Supplies, that was used to conduct the tests, was in the most commonly used sizes of the V-EMB, i.e. in the sizes of L3 and L4. The disposable pallet solution provided by Papyrus Supplies consists of one wooden nail-free pallet base unit (outer dimensions 1196x820x138mm), a cardboard bottom sheet, four wooden corner lists, a cardboard sleeve, a cardboard lid and a lid sheet, all components apart from the lid sheet can be seen in figure 4.2.

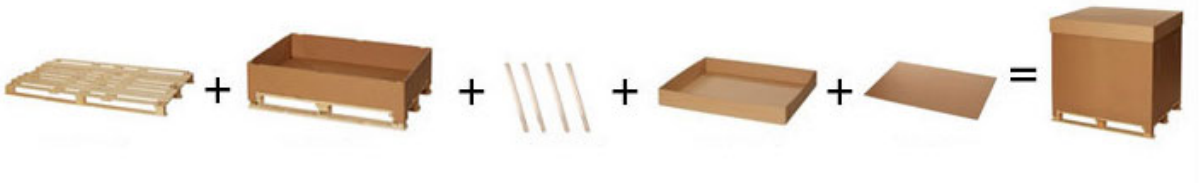


Figure 4.2. Composition of the Papyrus disposable pallet solution (apart from the lid sheet).

The sleeve has hatches on one short side and one long side, which are proportional in size to the height of the sleeve, i.e. larger hatch on the L4 equivalent than on the L3 equivalent. This, in turn, ensures that the side of the sleeve never is higher than the height of two pallet collars with the hatch folded down. The sleeve cannot be used with the V-EMB pallet base unit and the Papyrus Supplies disposable pallet base unit cannot be used with V-EMB pallet collars. In comparison to the V-EMB pallet, the disposable pallet skids are somewhat less wide (V-EMB 1225mm wide; Papyrus Supplies 1196 mm wide) but equal in length. The pallet should not carry more than 300 kg of goods, as the sleeve sides can break with the pressure from more weight. The pallet can be stacked in stacks of three and does withstand a static pressure of 450 kg with safety factor 6.

4.3 Pallet findings - Current processes and test result

The pallet flows were studied in their current state by the use of the MFM methodology but also in their possible future state with disposable alternatives through different tests. The examined and tested stations or processes for pallet flows were goods receiving, automated storage, local storage, internal sequencing, Pallets-On-Wheels loading and delivery, kitting, and handling and breakdown of empty packaging. The goods receiving station is the same for the two pallet flows, as well as the handling and breakdown of empty pallets. The wiper panels pallet travels according to the top flow in figure 4.3, and the dashboard component according to the bottom flow in the same figure, for more detailed description of the flows, see Appendix 7a and Appendix 7b.

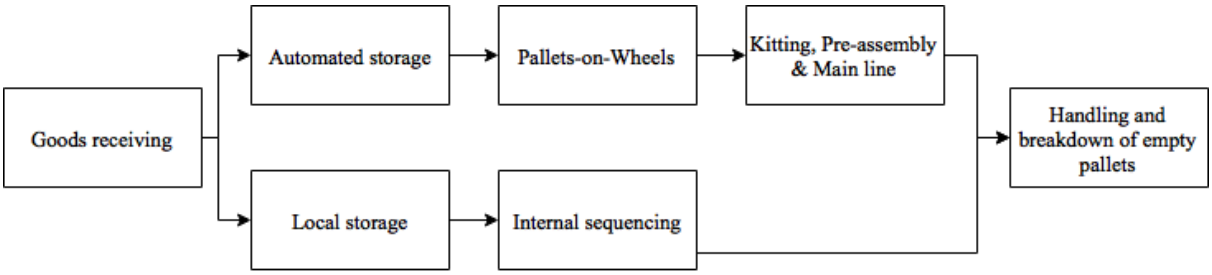


Figure 4.3. The two different pallet flows at Tuve factory.

4.3.1 Goods receiving

Goods receiving is the process of registering, unloading, controlling, and sorting goods, and then allocating it to a designated area. There are only one goods receiving area at the Tuve plant, which is located outside the factory but sheltered with a roof. All handling of the goods at this station is done by forklifts. Pallet identification and matching are done using scanning devices, and the assignment of storage areas is done manually by typing the storage number on the label. The process steps belonging to goods receiving in the MFM is; registration, unloading, scanning, pallet location, sorting, move pallet to conveyor, transportation on conveyor, and quality inspection, see Appendix 7a for more detailed explanations of the process steps.

If a pallet does not fulfil the demands on size, weight or dimensions according to its label, it is transferred to the repackaging station. Currently, all disposable pallets result in a quality reject and is re-packed into V-EMB.

Protective perspective
There are protective drawbacks to disposable packaging in goods receiving, as the material could more easily be damaged or brake if the long forks on the forklifts were placed wrong. The goods receiving operators' general view was that the Papyrus Supplies pallet would not provide sufficient or as much protection as the V-EMB. However, as noted by the Packaging Engineer and the forklift drivers at this station, a cardboard package immediately calls for a more cautious treatment which decreases the increased risk of damaging the packaging or goods. Furthermore, the Packaging Engineers further believed that disposable packaging might lead to a more even quality level than returnable since there would be new packaging for every usage loop, which will have an impact on all flow processes.

Concerning weather aspects, such as rain and moisture, the disposable solution is less durable and does not withstand the weather as good as the V-EMB pallet. The goods receiving processes should nonetheless be executed beneath a ceiling and during a somewhat limited time. However, the Papyrus Supplies pallet is to be discarded after one usage which lowers the need for weather endurance.

Handling efficiency perspective
The Packaging Engineers questioned the possibility of picking entire stacks of pallets from trailers, as done with the returnable V-EMB. The trailer unloading process was unfortunately never tested, since the incoming trailers are from external suppliers and their time could not be imposed on. Although, the friction when stacking the disposable pallet on top of each other was tested and no extensive sliding was done. Still, the concern of picking entire stacks remains.

The disposable pallet should not be stacked with more than two pallets on top to ensure a safe handling, but this should not be a major issue since L3 and L4 pallets rarely are stacked in higher stacks than three. The stacking weight limitations on the Papyrus Supplies pallet of 450 kg might however bring handling efficiency drawbacks since some of the V-EMB, which has a weight limitation for packaging and goods of 1000 kg in total, cannot be stacked on top. This might require new guidelines for loading procedures for trailers as well as train sets.

Ergonomic perspective
No implications on ergonomics were found when changing from returnable packaging to disposable packaging. This since all handling are done with the use of forklifts.

Informative perspective
Neither the Packaging Engineers or the goods receiving operators discovered any effects on the informative perspective. The label could be placed in the bottom left corner as on the V-EMB pallet and there was no issue with the glue's adherence to cardboard.

Figure 4.4. Symbol regarding stackability on the Papyrus Supplies pallets.

The pallets have informative symbols regarding their maximum stackability height of no more than three, as can be seen in figure 4.4. The symbol does not however include the weight limitation, nor explain whether V-EMB should be placed on top.

4.3.2 Automated storage

The automated storage is a high-bay warehouse for pallets where all handling is automated with conveyors and robots. To be stored in this storage, the pallet must complete several tests concerning weight and size dimensions. The storage is designed to handle the format of L-pallets with a height limitation corresponding to five pallet collars. Smaller pallets or damaged L-pallets can be placed on a slave pallet base unit to be inserted in the automated storage, which decreases the height limitation to four pallet collars. The storage is controlled manually by a control unit, in case of unexpected events. The process steps belonging to the automated storage in the MFM is transportation on conveyor, quality inspection, transportation to warehouse, inventory, Kanban signal, transportation on conveyor and temporary buffer area, see Appendix 7a for more detailed explanations of the process steps.

Protective perspective
All transportation of the packaging is automated by conveyors and elevators. Hence, there are no concerns that the forklifts' forks will damage the packaging or goods.

Handling efficiency perspective
The pallets are handled one at a time and by the pallet base unit, which in this case is a slave V-EMB pallet base unit, which denotes that the processes for V-EMB and the disposable solutions can be regarded as equivalent. Apart from the placement on a slave pallet base unit, no implications could be found on the handling efficiency in the automated storage since all other handling is done automatically.

Ergonomic perspective
No implications could be found on the ergonomically aspects in the automated storage. This is due to the fact that no handling is done manually.

Informative perspective
The label could be placed in the same corner as on the V-EMB pallet and there was no issue with glue's adherence to cardboard. The label carries all information that is needed in the automated storage and consequently, there is no use of or need for the packaging's symbols at this station.

4.3.3 Pallets-On-Wheels

Volvo Group uses a concept of movable storage units, called pallets-on-wheels. The units are unloaded and loaded with pallets near the automated storage's delivery track and then transported in groups of five in a predefined transportation route to the different use points. This concept is used for parts with high, stable consumption and high frequency of delivery from local suppliers. In the test activity for the POW loading and delivery, a L4-pallet equivalent was tested as this pallet size is used for the wiper panels. The process steps belonging to pallets-on-wheels in the MFM is move to pallets-on-wheels, temporary buffer area, prepare tow train, link pallets together, pallet location, tow train transportation, move lid, move parts, switch pallet, link pallets together, tow train transportation, remove lid, disconnect tow train, move empty pallet and temporary buffer area, see Appendix 7a for more detailed explanations of the process steps.

Protective perspective
The forklift drivers' views were that the disposable pallet will provide enough protection to the goods. They did however not view the level of protection as comparable to the V-EMB.

Handling efficiency perspective
The forklift drivers could not foresee any implications in their processes if changing the pallets from wooden to cardboard. The disposable pallet could, according to them, be used in the current process. A statement from the Packaging Engineers was that the more fragile packaging, the cardboard pallet, might call for more careful handling by the material handler.

Ergonomic perspective
When building the train in sequence and dragging the POWs into place, the Packaging Engineers noticed a potential positive effect with the lower weight of the disposable alternative, given that this is not compensate with more material inside. The ergonomics in the lifts, as the operators are lifting off two out every five pallet lids, would improve as the weight decreases.

Informative perspective
No effect on the informative perspective could be found. The label could be placed in the same corner as on the V-EMB pallet and there was no issue with the glue's adherence to cardboard.

4.3.4 Point of Use: Kitting, Pre-assembly & Main line

Kitting is a way of delivering optimally to the operator. Kitting is mainly applied for small and medium-sized parts and the kitted parts are placed on a trolley. The difference compared to sequencing is that different part families can be mixed within the same kit, but parts can be kitted together with a part in sequence. In the test activity for the kitting area, the picking of a wiper panel was tested in a L4-pallet equivalent.

Pre-assembly is performed close to the line and the often heavy parts are pushed to the main line using fixtures on wheels while an operator performs the sub-assembly of components. On the main line, the entire truck is produced and assembled. Regarding packaging, the pre-assembly stations and the assembly on the main line is the same as kitting with the exception that the picked parts are placed on a trolley in kitting but used in assembly at pre-assembly and on the main line. The picking from the pallet performed by the operator is nevertheless entirely the same and the operator does not manage the pallet itself in any of the stations.

Protective perspective
When picking material from the pallet, only the goods within the packaging are handled, not the packaging itself. Hence, and no issue regarding the packaging's ability to protect the goods can be noted in this activity.

Handling efficiency perspective
The possibility to fold down, or rip off and throw away the hatch, makes sure that the operator will never have to pick from a pallet deeper than a two-collar pallet, which might enable a more efficient picking process due to the easier reach. On the other hand,

if folded down and not placed upright afterwards, the hatch will obstruct the kitting aisle for the next operator and cart due to the narrowness of the aisles. This calls for a requirement to either always fold up the hatch, which takes away some efficiency while picking the item, or to discard the hatch with the first pick, which demands an entire new process on how to rip the hatch off and where to place it. Whether the benefits in handling efficiency will outweigh the time for this new process depends on, for instance, the possibilities to locate a bin nearby.

Ergonomic perspective
The Packaging Engineers saw ergonomic benefits with the Papyrus Supplies pallets due to the perforated hatch. The possibility to fold down, or rip off and throw away the hatch, makes sure that the operator will never have to pick from a pallet deeper than a two-collar pallet, i.e. L2. With the cardboard solution, even the entire wall could be discarded if preferred by operator. The operator at the kitting station expressed very positive opinions to the hatch and to a change from V-EMB to this disposable pallet provided by Papyrus Supplies.

Informative perspective
The pallet label is placed out of sight for the operators, as is the case for V-EMB as well, but no issue emerged due to the fact that the operators pick by light. The operators have no use for the label since all needed information is placed on a sign above the pallet location.

4.3.5 Local storage

The local storage is a storage area in connection to the workstations at the line and stores material mainly used in the production at the line. The local storage demands frequent deliveries of parts as space is limited. The storage can handle all pallet sizes, but is designed and optimized for storing L-pallets. The process steps belonging to local storage in the MFM is unloading, scanning of label, place pallet in local storage and inventory, see Appendix 7b for more detailed explanations of the process steps.

Protective perspective
The local storage operators' general view was that the disposable pallet would not provide as much protection as the V-EMB, but it could still be sufficient for certain goods. There were concerns about the packaging's protective function, as the disposable pallet could more easily be damaged if the forks on the forklifts were placed wrong. An empty disposable pallet base unit with sleeve was tested in a forklift mistreatment test, where it did withstand for several beatings and pushes.

Handling efficiency perspective
The Packaging Engineers saw an implication on the handling efficiency due to fragility of the packaging itself and that the cardboard pallets might have to be handled with more care, i.e. in a more time-consuming way, than wooden pallets by the fork lift driver. They also expressed a concern for the disposable pallet to have a higher a potential sensitivity to spreading of the forklift's forks. The disposable pallet was tested in an forklift spreaders endurance test, where the skid blocks moved a centimetre but the pallet as a whole pulled through. Furthermore, there was no issue with shelf compatibility for the Papyrus pallets, even though the skids on the pallet base unit are somewhat less wide.

