Analysis and comparison of reusable and one-way packaging solutions for gear manufacturing.

Their impact on the environment, automation and total cost.

CLAUDIA FERRARI
Abstract
Producer’s responsibility has gained relevance when it comes to sustainable development, and its role in closed loop product life cycle and sustainable manufacturing has become of vital importance. Hence, packaging solutions must have a high degree of sustainability, while maintaining high quality and protection of the components.

This master thesis aims to analyze the possibility of replacing a reusable plastic packaging material with a one-way cardboard solution; to verify and compare, using a Life Cycle Assessment Tool, their environmental burden and to analyze the overall costs and impact this would have for the Transmission Machining department of Scania CV AB, Södertälje.

The input data regarding materials, transport and end of life solution give an understanding of the impact this change would have on Climate Change by means of GWP – Global Warming Potential and allow to estimate the cost of environmental impact through EPS – Environmental Priority Strategy Methodology.

Finally, the report investigates the potential benefits and disadvantages of applying such changes from an automation, quality and productivity perspective.

Results show how the use of a one-way cardboard solution would allow Scania CV AB to reduce the environmental impact associated with the use of its packaging, while at the same time reducing the costs associated with it. Moreover, the implementation would increase the degree of automation, ergonomics, quality and safety of the production line.

Sammanfattning
Producentansvar har fått relevans när det gäller hållbar utveckling, och dess roll i livslängd med sluten slinga och hållbar tillverkning har blivit avgörande. Därför måste förpackningslösningar ha en hög grad av hållbarhet, samtidigt som hög kvalitet och skydd av komponenterna upprätthålls.

Detta masterprojekt syftar till att analysera möjligheten att ersätta ett återanvändbart plastförpackningsmaterial med en envägs kartonglösning; att verifiera och jämföra, med hjälp av ett livscykelbedömningsverktyg, deras miljöbelastning och analysera de totala kostnader och effekter som detta skulle ha för Transmission Machining avdelningen i Scania CV AB, Södertälje.

Ingångsdata avseende material, transport och livslängdslösning ger en förståelse för vilken inverkan denna förändring skulle ha på klimatförändringen med hjälp av GWP - Global Warming Potential och tillåta att uppskatta kostnaderna för miljöpåverkan genom EPS-strategin för miljöprioritering.

Slutligen undersöker rapporten de potentiella fördelarna och nackdelarna med att tillämpa sådana förändringar ur ett automations-, kvalitets- och produktivitetsperspektiv.

Resultat visar hur användningen av en envägs kartonglösning skulle göra det möjligt för Scania CV AB att minska miljöpåverkan i samband med användningen av förpackningen samtidigt som kostnaderna förknippas med det. Dessutom skulle genomförandet öka graden av automation, ergonomi, kvalitet och säkerhet i produktionslinjen.
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Introduction

*Sustainable Development* has been defined, by the World Commission for the Environment, as ‘a morally defensible form of economic and social development that meets the needs of the present without compromising the ability of future generation