Ergonomic perspective
No implications on ergonomics were found when changing from returnable packaging to disposable packaging. This since all handling are done with the use of forklifts.

Informative perspective
Neither the Packaging Engineers and the local storage operators uttered any implications on the informative perspective. The label could be placed in the same corner as on the V-EMB pallet and there was no issue with the adherence to cardboard, irrespective when done by glue or thumbtack.

4.3.6 Internal sequencing

Sequencing is regarded as a point of use and means that parts are picked from the short side of pallets in a sequencing aisle and placed on a rack in the same order as the product sequence on the production line. There can be material for one vehicle per rack, or parts for several vehicles in the same rack. In the test activity for the internal sequencing area, the picking of a component to the dashboard was tested in a L4-pallet equivalent. The process steps belonging to internal sequencing in the MFM is Kanban signal, take pallet from local storage, move lid, move parts and switch pallet, see Appendix 7b for more detailed explanations of the process steps.

Protective perspective
When picking material from the pallet, only the goods within the packaging are handled, not the packaging itself and no issue regarding the packaging's ability to protect the goods can be noted in this activity. However, there are concerns to the forklift handling while placing the full and removing the empty pallet to its picking location, as a cardboard pallet naturally is more fragile than a wooden one.

Handling efficiency perspective
Having the label on the short side with the perforated hatch, which was chosen due to is compatibility and benefits at the kitting station, resulted in no benefits for the operators in internal sequencing. The goods are picked by operators in one aisle but the pallets are placed in their locations by forklifts in the aisles beside, which demands the label to be placed away from the picking operators and towards the forklift drivers to enable scanning. Due to this, the hatches were also placed on the far end side to the operators picking aisle. Nevertheless, having perforated hatches on all sides or having the label on the opposite side would enable more efficient picking through an easier reach with the hatch down, compared to the same height of V-EMB where the collars are not removed.

Ergonomic perspective
The Packaging Engineers saw ergonomic benefits with the Papyrus Supplies pallets if the hatch was turned towards the operator. The possibility to fold down, or rip off and throw away the hatch, makes sure that the operator will never have to pick from a pallet deeper than a two-collar pallet, i.e. L2. With the cardboard solution, even the entire wall could be discarded if preferred by operator.

The disposable pallet's lid will further improve the ergonomics in the lift of the lid, from the full pallet to the empty one as part of the refill process, due to a lighter weight.

Informative perspective
The label could be placed in the same corner as on the V-EMB pallet and thereby be used in the same processes. Furthermore, there was no issue with the adherence to cardboard, irrespective when done by glue or thumbtack.

4.3.7 Handling and breakdown of empty pallets

Empty Pallets-On-Wheels are returned in the same delivery routes as the full V-EMB pallets are delivered in, since the full POW replaces the empty one at point of use and the empty one replaces the full one in the tugger train. The empty POW:s are returned to the POW loading area where the pallets are unloaded from the moveable units and loaded on a train set, which when full is transported to a docking point outside the factory. Empty pallets in the local storage, after been used in sequencing, are moved by truck to a train set at the short side of the storage. When the train set is fully loaded, it is transported to the same docking point. At the trailer loading location, the empty pallets are moved from the train set straight onto a trailer. The trailers are either loaded with only L-pallets, or with a combination of other pallet sizes than the L-format. Volvo Group's handling of the packaging ends with this, and the rest is outsourced to an external party.

The trailer is transported by truck to a DFDS terminal in Arendal. The empty pallets are unloaded outside at the backside of the terminal and are, if needed, sorted according to size. Thereafter, the pallets are moved to a conveyor that transports them into the terminal, where firstly a manual control of the pallet collars is performed and any garbage is removed. The pallets are then automatically dismantled, where one robot is assigned for dismantling pallets with one or more damaged pallet collars and two are assigned for undamaged pallet collars. At the end of the conveyor, the bottom sheet is removed and sorted one of different piles and thereafter the pallet base unit. DFDS is responsible for continuous maintenance, repairs, and cassations of V-EMB.

The process steps belonging to handling and breakdown of empty pallets in the MFM is load empty pallet on the train set, transportation to yard, load on trailer, transportation, unloading, sorting, move pallet to conveyor, transportation on conveyor, manual control, disassembly of pallets and removal of bottom sheet, see Appendix 7a and Appendix 7b for more detailed explanations of the process steps.

Protective perspective
The empty packages do not contain any goods and the protective perspective in that sense is therefore not necessary to evaluate. Furthermore, if the disposable packaging itself were damaged when empty, it would not matter since it is to be discarded after one use which can be seen as a benefit compared to returnable packaging that are to be used more than once.

Handling efficiency perspective
If the empty disposable pallets are taken out of the factory in the same way as V-EMB there will be no difference to material handling up to this point. An in-house breakdown and sorting of the wood and cardboard from the disposable pallets at the Tuve factory will unavoidably be more time consuming compared to only stacking the pallets in a return trailer. The Packaging Engineers note that this process cost must be compensated

by less cost of automatic break-down at DFDS in order for the implementation to even be considered. The process of removing the label before the next usage loop is unnecessary for the disposable pallet since the pallet is to be discarded after one use.

Ergonomic perspective
The Packaging Engineers explain that breakdown and sorting of wood and cardboard must be secured in a ergonomically correct way. The disposable pallet solution might bring ergonomic improvements in all factories apart from Tuve due to no handling of pallet collars.

Informative perspective
There are no symbols that explain the recyclability of the pallet components. Since the pallet is made out of both wood and cardboard, symbols that explains the recyclability would be preferable to have.

4.3.8 Pallet effects summary

To make an overall evaluation of the disposable pallet, and see where the effects might be greater or less, a compilation of the effects of a change to disposable pallets can be seen in Table 4.2. The effects have been graded as no effect, positive effect, or negative effect, in order get an overview of where and on which perspective to put most effort.

Table 4.1. Compilation of the effects of a change to disposable pallets.

Disposable pallet solutions	**Protective perspective**	**Handling efficiency perspective**	**Ergonomic perspective**	**Informative perspective**
Goods receiving	Negative effect *(fragility of material)*	Negative effect *(fragility of material)*	No effect	No effect
Automated storage	No effect	No effect	No effect	No effect
Local storage	Negative effect *(fragility of material)*	Negative effect *(fragility of material)*	No effect	No effect
Internal sequencing	No effect	Positive effect if hatch towards operator	Positive effect if hatch towards operator	No effect
POW	No effect	No effect	No effect	No effect
Point of Use	No effect	Positive effect *(better reach due to hatch)*	Positive effect *(better reach due to hatch)*	No effect
Handling and breakdown of empty pallets	Not applicable	Negative effect	Negative effect	No effect

4.4 Box preconditions

There are in general two different ways a box can be stored at the Tuve plant, either in local storage, i.e. supermarket, or in an automated storage. Since the automated storage for boxes is very sensitive and could not handle boxes made out of cardboard, this type of flow has been demarcated from the study.

With this as a limitation, four box flows were decided upon, where two were heavy (above 10 kg) and two were lightweight (below 7 kg). Two of them went to a pre-assembly station, one to a kitting station and one to the main line. These box flows together represented the processes that Volvo Group wanted to investigate.

4.4.1 Returnable box

Volvo Group's standard returnable packaging, V-EMB, includes eight different box sizes. All sizes vary in inner and outer dimensions and therefore also in the weight of the empty box. All boxes are conical with a border on top in order to be able to hold the box in an easier way. The two pre-decided types of boxes that were used when conducting the MFM and the test activities are called 750 and 780, see figure 4.5.

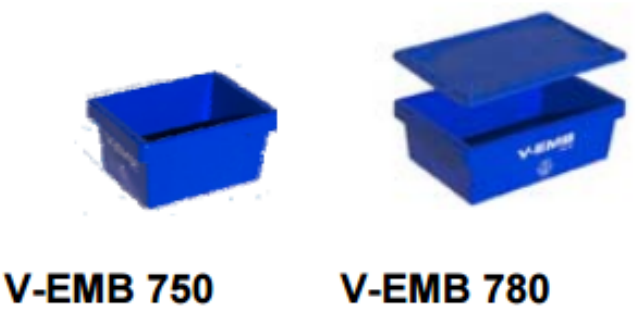


Figure 4.5. Volvo Group's standard returnable boxes in plastic, in the sizes 750 and 780.

The 750 box has a size of 400x300x200, with a volume of 15.7 litres and an empty box with lid has a weight of 1.51 kg. The 780 box has a size of 600x400x200, with a volume of 36.6 litres and an empty box with lid has a weight of 2.89 kg. All boxes can carry up to 40 kg but Volvo Group has a restriction of 12 kg if a box is to be handled manually, which applies to all sizes on boxes.

4.4.2 Disposable box

The disposable boxes that was used to conduct the tests comes from Papyrus Supplies whom can offer disposable box solutions in corrugated board in sizes which are equivalent with Volvo Group's standard plastic boxes. The size of a 750 disposable box has the dimensions of 360x265x190 mm which corresponds to 18.1 litres and the size of the 780 disposable box has the dimensions of 549x358x190 mm which corresponds to 37.3 litres.

Figure 4.6. The Papyrus Supplies boxes: corresponding to V-EMB 750 and to V-EMB 780.

The boxes can be seen in figure 4.6, and noteworthy is that the equivalent to the V-EMB 750 box has horizontal handles on the long sides, whereas the equivalent to 780 has vertical handles on the short sides as well as horizontal and diagonally placed handles on the long sides. Compared to the V-EMB, the disposable box solutions provided by Papyrus Supplies are not conical which means that the inner volume and thus the load capacity is greater. The maximum weight a disposable box can carry is 15 kg. However, since Volvo Group has a restriction of 12 kg, this is not an issue. The main advantages of disposable boxes according to Papyrus Supplies are as follows; recyclable, low weight, stackable, quick to fold and unfold, and no washing.

4.5 Box findings - Current processes and test result

Using the MFM methodology, the box flows were studied in their current state processes but also tested in their possible future state with disposable packaging through different tests. The four box flows that were tested covered together the following stations or processes; goods receiving, local storage, supermarket, kitting, pre-assembly, main line, and handling and breakdown of empty packaging. The flow, i.e. the order of the stations, can be seen in figure 4.7, for more detailed description of the flows, see Appendix 8a, 8b and 8c.

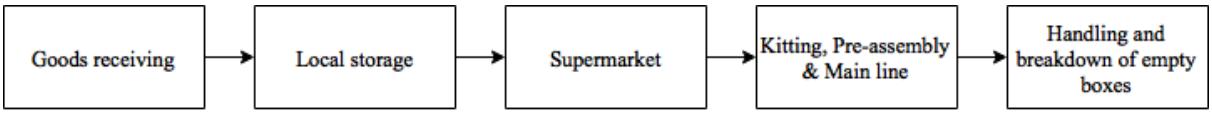


Figure 4.7. The box flows at Tuve factory.

4.5.1 Goods receiving

When the carrier arrives at the plant, arrival registration as well as formal documentation are made. The carrier is assigned an unloading spot and the goods are unloaded by a forklift. The forklift driver scans the labels in order to identify the box and ensure that the goods are consistent with the order confirmation. Meanwhile scanning of the label is done, the forklift driver writes down the location of the box on its label. The goods are then sorted depending on storage location and moved and loaded on a train set. When the train set is fully loaded, it is used to transport the goods from the yard in to the designated unloading area near the supermarket.

The plastic boxes are stacked on pallets in various combinations with a wooden lid on top of the top layer of boxes, and are held together with plastic straps. Each box on the pallet has one label and often (when there are many boxes on one pallet) there is a joint label, which facilitates the scanning process. The process steps belonging to goods receiving in the MFM is registration, unloading, scanning, pallet location, sorting, place

box on the train set and transportation on train set, see Appendix 8a, 8b and 8c for more detailed explanations of the process steps.

Protective perspective
Regarding protection of the goods, there are possibilities to put the forks wrong when lifting the goods with a forklift and consequently damage the cardboard boxes. Based on the results and comments gathered while executing the tests, the general view was that disposable boxes in cardboard would not provide the same protection as the V-EMB. Boxes in cardboard would however call for a more careful treatment, which was confirmed by the forklift drivers working at the goods receiving station.

In addition to potential damage of the boxes due to handling, the weather aspect is another concern that has to be taken into consideration. The disposable boxes in cardboard does not withstand rain and moisture as good as the V-EMB boxes in plastic do. However, the process of unloading, sorting the goods and transport it into to the plant is performed mainly beneath a ceiling and during a limited time, which the disposable boxes should be capable of resisting since they are to some extent water-resistant.

Handling efficiency perspective
Due to the fact that disposable boxes most probably require a more careful treatment, a switch towards a disposable packaging solution will result in a drawback on the full time equivalent according to the Packaging Engineers and the forklift drivers at the goods receiving station. In addition to increased handling time of disposable boxes, as it looks today, most boxes that arrives in cardboard and not V-EMB packaging, will be sent to the reject station which means that the standard operating procedure need to be secured and updated since disposable boxes requires a different handling

Ergonomic perspective
Since all handling are done by forklifts, no impact on the ergonomic perspective could be found if the V-EMB boxes are replaced by disposable solutions in cardboard.

Informative perspective
Given the design of the Papyrus Supplies boxes in cardboard, the label can be placed in the same way as today. This means that the informative perspective in terms of scanning will not be affected if those cardboard boxes should be implemented. The boxes do not have any symbols that guides the procedures within goods receiving.

4.5.2 Local storage

The local storage is a storage area in connection to, and above, the supermarket. The space in the local storage is limited which results in a requirement for smaller, but frequent deliveries. The storage is optimized for L-pallets, which suits the L-pallet base units that the 750 and the 780 box are placed on when coming from the supplier. When the boxes are delivered from the goods receiving station on the train set, they are first placed on a temporary buffer area. Depending on the number of boxes in the supermarket of the specific item, the boxes are either placed directly in the supermarket racks or in the local storage.

The process steps belonging to local storage in the MFM is unloading, temporary buffer area, remove lid, scanning of label, place box in local storage and inventory. See Appendix 8a, 8b and 8c for more detailed explanations of the process steps.

Protective perspective
The main concern regarding the protective perspective is the possibility to put the forks wrong when handling the goods with a forklift and consequently damage the cardboard boxes. However, cardboard boxes would call for a more careful treatment. The general view was that disposable boxes in cardboard would not provide the same protection as the V-EMB but it could still be sufficient.

Handling efficiency perspective
When the pallet with boxes arrives from the goods receiving, it is strapped with a lid on top. The lid is either removed before or after it is placed in the local storage depending on if there is a need on the specific part number in the supermarket flow racks. Anyway, since only L-pallets lids are handled in today's process at the local storage area, there is no place to put disposable lids. This process must be secured before an implementation of disposable boxes is possible.

Due to the fragility of the disposable boxes, it may call for a more careful treatment. This might have an impact on the handling efficiency perspective.

Ergonomic perspective
No implications on ergonomics were found when changing from returnable packaging to disposable packaging. This since all handling are done with the use of forklifts.

Informative perspective
No implications were found during the tests regarding the informative perspective. The label can be placed and scanned in the same way as on V-EMB.

4.5.3 Supermarket

Supermarket is a storage used for small and medium-sized parts in boxes with a predetermined inventory with the purpose to supply downstream processes. The boxes are stored in flow racks and the parts that are stored in the supermarket are parts that goes to many workstations or several points of use, and only full boxes are handled in the supermarket. The supermarket is placed close to the point of use, in order to reduce the internal transportation as much as possible. The supermarket is divided into three different categories; low, medium and high volume, where the high-volume parts are the easiest to pick and this zone is marked with green, and the low-volume parts are placed in a more remote place and this zone is marked with red. In addition to the red and green zone, there is also a yellow zone, where the medium volume parts are placed. The FiFo principle is maintained in supermarket which ensures that the oldest parts always are used first. Each item in the supermarket has one specific allocated place and when it is needed by a downstream process, the material handler withdraws the exact amount that is needed at point of use. In order for the material handler to know where to deliver the box, scanning devices are used and the location of each box is written down on a paper. Scanning of labels is also used as a signal of delivering more goods to the supermarket.

The process steps belonging to supermarket in the MFM is place box in supermarket, inventory, signal from PoU, take box from supermarket, scanning, pallet location, transport box to kitting/pre-assembly/main line and place box in shelf at kitting/pre-assembly/main line. See Appendix 8a, 8b and 8c for more detailed explanations of the process steps.

Protective perspective
The Packaging Engineers see no or minimal difference regarding the protective perspective. During the tests, it was however pointed out that when the handles were pressed, there is a possibility to damage the product or to injure the operator if there are sharp items in the boxes. This concern has to be reviewed product by product if considering a change to disposable packaging.

Handling efficiency perspective
Regarding the handling efficiency perspective, the major implication found when changing from V-EMB to cardboard boxes was the location of the handles, which according to the Packaging Engineers, the ergonomics and the material handlers at the supermarket foresees a negative impact on handling efficiency. The location of the handles on the equivalent 750 box in cardboard is a major concern for the persons handling the boxes. Since the boxes are positioned with the short side forward in the supermarket, where there are no handles at all at the 750 equivalent, it is difficult to grab it and lift it out of the supermarket. During the test activity, potential solutions were discussed and the ergonomics and the material handlers at the supermarket thought that a vertical handle on the short side, as on the 780 equivalent, was a reasonable solution to the problem.

Due to the fact that the V-EMB boxes are conical and the disposable boxes are not (resulting in an increased volume of 15.3% for 750 and 1.2% for 780), a change to the disposable boxes might result in increased fill rate depending on the product design and weight.

As the processes in the supermarket works today, the lid is removed from the box before it is put into the racks. Since only plastic boxes are handled in today's processes, there is no process to handle disposable lids and no bin to throw the lids in, if that procedure is decided upon. In addition, there is a small concern that cardboard fibres will disperse when handling the box and pushing in the handles.

Ergonomic perspective
According to the ergonomics, Packaging Engineers and the Logistics Technician, it was more difficult to fetch and lift a cardboard box compared to a plastic box due to lack of handles. The cardboard box itself has a lower weight than the plastic boxes which might be positive from an ergonomic point of view. However, the lower weight of the packaging might be compensated by filling up the boxes with more parts up to weight limit of 12 kg, in product cases where the volume and not the weight have been the limitation. This will, in those cases, eliminate the ergonomic benefits but may increase the handling efficiency.

The two chosen boxes, the 750 box and the 780 box, differ slightly from one another in terms of handling and ergonomics influence. As mentioned earlier, the location of the handles on the 750 box is a major concern for the persons handling the boxes. However,

the 780 box has a positive effect on the ergonomic perspective according to the ergonomics due to the vertical handle at the short side of the box. The vertical handle makes it easy to lift the box over the edge that exist on the racks in the supermarket. From an ergonomic point of view, it is better to have the handle vertical compared to horizontal due to rotation of the wrist that is required to lift a box with a handle placed horizontally.

Informative perspective
No implications were found during the tests regarding the informative perspective since the label can be placed and scanned in the same way. Furthermore, empty disposable boxes can as well be used for ordering, as the V-EMB boxes are, if not thrown away when emptied.

4.5.4 Point of Use: Kitting, Pre-assembly & Main line

The interface between internal handling and manufacturing is called point-of-use. There are three points-of-use: kitting station, pre-assembly station and main line. The picking from the boxes performed by the operator is nevertheless entirely the same and the operator does not manage the box itself in any of the stations, except from when placing the box on the shelf above when empty.

Kitting is a way of delivering optimally to the operator and it is made close to the main line. Individual parts are grouped and packed together, and supplied to the main line as one unit. Kitting is mainly applied for small and medium-sized parts. In the test activity for the kitting area, the picking was tested in a 780 box equivalent.

Pre-assembly is performed closest to the main line and the sub-assemblies are pushed to the main line using fixtures on wheels. In the test activity for the pre-assembly station, the picking was tested in both a 780 and a 750 box equivalent.

Main line is a manufacturing process where parts are added as the semi-finished truck is moving from one workstation to another until the final truck is produced. The main line is supported by sub-flows (such as kitting and pre-assembly) in order to take out diversity from the main line and instead, create diversity in the sub-flows. Short throughput times in the main line and high production precision is thus created.

Protective perspective
No implications were found regarding the protective perspective. This due to the fact that it is only the parts that are handled, i.e. picked, at the kitting, pre-assembly and main line stations, and not the box itself, apart from when empty.

Handling efficiency perspective
According to the operators at the kitting, pre-assembly and main line station, there are no difference of picking parts from a cardboard box compared to a plastic box. However, for the material handler placing the box in the racks it differs slightly due to the fact that the width of the racks varies at the different stations. The rack placed at the main line was too narrow in width (the racks are designed to fit for the conical V-EMB) which resulted in that the disposable box standing inaccurate. This has to be secured before an implementation of cardboard boxes is possible.

Ergonomic perspective
According to the Packaging Engineers, the operators and the ergonomics, picking parts out of the box is the same regardless if it is made out of plastic or cardboard. The fact that the cardboard box weighs less than the plastic box is however positive, especially when handling empty boxes which should be placed on a shelf in the red zone (the means of a red zone is described in 4.5.3).

Informative perspective
The informative perspective will not be affected by a switch to disposable packaging instead of V-EMB. The operators do not use the label as it is today, either they pick by light or use the information that is placed on a sign beneath the box at the racks. However, it is of high importance that the disposable box is not thrown away after it has been emptied but placed on top of the storage racks since it is used as a Kanban signal for delivering more parts to point of use.

4.5.5 Handling and breakdown of empty boxes

Empty V-EMB boxes are returned in the same delivery routes as the full boxes are delivered in. The picked-up boxes are left at the downsizing station, located close to the supermarket where the delivery route starts, by the material handler. The V-EMB 780 boxes are placed on one pallet and stacked until there are 40 boxes and 40 lids, and the V-EMB 750 boxes are placed on one pallet with 80 boxes and 80 lids. As soon as one pallet is full with empty returnable boxes, a lid is placed on top and then strapped. The pallet is placed on a train set which is transported out to the trailer loading area when it is fully loaded. The empty boxes that are placed on a pallet are loaded onto a trailer which when full is transported to a DFDS terminal in Arendal. When the trailer loaded with empty boxes leaves the yard, Volvo Group's handling of the packaging ends, and the rest is outsourced to an external party.

When the trailer arrives at the DFDS terminal in Arendal, a forklift driver unloads it at the yard, sorts the boxes depending on size and then the boxes are stored there until it is transported to the washing machinery. The boxes with the highest demand are placed on a conveyor which takes the boxes into the washing machinery. At the washing machinery, the boxes are being washed, dried and stacked in bundles again with a lid on top and two plastic straps. The cleaned boxes are transported out by a conveyor where the forklift driver picks it up and place it under a roof, ready for a new usage loop. See Appendix 8a, 8b and 8c for more detailed explanations of the process steps.

Protective perspective
The purpose behind disposable boxes is that it should be used only once, which means that the processes of washing and storage of the empty box are eliminated which in turn results in having new and clean packaging all the time. V-EMB tends to vary in condition which might result in a positive effect regarding the protective perspective if changing to disposable boxes instead of V-EMB. Other than the cleanliness of the box and thereby the protection of the parts, the protective perspective is not affected since the empty packages do not contain any goods.

Handling efficiency perspective
If the empty disposable boxes are handled in the same way as the returnable boxes are today, the only inefficiency the Packaging Engineers can see on the handling efficiency

is the requirement to have two docking points - one for V-EMB and one for disposable packaging. It will, however, most likely consume less time to throw away the disposable boxes than to stack the V-EMB boxes.

The benefit of cardboard boxes compared to plastic boxes is the elimination of the process of washing the empty boxes. Disposal of cardboard waste have to be compared with the time and cost of handling empty plastic boxes. The process of removing the label before the next usage loop is unnecessary for the disposable boxes. This since the boxes are to be discarded after one use.

Ergonomic perspective
According to the Packaging Engineers, the disposal of cardboard waste must be secured in an ergonomically correct way. It should be compared with ergonomics impact of bundling returnable plastic boxes. A returning advantage of the cardboard boxes regarding the ergonomic perspective is however the weight of the packaging.

Informative perspective
There might be a risk that the disposable packaging is thrown away directly after it is empty but since the box is used as a Kanban signal, it has to be returned to the downsizing station as the returnable packaging do.

4.5.6 Box effects summary

An overall evaluation of the disposable box and a compilation of the effects of a change to disposable boxes can be seen in Table 4.3. The effects have been graded as no effect, positive effect, or negative effect, in order get an overview of where and on which perspective to put most effort.

Table 4.2. Compilation of the effects of a change to disposable boxes.

Disposable box solutions	**Protective perspective**	**Handling efficiency perspective**	**Ergonomic perspective**	**Informative perspective**
Goods receiving	Negative effect *(fragility of material)*	Negative effect *(fragility of material)*	No effect	No effect
Local storage	Negative effect *(fragility of material)*	Negative effect *(fragility of material)*	No effect	No effect
Supermarket	Negative effect *(possibility of damage depending on product)*	Negative effect *(location of the handles)* Positive effects for certain products (increased volume)	Negative effect *(lack of handles on the 750 box on the short side)* Positive effect *(the vertical handles on the 780 box)*	No effect

Point of Use	No effect	No effect	Positive effect	No effect
Handling and breakdown of empty boxes	Not applicable	Negative effect	Negative effect	No effect

4.6 Overall packaging evaluation

To make trade-offs between the various perspectives and deciding upon what the minimum requirements are on the packaging is necessary when evaluating whether to use returnable or disposable packaging. As stated by Coyle et al. (1996), one of the most important factors when choosing packaging is the physical characteristics of the product, for instance dimensions, weight, and type of material. As an example, the Papyrus Supplies pallet has a weight limit of 300 kg compared to the V-EMB who can carry up to 1000 kg, which limits what products disposable packaging can be used. Table 4.1 presents the advantages and disadvantages with returnable and disposable packaging, which is a summary of the tests and the theory.

Table 4.3. Advantages and disadvantages with returnable and disposable packaging.

	Advantages	**Disadvantages**
Returnable packaging	• Weatherproof • High stackability • Long lasting • High carrying weight limit	• Expensive to purchase • Requires washing, maintenance and repair • Tied up capital in packaging • Return transports are required • Requires administration and control • Heavy compared to cardboard
Disposable packaging	• Recyclable • Lightweight material • No return transports • Inexpensive to purchase • Volume effective	• Weather sensitive • Disposal fees • Less stackability • Lower carrying weight limit

4.7 Volvo Car Corporation Benchmark

Volvo Group and VCC have had a standard V-EMB packaging pool together during a period of time, but in 2014 when VCC exited the Volvo Group packaging collaboration, VCC had severe problems with availability of the V-EMB packaging. The standard V-EMB packaging pool was split but VCC did not have enough packaging in order to manage their packaging demand. To cope with the shortage, suppliers shipping material in long distance flows were instructed to pack in disposable packaging which lead to problems with low filling degree, poor quality, increased part price, and insufficient control.

As a response, VCC developed a disposable standard packaging together with their strategic partner Papyrus Supplies and introduced the solution as the primary packaging alternative for long distance flows. VCC started with replacing L-packaging but are now moving over to introduce the container adapted version as well as other available

sizes. VCC has spent 2.5 years to develop, test and implement this concept and the disposable packaging solutions provided by Papyrus Supplies are now used in high volumes, especially in the aftermarket business. The disposable packaging that VCC now uses are the same disposable packaging that are used when conducting the test activities in this master thesis, which makes VCC a good benchmarking object.

Suppliers are instructed to use Papyrus Supplies disposable packaging, both pallets and boxes. The suppliers of VCC, are ordering the disposable packaging directly on Papyrus Supplies web portal. Papyrus Supplies manage the orders, the distribution and invoice the supplier directly, which means that VCC do not need to administrate this at all. Instead, the suppliers of VCC add the cost of packaging to the part price, however VCC have negotiated the price with Papyrus Supplies and have good control of the change in part price.

VCC currently uses both V-EMB and disposable pallets and boxes in their flows. Both the returnable and disposable alternatives are handled in mostly the same processes throughout the factory until the packaging is empty and is to be discarded or sorted before the return procedure. In contrast to Volvo Group, VCC keeps the lids on the boxes in the supermarket to protect the goods from dust, and removes the returnable lids or places the disposable boxes inside the upside down disposable lids prior to delivering at point of use. The returnable lids are gathered on the delivery train, which also collects the empty boxes of both kinds. The placement of the disposable box inside the lid results in a single discarding process, instead of one process for the gathering and discarding the lids and one for the box. All empty boxes are transported to the V-EMB box sorting area, where a compressor is kept and in which the cardboard boxes and lids are thrown.

Empty disposable pallets are placed on a separate train set to not infer with handling efficiency while placing empty V-EMB on train sets. The different train sets are transported to different locations, either to a breakdown of disposable pallets area or to a trailer loading area. Otherwise the disposable pallets are handled the same as the V-EMB pallets.

5 DISCUSSION

This chapter discusses the effects of implementing disposable packaging in according to the four perspectives. The handling and breakdown of disposable packaging is then discussed, followed by a discussion regarding various aspects that are important, but are not part of the scope.

5.1 Discussion regarding the effects

As mentioned in the introduction, there exists no common view on whether disposable packaging is a valid alternative to returnable packaging and there is no standardization or consensus on how to work with disposable packaging within Volvo Group. Hence, this chapter will firstly evaluate the different packaging requirement perspectives, and thereafter discuss proposed handling processes for empty disposable packaging.

5.1.1 The disposable packaging

Bowersox et al. (2013) state that in general, it is preferable to use returnable packaging in flows where the turnover rate is high, the geographical transportation distance is short and when the flow consists of large volumes without any major variations. Consequently, the disposable solutions will be economically viable in flows where the purchase and disposal costs does not exceed the costs of the returnable packaging system, such as transportation, handling, breakdown, washing, control and administration costs. Hence, the primary area of use of the examined disposable packaging solutions for Volvo Group is the long-distance material flows, where the usage loop is expensive due to high custom taxes, time consuming with a long-distance repositioning of empty packaging, or difficult to handle due to an insufficient retrieval of packaging. However, as this master thesis is delimited from looking at the cost, environmental and supply chain perspective, there will only be a general discussion about flows where disposable packaging might be suitable.

Since Volvo Group desires to harmonize and standardize the Volvo Group's returnable packaging pool by reducing the different types of packaging sizes as the other stream of *Next Generation Packaging*, the possible future replacement of returnable packaging with disposable packaging should also be standardized and only available in certain, pre-defined sizes. There might otherwise be a risk to lose all the desired benefits of the other stream, if a decrease in returnable packaging sizes were compensated with an excess in disposable packaging sizes.

The protective perspective
According to Gourdin (2001), an insufficient level of protection will result in a lack of quality, but a redundant level of protection will result in unnecessarily high costs. The Papyrus Supplies solutions are undoubtedly more fragile than V-EMB, since cardboard is more easily damaged than plastic and wood. As argued by Chan et al. (2005), the degree of protection must be economically viable, and a disposable packaging solution, designed to endure only a single usage loop, maybe should not be as durable as the returnable solution, which is designed to withstand a significant amount of usage loops.

If not handled inattentive or careless and provided that the weight restrictions are kept, the packaging containers should be able to ensure sufficient protection and the quality of the parts during all of the factory's processes. Even though, the disposable solutions

must be quality secured to withstand the same strain as V-EMB at least one turn through the supplier chain. For instance, the aspects of stackability during trailer transportation and dynamic pressure have not been tested.

If endurance throughout the supply chain is proven, a positive aspect of the Papyrus Supplies solutions is that every usage loop will have new packaging in top condition meanwhile returnable V-EMB can be in varying condition. This will most likely a more even quality level on disposable packaging than returnable.

Since the disposable packaging solutions result in a higher risk of damaged or broken packaging, the goods carried by disposable pallets could preferably be packed in racks to be preserved within the package even if there was a hole in the side. The issue is regarded as less substantial for the boxes, since these carry smaller and often less valuable goods. Nevertheless, the choice of the part numbers where the V-EMB might be replaced with disposable alternatives will be decided upon by Volvo Group.

The handling efficiency perspective
The Papyrus Supplies solutions offer both benefits and drawbacks to handling efficiency. The cardboard pallet offers potential of improved handling efficiency when picking parts due to the hatch. Otherwise there was no major difference for material handling if changing from a returnable pallet to a disposable alternative since the handling is mostly performed with trucks. Storage compatibility, which was a big concern prior to the tests, will not restrict the area of usage as the pallet solution turned out to be compatible with both automatic and manual storages without alterations.

The disposable boxes have a larger carrying volume. The V-EMB 750 box can carry 15.7 litres and the equivalent Papyrus Supplies box can carry 18.1 litres. The V-EMB 780 box can carry 36.6 litres and the equivalent Papyrus Supplies box can carry 37.3 litres. This may improve the handling efficiency as it enables the packaging to carry more goods for part numbers where weight is not the limitation. The 15.3% volume increase to the 750 equivalent and 1.2% volume increase to the 780 equivalent brings the possibility of having a lower frequency of goods deliveries to both the factory and production, as well as a lower handling frequency of empty packaging. However, the boxes are regarded as somewhat inconvenient to handle in the supermarket which, according to Chan et al. (2005), may result in workload disorders as well as product damage. Furthermore, it does not satisfy the Volvo Group requirement of containers being easily picked up and taken out. Another design of the handles, where there is a vertical handle on the short side of the 750 equivalent as on the 780 equivalent, have the possibility to ease this matter

The breakdown of disposable packaging will result in added waste, and it also requires a certain amount of space. An efficient handling procedure of the cardboard waste, and locations that facilitates the breakdown of empty packaging, are required before an implementation is possible. Those locations in production where the removal of V-EMB lids is currently performed and where breakdown of disposable packaging should exist, will be affected. Example of such locations where there is a need for new procedures to handle the disposable packaging waste are the handling of box lids at the supermarket and of pallet lids at the PoW station. The lids should not be mixed and stacked with the V-EMB lids as this only would result in the need of a sorting process. One alternative is to ensure space to stack the disposable lids beside the area where the

V-EMB is stacked, before taking the entire bundle of lids to a compressor or recycling bin. Another alternative is to directly throw the disposable lids in compressor or recycling bin, preferably close to the areas where the lids are removed, that is, close to the POW loading area for pallet lids and close to the supermarket for box lids. An alternative solely for the boxes is to place the boxes inside the upside-down lids, as done at VCC, which facilitates only having the need for one collection and recycling process.

As it is today at Volvo Group, the racks differ slightly at the various workstations. The racks placed at the main line was too narrow in width (the racks are designed to fit for the conical V-EMB) which resulted in that the disposable box standing inaccurate. This has to be reviewed case by case if a implementation of cardboard boxes is up-to-date in one specific part flow.

A remaining concern for both the pallet and box solutions is in goods receiving, where the more fragile packaging might call for more careful handling and it might be required to develop new process guidelines, mainly for stacking. Another issue is after final consumption, where recycling processes ought to be developed, and an efficient handling of empty packaging must be secured.

The ergonomic perspective
As mentioned in the empirical findings chapter, Volvo Group have defined their own basic packaging requirements that all packaging container must fulfil. The ergonomic demands that must be fulfilled are that the packaging must be easily built-up and collapsed, lightweight, and safe. Rosenau et al. (1996) stress the importance of compass the ergonomic requirements in terms of weight limits, optimal handholds and reach requirements when designing a packaging. When studying the packaging solution and analysing whether it is good or bad from an ergonomic point of view, it is therefore mostly based on weight and handleability.

Regarding the weight of the packaging, the more lightweight the material is, the more ergonomically positive is the packaging considered to be. Since the pallets are mostly handled by forklifts and the boxes are handled more manually, the largest impact concerning the lighter weight of the disposable packaging will affect the boxes. However, since the disposable boxes (equivalent to the 750 and 780 V-EMB boxes) can carry a larger volume, 15.3% more for the 750 box and 1.2% for the 780 box, there might be a chance of filling the boxes more which henceforth will not bring ergonomic benefits. However, the handling of empty packaging will affect the ergonomics positively if changing to disposable boxes instead of V-EMB boxes.

It is not only the weight of the packaging that influences the ergonomics though, the design of the packaging has a significant role as well when it comes to handleability. The design and the location of the handles of the disposable boxes is the major concern, especially at the supermarket where the boxes are placed in flow racks. During the tests, suggestions for improvements regarding the handles on the 750 box came up. Adding a handle on the short side would facilitate the handleability, especially when lifting out the boxes from the flow racks in the supermarket. From an ergonomic point of view, it is better to have the handle vertical, as on the 780 box, compared to horizontal due to rotation of the wrist that is required to lift a box with a handle placed horizontally. Ergonomically correct handling, especially of the 750 box in cardboard, must therefore

be secured. Furthermore, the grip comfort would improve if the folded-in flap was placed on the other side of the handle, with the folded flap turned towards the middle of the box instead of towards the edge.

The weight of the disposable pallet may give a positive impact on the ergonomic perspective, but the major ergonomically benefit with the Papyrus Supplies pallet is the hatch that exists on one short side of the pallet. The operator does not have to stretch over the collars since the disposable pallets always can be folded down to a L2 equivalent.

The information perspective
Volvo Group's basic requirements oblige the containers to support efficient handling. A new way of working with disposable boxes must be implemented in order to secure ordering of new parts, where the cardboard boxes are placed on top shelf of the station's storage racks as a Kanban signal and returned in the same way. Currently most cardboard boxes are thrown away in the nearest container when emptied, and if thrown away at line side then ordering cannot be secured.

The disposable solution will have a positive impact on the informative perspective, since there will be no risk of having old labels, that were not washed off, still attached in the new usage loop. This completely removes the risk of scanning an old faulty label.

As recommended by Chan et al. (2005), information regarding handling instructions, for instance the stacking directives, should be mediated by the packaging in a clear and easily understood way. The symbols on another type of packaging used by Volvo Group can be seen in figure 5.1.

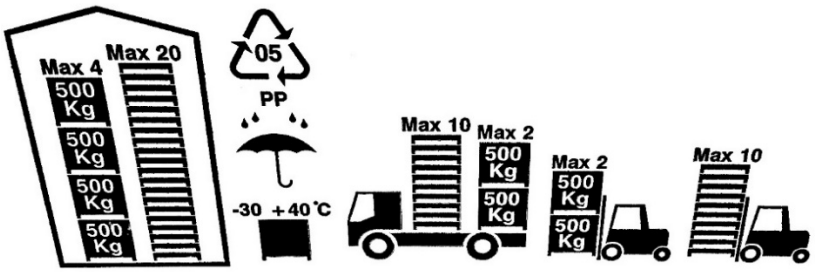


Figure 5.1. Symbols used on V-EMB 400.

The Papyrus Supplies boxes have no symbols, whereas the V-EMB equivalents have symbols for carrying weight limit and stacking restrictions. The cardboard pallet does have the stacking height directives printed, but should at least also have the stacking weight limitations printed. An extended use of symbols on the disposable solutions would decrease the risk of negative effects on the protective aspects and handling efficiency.

5.1.2 Handling and breakdown of empty disposable packaging

There are no current, standardized procedures for how to manage empty cardboard packaging in the factory. The cardboard boxes that do appear, small sized boxes on the line side and larger boxes in kitting stations, are thrown away without any breakdown or unfolding in the nearest bin or container. There are no cardboard pallets but some parts arrive in disposable wooden cages, that are placed outside and then disposed by

the cleaning company to an undefined cost. If the usage of disposable packaging is to increase, Volvo Group must implement procedures to manage handle the waste in a proper manner.

To minimize the interference with current processes, one solution is to maintain the same material handling procedures for the disposable pallets. Assuming that empty pallets are taken out of the factory in the same way as V-EMB, the Packaging Engineers noted that the only inefficiency to material handling is to have two docking points outside, the current one for V-EMB and one for disposable packaging, preferably the waste station. However, the lighter weight of the disposable pallets increases the risk of the packaging blowing off the train sets during outside transportation. Different loading scenarios for train set transportation must be tested and special loading guidelines ought to be developed to ensure safety during transportation to the docking stations. A decision has to be made whether the pallet components should be sorted at a waste station, with the cardboard sleeve placed in the compressor and the corner lists and pallets base unit thrown in the recycling bin for wood, or if the pallet components should be stacked and bundled inside the factory and transported to the waste station for pickup. On one hand, sorting at the waste station will either require extended time for the train set route if the driver where to sort, which results in a lower frequency that may not suffice the need, or personnel at the waste station at certain times. On the other hand, stacking and bundling inside the factory will require approximately 25 to 30 square meters of space, which is very limited inside the factory, in connection to the POW loading area. The waste would then be fetched from the waste station and recycled by an external party, Stena Metall Group. The decision should be based upon the costs for the different alternatives.

A solution for the boxes might be for Volvo Group to invest in a smaller sized compressor to keep in the area in which the V-EMB boxes are sorted and stacked. In that case, the material handling up to this point could be the same. The difference is that the disposable boxes should be thrown in the compressor, whereas the V-EMB is handled the same as today. This solution requires both space and an investment in equipment. The practical implementation should however not be an issue.

The Tuve factory sends all their empty V-EMB packaging to a terminal for automatic breakdown, but this is not the case for all of Volvo Group's production plants as most of them executes a manual breakdown on site. Regarding the boxes, where the V-EMB are sorted, stacked, and washed, the disposable solutions might not bring any significant efficiency improvements since the disposable box also needs to be broken down, i.e. unfolded, and stacked or discarded. However, the label removal process will be eliminated. The pallets, on the other hand, will result in considerable ergonomic benefits since the disposable solution is substantially lighter and easier to handle. The Papyrus Supplies pallet should not require more than one operator to dismantle, compared to V-EMB where the collars only ought to be lifted by a couple of operators, which will increase the breakdown efficiency.

In order to get an overview of the differences in number of process steps between using returnable packaging and disposable packaging, an analysis of the MFM have been carried out. The analysis denominates the activities; handling, administration, transport and storage. The HATS analyses for the various flows can be seen in Table 5.1, Table 5.2 and Table 5.3.

Table 5.1. Compilation of the HATS analysis for Pallet flow 1.

HATS analysis for pallet flow 1	**Number of processes using returnable packaging**	**Number of processes using disposable packaging**	**Difference in number of process steps**
Handling (H)	20	19	-1
Administration (A)	7	6	-1
Transport (T)	9	7	-2
Storage (S)	9	7	-2

The HATS analysis for Pallet flow 1, which goes through the automated storage, is based on Appendix 7a and Appendix 9a.

Table 5.2. Compilation of the HATS analysis for Pallet flow 2.

HATS analysis for pallet flow 2	**Number of processes using returnable packaging**	**Number of processes using disposable packaging**	**Difference in number of process steps**
Handling (H)	15	15	0
Administration (A)	6	5	-1
Transport (T)	5	3	-2
Storage (S)	7	5	-2

The HATS analysis for Pallet flow 2, which goes through the local storage, is based on Appendix 7b and Appendix 9b.

Table 5.3. Compilation of the HATS analysis for boxes.

HATS analysis for boxes	**Number of processes using returnable packaging**	**Number of processes using disposable packaging**	**Difference in number of process steps**
Handling (H)	21	11	-10
Administration (A)	7	7	0
Transport (T)	8	4	-4
Storage (S)	9	5	-4

The HATS analysis for the box flows, is based on Appendix 8a, 8b, 8c and Appendix 10.

5.2 Discussion regarding aspects outside of the scope

First of all, the supply chain perspective is discussed since this research should be weighed against the supply chain perspective as there might be trade-offs to consider. Furthermore, it must be decided which flows where a change to disposable packaging could be suitable and the KD flows, which is not part of the scope, are explored since these were detected to have potential. Lastly, the attitudes towards disposable packaging, which are considered to highly affect a possible implementation of a packaging change, are reviewed.

5.2.1 The supply chain perspective

In this thesis project, the aspects of costs were excluded due to the fact that the thesis only investigated one factory's processes. In order to fully examine the cost impacts of a packaging change, all aspects of the supply chain should be compared according to corresponding parameters and this will instead be done in Volvo Group's project Next Generation Packaging. The same rationale applies to the analysis of environmental aspects, which also was delimited from the thesis scope. Nevertheless, packaging consume energy, generate emissions, and create waste throughout their life cycle (Azzi et al., 2012), and a packaging solution with a comparatively highly negative environmental impact should preferably not be implemented without compensation in other parts of the supply chain. Hence, the entire supply chain perspective must be evaluated before a big change regarding the packaging pool can be implemented, in order to enable a fair comparison of potential trade-offs. The Papyrus Supplies pallet would, for example, bring considerable ergonomic benefits but protective drawbacks within the factory's processes. Considering the bigger picture, the use of disposable pallets in long distance flows, where repositioning is hard, costly and slow, would untie more of the limited V-EMB packaging pool to short distance flows where the packaging turnover is higher. It could also diminish the dependency on V-EMB if the factories' processes were adjusted to being able to handle both V-EMB and a standardized, disposable solution.

5.2.2 Knocked-Down production

An alternative path that is not covered by the chosen pallets flows regards the knocked-down (KD) flows within the Tuve factory. The KD business set-up makes it possible to sell vehicles in countries where Volvo Group cannot be competitive with Completely Built-Up (CBU) deliveries. Volvo Group uses the KD set-up when there are differences in import custom duties between CBU and KD, demands for a certain level of Regional Value Content, demands to provide local manufacturing jobs or other strategic or political initiatives. The components are handled differently depending on where the components are produced, and the customs regulations in the receiving plant's country. The end product is the same, whether the product has been assembled at a CBU plant or a KD plant.

Volvo Group often consolidates the components at the sending plant or in the shipping facilities but they can also be sent directly to the KD plant. They choose the most cost-effective solutions depending on the situation and to make the process efficient and flexible, there are some logistics principles. Volvo Group uses the pre-delivery functionality, which means using the existing unit-loads without repacking, when the regulations in the receiving country allow it. Standard Volvo packaging is used for the

KD markets to avoid extra handling, but with standardized disposable solutions instead there would be no need of control or administration to return the packaging. The KD flows are the ultimate representation of the long-distance flows where a disposable packaging solution could lower the tied-up capital and indirectly help to increase the V-EMB packaging turnover.

In a test of the picking process for KD, the Papyrus Supplies pallet's hatches was placed on the wrong side in comparison to the operator at every other picking station. The cardboard pallet could not be packed ergonomically without hatches on all side since the operator could not use its lifting tool to disassemble the disposable pallet. However, with hatches on all sides as proposed in earlier chapters, this problem would too be solved. Because of the incompatibility of disposable boxes in the automated box storage, the products in boxes for knocked-down production could not be investigated at the Tuve plant. However, knocked-down production parts are delivered from other of Volvo Group's plants where automated storage for boxes do not exist. This means that disposable packaging could possibly be used in KD production flows anyway which may weigh up the somewhat negative effect in production.

5.2.3 Attitudes towards disposable packaging

During the tests, it was noticeable that the attitudes towards disposable packaging differed a lot. There were differences on the attitudes towards the pallets solution and the box solutions. In addition, there were differences between those who worked directly with the packaging in production or material handling, and those who worked indirectly with the packaging.

The attitude among the operators towards the disposable pallet was overall positive, apart from the operators in goods receiving who were concerned about the fragility of the material, since it brings immediate ergonomic benefits to the operators in production and does not affect material handling significantly. The personnel working indirectly with the material, such as the Packaging Engineers, Logistics Engineer and Logistics Developer, were positive as they could envision the bigger picture and saw the potential of solving the long distance and retrieval issue of the KD markets.

The attitude towards the boxes were however mostly neutral or negative. The boxes do not bring any obvious benefits to neither production nor material handling. In was the most negative in the supermarket, but the Ergonomic Experts did see the potential for improvements that could bring both ergonomic and handling efficiency benefits after some time getting used to the new handling and gripping procedure, i.e. a learning curve for the operators.

If these disposable packaging solutions from Papyrus Supplies were to be implemented, with or without alterations, there will be some managerial implications and the management ought to have a strategy for how to implement this change. Regardless of the implementation strategy, there should be standardized procedures and guidelines to prevent fear of incorrect handling, which might lower the negativity towards a change, but this thesis work will not go further into details on change management. To be noted, the VCC management just decided to implement the Papyrus Supplies packaging solutions and the factory staff had to adjust accordingly.

6 CONCLUSION

The disposable packaging studied in this master thesis, are in general relatively well adapted to Volvo Group's internal processes. The main reason for this is that the project *Next Generation Packaging* has done a thorough investigation of disposable packaging alternatives available on the market and decided upon the most suitable disposable packaging to test. The fact the disposable packaging has almost the same dimensions as the V-EMB and are used by VCC today, has been of great importance. There are however some concerns that Volvo Group has to consider before an implementation of disposable packaging is possible.

A crucial effect of a change from V-EMB to disposable packaging, both pallet and box solutions, was found at the goods receiving station where disposable packaging had a significant impact on the protective perspective, due to fragility of the material and less weather endurance, and on the handling efficiency perspective, since the cardboard packaging requires a more cautious handling and the weight restrictions decreases stackability.

Another key concern is the handling and breakdown of empty packaging, both pallets and boxes, for which there are no current process. An increased usage of disposable packaging implies for Volvo Group having to develop the procedures and allocating resources and capacity to handle and break down empty packaging.

A usage of the disposable pallet solutions in their current state would benefit the ergonomic perspective at the kitting station, whereas an altered version with hatches on all sides would entail benefits for the internal sequencing as well. Hatches on all sides of the pallet solutions would bring ergonomic benefits to all stations where there is picking from a pallet, regardless if the label is turned towards or on the far end side from the operator.

The disposable box solutions had the most impact in the supermarket. The 750 box equivalent led to a negative impact on both the ergonomic perspective and the handling efficiency perspective due to the lower handleability of the horizontal short side handle. The effects of the 780 box equivalent was, however, positive due to the vertical short side handle which improved the ergonomics and the handling efficiency. A vertical short side handle on the 750 box equivalent instead of the current horizontal handle, and the vertical handle flaps towards the middle on both box sizes would solve and further improve the ergonomic perspective and handling efficiency perspective issues in the supermarket.

With some shelf adaptation at PoU, the packaging solutions could, in the rough, be handled in the same internal logistics processes up to the handling and collection of empty packaging. However, guidelines for stacking and loading on train sets ought to be developed. The breakdown of empty cardboard packaging does require new processes, as well as space and locations for handling of empty packaging, and a compressor for cardboard boxes. Furthermore, the handling and breakdown of the box lids must be defined, in either a common (by placing the boxes inside the upside-down lids before supermarket) or a separate process to the boxes.

REFERENCES

Arbetsmiljöverket (2016), ”Arbetsställning och belastning – ergonomi”. Retrieved from: https://www.av.se/halsa-och-sakerhet/arbetsstallning-och-belastning---ergonomi/ [2017-02-10].

Battini, D., Faccio, M., Persona, A. & Sgarbossa, F. (2011), "New methodological framework to improve productivity and ergonomics in assembly system design", International Journal of Industrial Ergonomics, vol. 41, no. 1, pp. 30-42.

Bell, J. & Nilsson, B. (2006), *Introduktion till forskningsmetodik*, 4., [uppdaterade] uppl. edn, Studentlitteratur, Lund.

Bowersox, D.J., Closs, D.J., Cooper, M.B. & Bowersox, J.C. (2013), *Supply chain logistics management,* 4., international edn, McGraw-Hill, New York, NY.

Bryman, A., Bell, E., Mills, A. J. & Yue, A. R. (2011), *Business research methods.* Oxford: Oxford University Press.

Chan, F. T. S., Chan, H. K. & Choy, K. L. (2005),” A systematic approach to manufacturing packaging logistics”, *International Journal of Advanced Manufacturing Technology*, vol. 29, no. 9, pp. 1088-1101.

Coyle, J.J., Bardi, E.J. & Langley, C.J. (1996), *The management of business logistics*, 6.th edn, West, Minneapolis.

Denscombe, M. (2009), *Forskningshandboken: för småskaliga forskningsprojekt inom samhällsvetenskaperna,* 2. uppl. edn, Studentlitteratur, Lund.

Dominic, C., Johansson, K., Lorentzon, A., Olsmats, C., Tiliander L., & Weström P. (2000), *Förpackningslogistik*, 2:nd edn, Packforsk: Kista.

Enarsson, L. (1998), "Evaluation of suppliers: how to consider the environment", *International Journal of Physical Distribution & Logistics Management,* vol. 28, no. 1, pp. 5-17.

Finnsgård, C., Medbo, L. & Johansson, M.I. (2011), "*Describing and assessing performance in material flows in supply chains: a case study in the Swedish automotive industry*", Paper presented at the Swedish Production Symposium 2011, SPS11, May 3-5, Lund, Sweden.

García-Arca, J., Prado-Prado, J.C. & Antonio-García-Lorenzo. (2006), "Logistics improvement through packaging rationalization: a practical experience", *Packaging Technology and Science*, vol. 19, no. 6, pp. 303-308.

Golinska, P. (2013) *EcoProduction: Environmental Issues in Automotive Industry (1)*, Springer Berlin Heidelberg.

Gourdin, K. (2001), *Global logistics management: a competitive advantage for the new millennium*. Blackwell Publishers Ltd, Oxford UK.

Gustafsson, K., Jönsson, G., Smith, D., Sparks, L., (2005), *"Packaging logistics and retailers´ profitability: an IKEA case study",* Faculty of Engineering, L., Institutionen för designvetenskaper, Lunds universitet, Department of Design Sciences, Institutioner vid LTH, Packaging Logistics, Förpackningslogistik, Lunds Tekniska Högskola, Departments at LTH & Lund University 2005.

Hellström D, Saghir M. (2007), "Packaging and logistics interactions in retail supply chains", *Packaging Technology and Science*, vol. 20, no. 3, pp. 197–216.

Hise, R.T. & McNeal, J.U. (1988), *Effective packaging management*, Elsevier Inc, Greenwich.

Johnson, A. (2008), "Sustainability", *Packaging Digest*, vol. 45, no. 2, pp. 43.

Kroon, L. & Vrijens, G. (1995), "Returnable containers: an example of reverse logistics", *International Journal of Physical Distribution & Logistics Management,* vol. 25, no. 2, pp. 56-68.

Levy, G.M., SpringerLink (Online service) & SpringerLink Archive (e-book collection) 1992;1993;1999;, *Packaging in the Environment,* Springer US, Boston, MA.

Lockamy, A. (1995), "A Conceptual Framework For Assessing Strategic Packaging Decisions", *The International Journal of Logistics Management,* vol. 6, no. 1, pp. 51-60.

Lumsden, K. (2006), *Logistikens grunder,* 2:a [utök. och uppdaterade] utgåvan, Lund: Studentlitteratur.

McKerrow, D. (1996)," What makes reusable packaging systems work", *Logistics Information Management,* vol. 9, no. 4, pp. 39.

Mollenkopf, D., Closs, D., Twede, D., Lee, S. & Burgess, G. (2005)," Assessing the viability of reusable packaging: A relative cost approach", *Journal of Business Logistics,* vol. 26, no. 1, pp. 169-197.

Nyström, Anna (2006), "Pengar finns i ditt avfall", *Miljö & Utveckling*, 2006-05-15. Retrieved from: http://www.miljo-utveckling.com/nyheter/artikel.php?id=16871 [2017-03-05]

Odette Sweden AB, (2013), "*Slutrapport NAF – Effektivare system för returemballage inom fordonsindustrin*", Retrieved from: http://www.odette.se/om-oss/aktuellt/nu-finns-en-slutrapport-fran-projektet-naf-effektivare-system-for-returemballage-inom-fordonsindustrin_1 [2017-02-02].

Olsmats C. (2000), *"Future demands in the packaging flow"*. In Packaging logistics review, Sjöström K (ed). Econpap: Finland, pp. 91–100.

Paine, F.A. (1981), *Fundamentals of packaging,* Rev. edn, Inst. of packaging, Stanmore.

Patel, R. & Davidson, B. (2003), *Forskningsmetodikens grunder: att planera, genomföra och rapportera en undersökning,* 3., [uppdaterade] uppl. edn, Studentlitteratur, Lund.

Pålsson, H., Finnsgård, C. & Wänström, C. (2013),” Selection of Packaging Systems in Supply Chains from a Sustainability Perspective: The Case of Volvo: Selection of packaging systems in supply chains”, *Packaging Technology and Science,* vol. 26, no. 5, pp. 289-310.

Richey, R. G., Daugherty P. J., Genchev S. E., and Autry C. W. (2004), “Reverse Logistics: The Impact of Timing and Resources”, *Journal of Business Logistics,* vol. 25, no. 2, pp. 229-250.

Robertson, G.L. (1990), "Good and Bad Packaging: Who Decides?", *International Journal of Physical Distribution & Logistics Management*, vol. 20, no. 8, pp. 37-40.

Rosenau, W.V., Twede, D., Mazzeo, M.A. & Singh, S.P. 1996, "Returnable/reusable logistical packaging: A capital budgeting investment decision framework", *Journal of Business Logistics*, vol. 17, no. 2, pp. 139.

Rother, M. & Shook, J. (2003), *Learning to see: value stream mapping to create value and eliminate muda*, Version 1.3 edn, Lean Enterprise Institute, Brookline, Ma.

Rundh, B., (2005), "The multi-faceted dimension of packaging: Marketing logistic or marketing tool?", Avdelningen för företagsekonomi, Karlstads universitet & Fakulteten för ekonomi, kommunikation och IT 2005, British Food Journal, vol. 107, no. 9, pp. 670-684.

Skjøtt-Larsen, T., Kotzab, H., Schary, P.B. & Mikkola, J.H. (2007), “Managing the global supply chain”, 3.;3rd; edn, Copenhagen Business School Press, Copenhagen.

Twede, D. (1999), "Can you justify returnables?", *Transportation & Distribution,* vol. 40, no. 4, pp. 85.

Twede, D. & Clarke, R. (2004), "Supply Chain Issues in Reusable Packaging", *Journal of Marketing Channels,* vol. 12, no. 1, pp. 7-26.

Twede, D. & Parsons, B. (1997), *Distribution packaging for Logistical Systems*: A Literature Review. Surrey, Pira International.

Vijayvargy, L. & Agarwal, G. (2013), ”A Comparative Study of Green Supply Chain Management Practices in Indian, Japanese and Chinese Companies”, *The IUP Journal of Supply Chain Management*, vol. 10, no. 3, pp. 7.

White, P., Franke, M., Hindle, P., SpringerLink (Online service) & SpringerLink Archive (e-book collection) (1995), *Integrated Solid Waste Management: A Lifecycle Inventory,* 1st edn, Springer US, Boston, MA.

Witt, C.E. (1999), "Transport Packaging: Neat and clean or down and dirty", *Material Handling Engineering,* vol. 54, no. 9, pp. 71.

APPENDIX

Appendix 1 - Interview questions: Indirect functions

Interview questions for the "Support" functions

- What is your role in the company and what are your most important work tasks?
- How would you be affected in your daily work if an extent of the V-EMB were exchanged to disposable cardboard solutions?
    - Protective perspective
    - Handling efficiency perspective
    - Ergonomic perspective
    - Information perspective (labels, scanning)
    - Handling and breakdown of empty packaging
- How do you believe the operators in the factory will be affected in their daily work if an extent of the V-EMB were exchanged to disposable cardboard solutions?
    - Protective perspective
    - Handling efficiency perspective
    - Ergonomic perspective
    - Information perspective (labels, scanning)
    - Handling and breakdown of empty packaging
- In what ways and how do you see that the disposable packaging and/or the goods could be damaged in material handling?
    - Any particularly exposed process/processes?
    - How common do you think it would be that damages of this kind will occur?
    - How can this be prevented?
- What demands do you see that the disposable cardboard solutions must fulfill?
- What do you see is required in order to change the packaging pool?
- What initiates development of new packaging?

Appendix 2 - Interview questions: Direct functions

Interview question for the "Hands-on" functions

- Please describe your work situation today.
- If you imagine working with disposable cardboard packaging instead, what would the difference be?
- In what ways and how do you see that the disposable packaging and/or the goods could be damaged in material handling?
    - Any particularly exposed process/processes?
    - How common do you think it would be that damages of this kind will occur?
    - How can this be prevented?
- How would you be affected in your daily work if the V-EMB were exchanged to disposable cardboard solutions in a certain flow?
    - Protective perspective
    - Handling efficiency perspective
    - Ergonomic perspective
    - Information perspective (labels, scanning)
    - Handling and breakdown of empty packaging
- What demands do you see that the disposable cardboard solutions must fulfill?
- How would your work be affected if there was a mix between V-EMB and disposable packaging?

Appendix 3 - Packaging evaluation matrix for pallets

Filled in by the team of Packaging Engineers

Disposable pallet	**Protective perspective**	**Handling efficiency perspective**	**Ergonomic perspective**	**Informative perspective**
Goods receiving	Cardboard sleeve pallets might have to be handled with more care than wooden frames pallets by the fork lift driver due to fragility of the packaging itself.	Depending on durability of one-way solution. WoW must be secured in SOP if more fragile with possibly negative impact on FTE. Possibility of picking entire stacks of pallets from trailers perhaps not possible. No forks to come in contact with sleeve (is the case with wooden frames today). Square wooden blocks more fragile than current plastic blocks with steering when pushed by forks. Disposable pallet more sensitive to forklift spreaders.	Same	Same
Storage	Same	Same	Same	Same
PoU (Kitting, Pre-assembly, Internal sequencing, Line)	Same	More efficient picking of parts through the door. Door can be ripped off and thrown away (or entire wall if preferred by operator).	More ergonomic picking of parts through the door. Door can be ripped off and thrown away (or entire wall if preferred by operator).	Same
Train transportation	Same	Same (drawer effect compensated by lower weight on cardboard lid compared to wooden lid)	Same (drawer effect compensated by lower weight on lid)	Same
Forklift transportation	Cardboard sleeve pallets might have to be handled with more care than wooden frame pallets by the fork lift driver due to fragility of the packaging itself.	More fragile packaging might call for more careful handling by Material handler.	Same	Same
Handling of empty packaging	N/A	Depending on chosen solution, but assuming that empty pallets are taken out of the factory in the same way as V-EMB then the only inefficiency is to have 2 docking points outside -	Depending on chosen solution, but assuming that empty pallets are taken out of the factory in the same way as V-EMB then no difference to material handling.	Same

		one for V-EMB and one for disposable packaging.		
Breakdown of empty packaging	N/A	More time consuming break-down and sorting of wood and cardboard in Tuve compared to return trailer to VTA (cost might be compensated by less cost of automatic break-down at VTA). Other factories than Tuve might have more efficient break-down with disposable pallets with cardboard sleeve.	Break down and sorting of wood and cardboard must be secured in a ergonomically correct way. Might be an ergonomical improvement in all factories but Tuve due to no handling of pallet frames.	Same
Packaging maintenance vs. disposal	Positive with disposable packaging is that we always have new packaging meanwhile returnable V-EMB can be in varying condition. Negative could be that disposable pallets may offer less protection than returnable packaging due to thinner and more fragile packaging material.	No consideration has to be taken to continuous maintenance and repair of disposable packaging.	Same	Same
"Good enough" need	Disposable packaging may offer less protection to parts compared to returnable. The disposable solution must be quality secured (i.e. possible to withstand the same strain as V-EMB at least one turn through the supplier chain)	Cardboard sleeve offers potential of improved handling efficiency of picking parts due to the doors. No major difference for material handling with disposable vs. returnable. Main questionmark is up to Goods receiving and after final consumption where we will have the biggest impact. Very positive that the sleeve solution turned out to be compatible with both automatic and manual storages.	Cardboard sleeve with doors offers ergonomical potential which cannot be achieved with pallet frames. Main impact for supplier and Volvo plants after final consumption where factories with own break-down might experience an improvement in handling cardboard walls and lids (light) instead of wooden frames and lids (heavy). Tuve plant will either have to secure this activity internally in an OK way, or outsource it to VTA and pay for it like done today with V-EMB break-down.	Same

Appendix 4 - Packaging evaluation matrix for boxes

Filled in by the team of Packaging Engineers

Disposable box	**Protective perspective**	**Handling efficiency perspective**	**Ergonomic perspective**	**Informative perspective**
Goods receiving	Pallets with cardboard boxes might have to be handled with more care than pallets with plastic boxes by the fork lift driver due to fragility of the packaging itself.	Depending on durability of one-way solution. WoW must be secured in SOP if more fragile with possibly negative impact on FTE.	Same	Same
Storage	Same	Not compatible with automatic storages in Tuve and Gent.	No automatic handling since not compatible with automatic storages in Tuve and Gent. Negative ergonomic impact with manual handling.	Same
Supermarket	Same	More easy to handle a plastic box than a cardboard box due to the handles.	More difficult to fetch and lift a cardboard box compared to a plastic box due to lack of handles. Less weight of box sometimes positive, but often compensated by more parts in each box up to weight limit of manual handling.	Same
PoU (Kitting, Pre-assembly, Line)	Same	Same	Picking parts out of the box is the same regardless if plastic or cardboard boxes. Less weight of cardboard box especially positive when handling empty boxes (often to be placed on shelf in red zone).	Same, but important to not lose signal to order more parts by throwing away the box after it has been emptied.
Train transportation	Same	Easier handling of plastic boxes compared to cardboard boxes (fetch and lift) due to the handles.	More difficult to fetch and lift a cardboard box compared to a plastic box due to lack of handles. Less weight of box sometimes positive, but often compensated by more parts in each box up to weight limit of manual handling.	Same
Forklift transportation	N/A	N/A	N/A	N/A

Handling of empty packaging	N/A	Depending on chosen solution, but assuming that empty pallets are taken out of the factory in the same way as V-EMB then the only inefficiency is to have 2 docking points outside - one for V-EMB and one for disposable packaging.	Same	N/A
Breakdown of empty packaging	N/A	Disposal of cardboard waste to be compared with time of bundling plastic boxes. No washing of dirty plastic boxes (benefit for VGLS)	Disposal of cardboard waste must be secured in a ergonomically correct way. To be compared with ergonomics impact of bundling returnable plastic boxes.	N/A
Packaging maintenance vs. disposal	Positive with disposable packaging is that we always have new packaging meanwhile returnable V-EMB can be in varying condition. Negative could be that cardboard boxes may offer less protection than plastic boxes due to thinner and more fragile packaging material.	No sorting or cleaning needed with cardboard boxes.	N/A	N/A
"Good enough" need	Same as long as the cardboard boxes are made durable enough to be used at least once through the supplier chain.	This is the major question mark. Efficient handling of both filled and empty cardboard boxes in the factories must be secured.	This is one major question mark. Ergonomically correct handling of especially filled cardboard boxes in the factories must be secured.	Way of working must be implemented to have cardboard boxes returned in the same way as plastic boxes to secure ordering new parts. If thrown away at line side then ordering not secured.

Appendix 5 - Test questionnaire

Evaluation questionnaire: Disposable packaging

It would be of great help to us if you would like take the time to respond to some short questions. The questionnaire takes approximately 3 minutes to fill in and your answers will be anonymous.

Station: _____

Take a stand to all statements on a scale from 1 to 5:	Doesn't agree at all				Agrees completely
1. The disposable packaging provides sufficient goods protection	1	2	3	4	5
2. The disposable packaging provides equivalent goods protection as V-EMB does	1	2	3	4	5
3. The disposable packaging is equivalent to V-EMB in handling	1	2	3	4	5
4. The disposable packaging can be handled in the current material handling processes	1	2	3	4	5
5. The disposable packaging can improve the ergonomy regarding weight	1	2	3	4	5
6. The disposable packaging can improve the ergonomy regarding handling	1	2	3	4	5
7. The disposable packaging can improve the ergonomy regarding picking	1	2	3	4	5
8. The disposable packaging can have the same label as V-EMB	1	2	3	4	5
9. The disposable packaging can be handled in the current scanning and information processes	1	2	3	4	5
10. The disposable packaging litters the production environment	1	2	3	4	5

11. The breakdown of the disposable packaging is easy	1	2	3	4	5	

Other comments:

_____

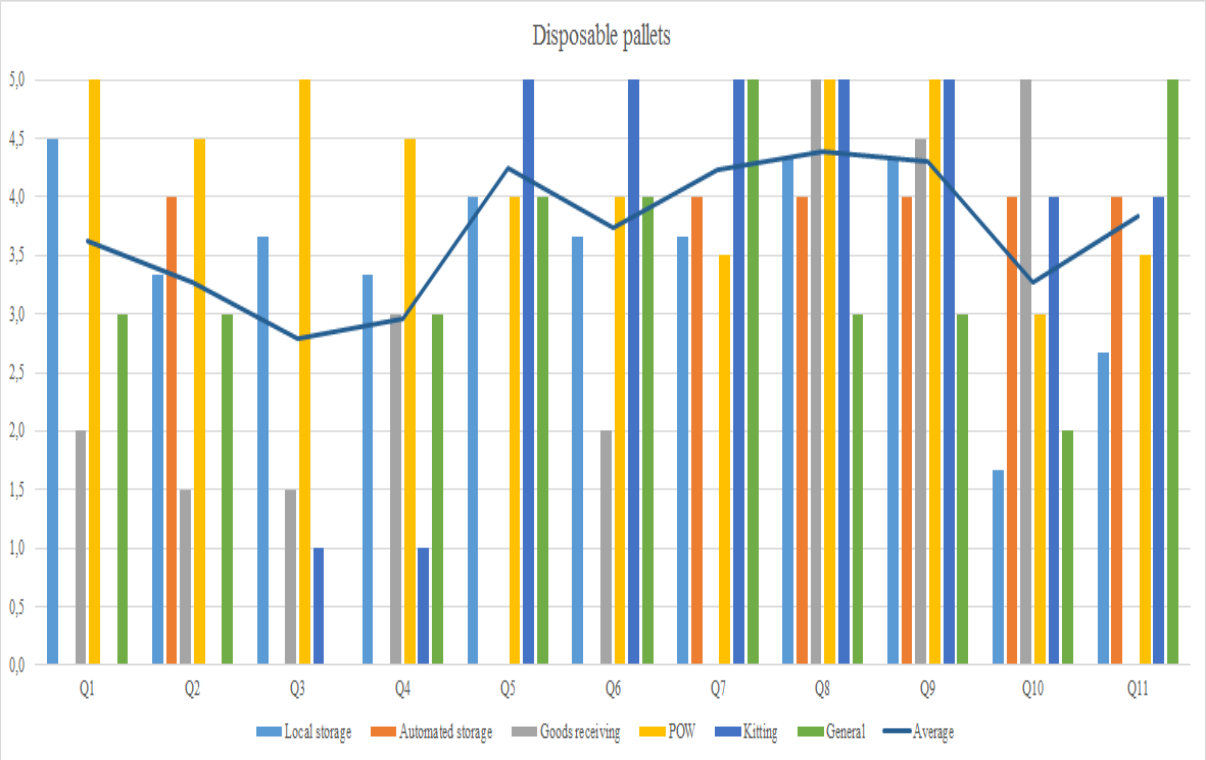
_____

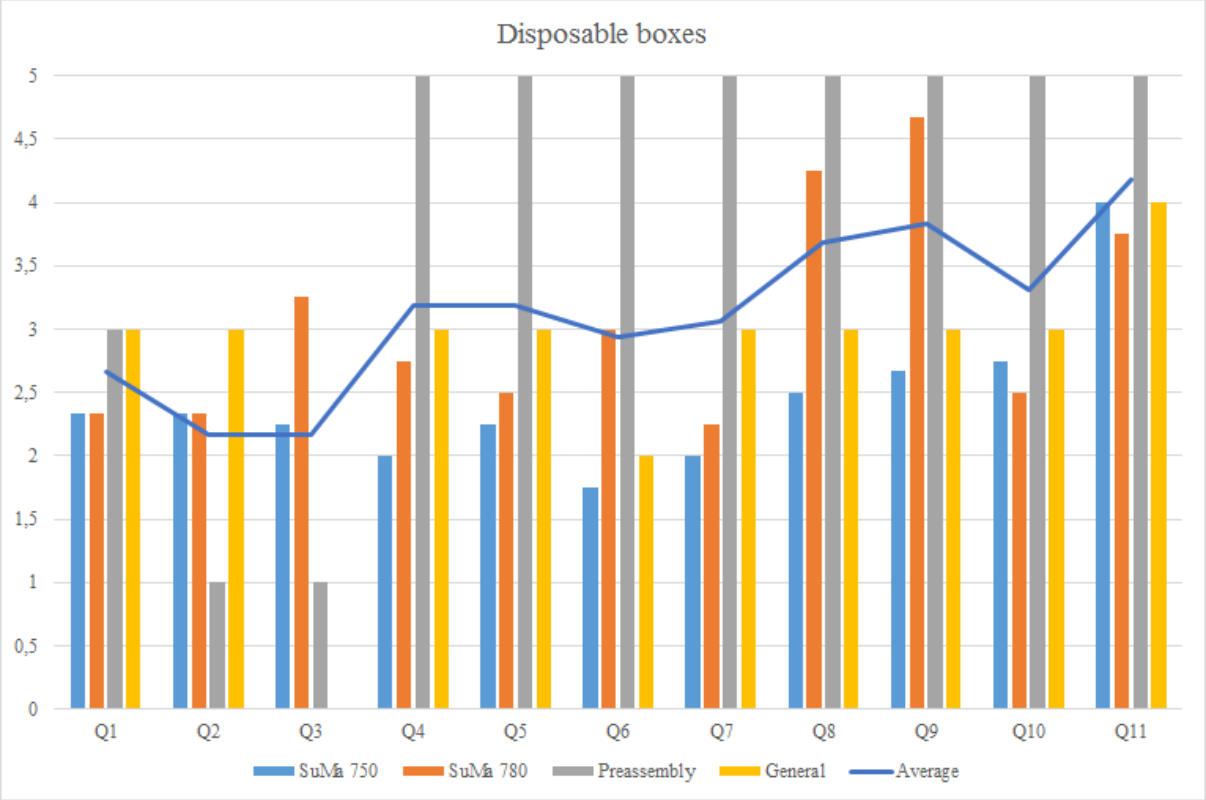
_____

_____

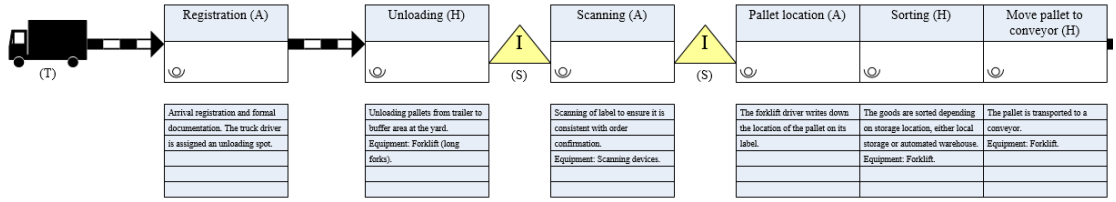
_____

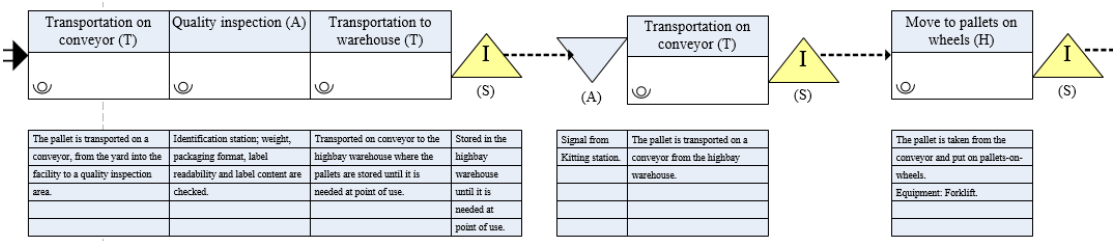
Appendix 6 - Results from questionnaire

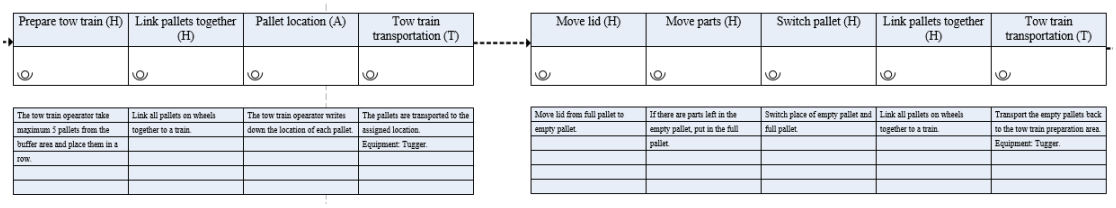


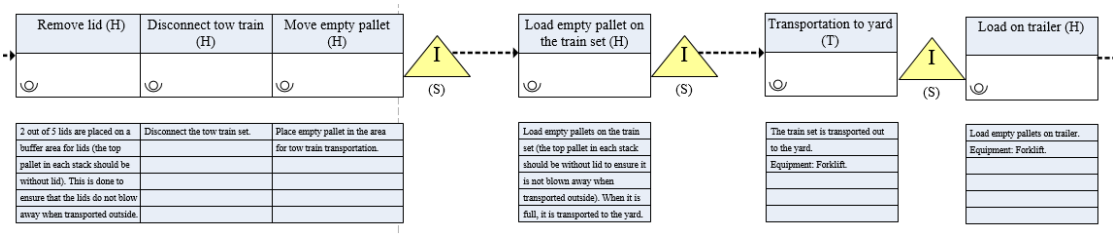


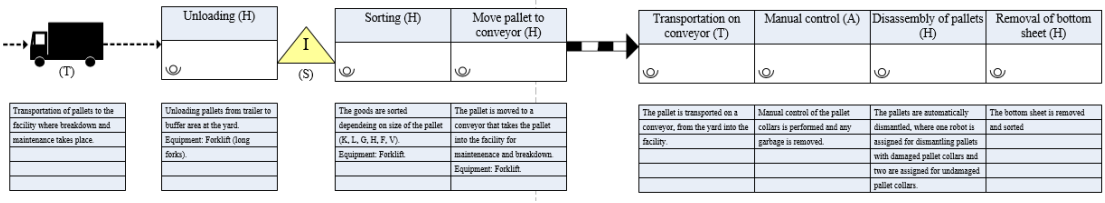
Appendix 7a - MFM Pallet flow 1



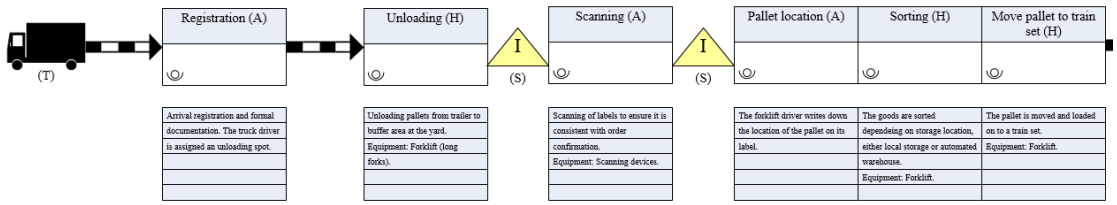


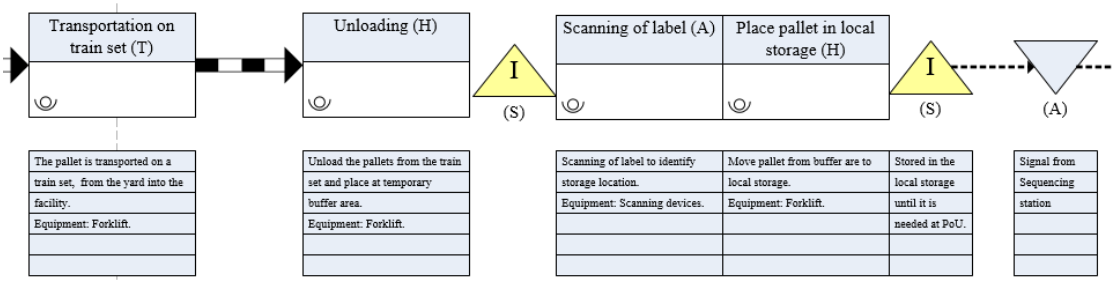


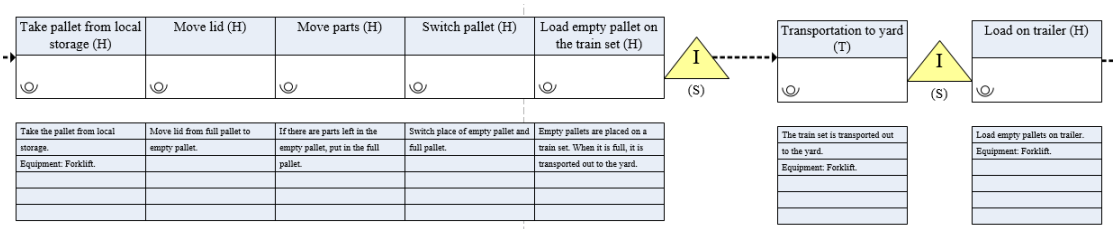


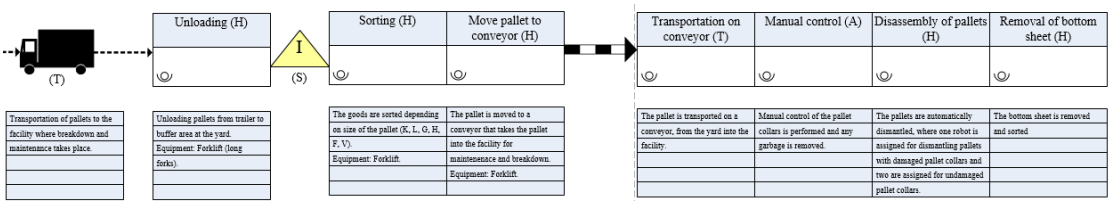


Appendix 7b - MFM Pallet flow 2

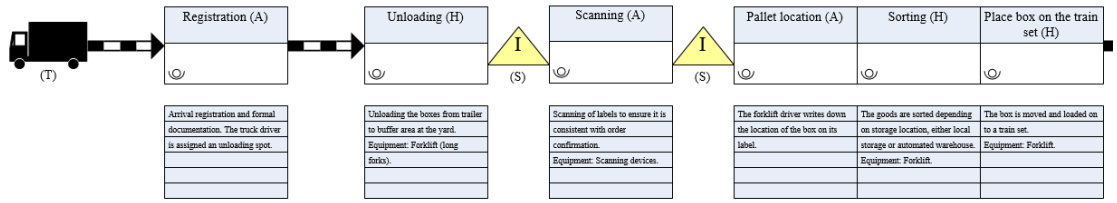


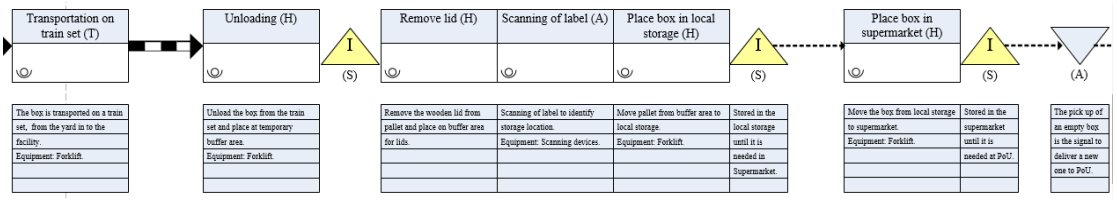


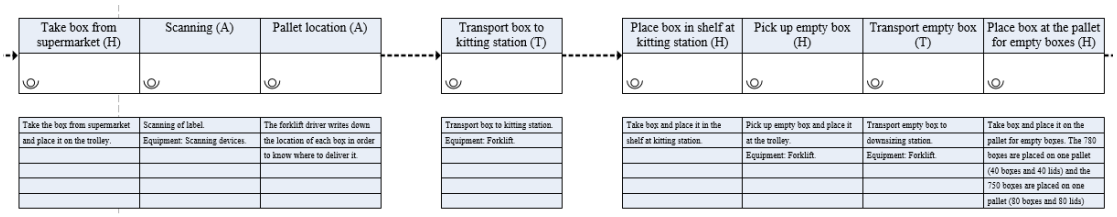


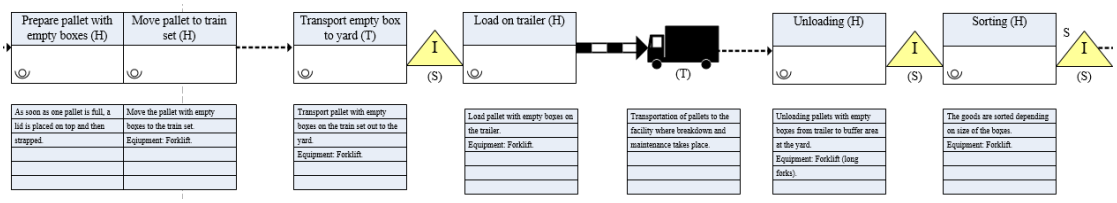


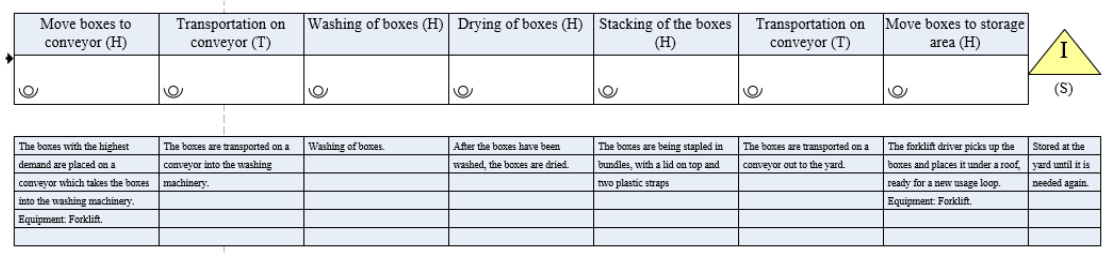
Appendix 8a - MFM Box flow 1



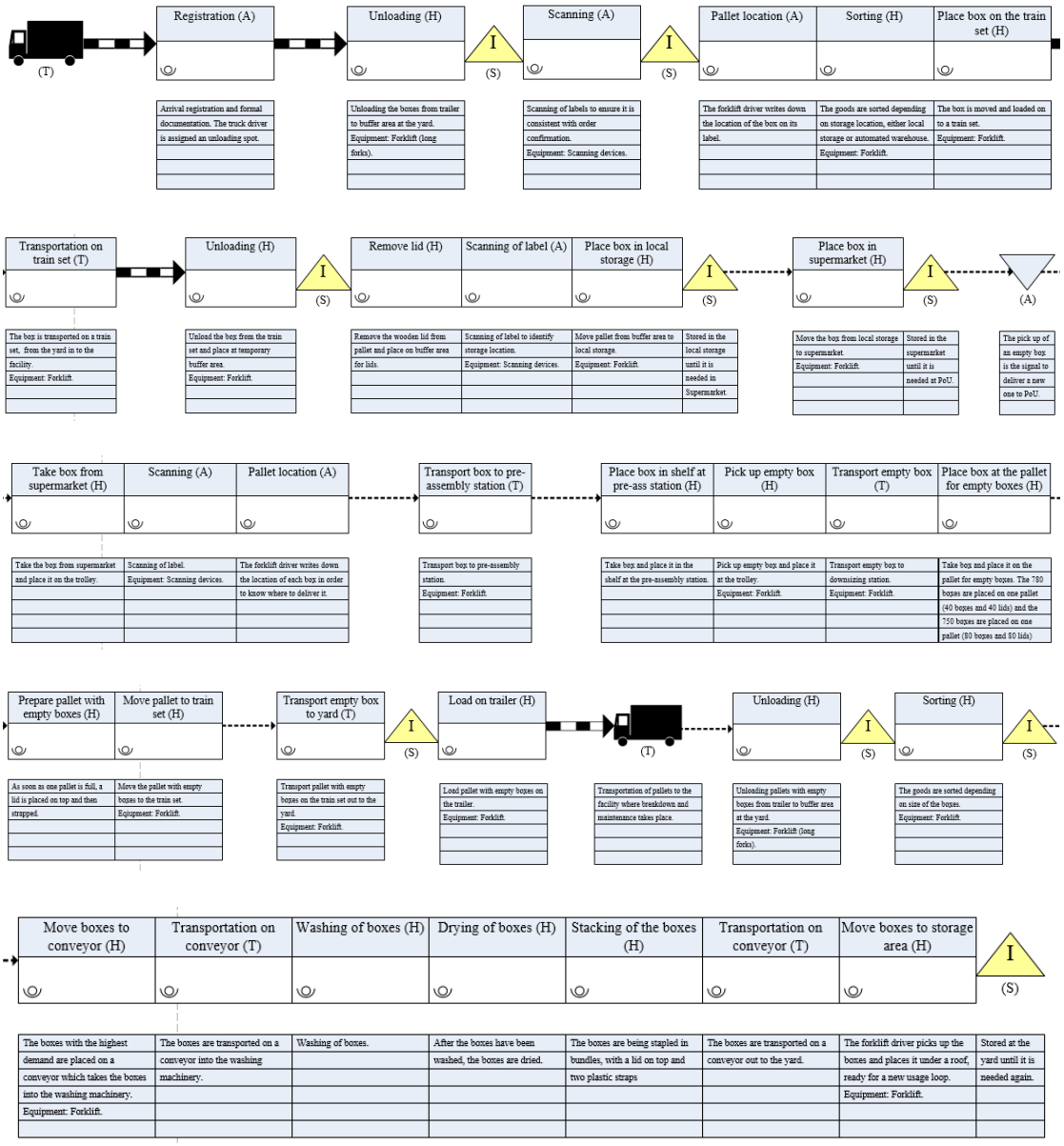




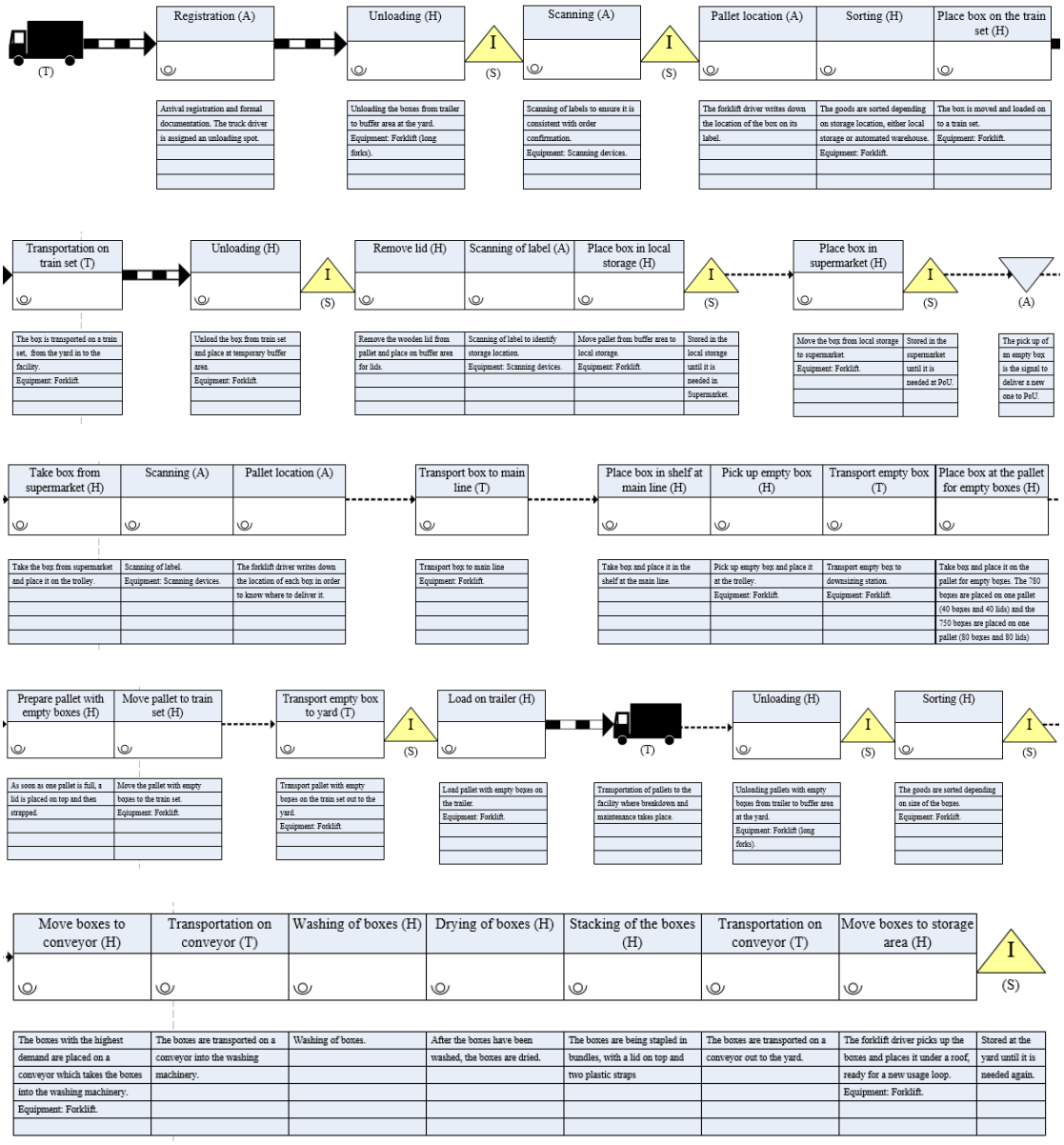




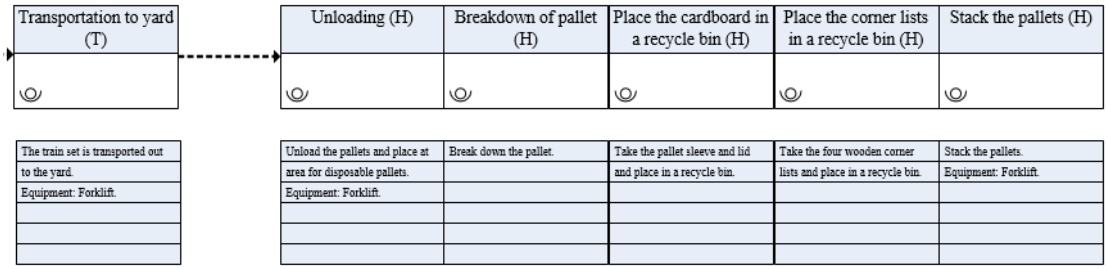
Appendix 8b - MFM Box flow 2



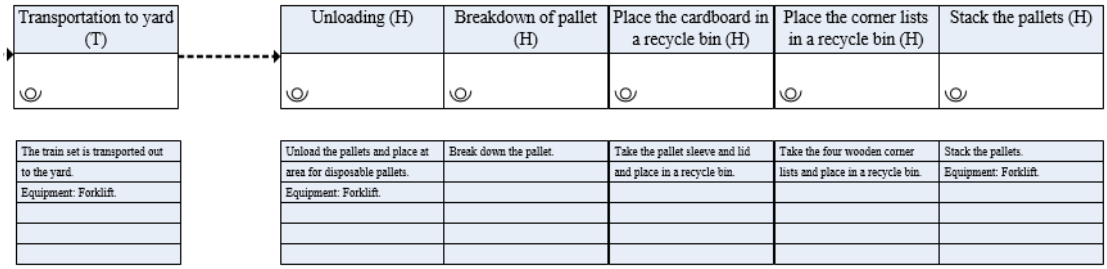
Appendix 8c - MFM Box flow 3



Appendix 9a - MFM Pallet flow 1 with disposable packaging



Appendix 9b - MFM Pallet flow 2 with disposable packaging



Appendix 10 - MFM Box flow with disposable packaging

Place box in shelf at PoU (H)	Pick up empty box (H)	Transport empty box (T)	Throw box in compressor (H)
			

Take box and place it in the shelf at PoU.	Pick up empty box and place it at the trolley. Equipment: Forklift.	Transport empty box to downsizing station. Equipment: Forklift.	Throw the box in the compressor located at the downsizing station.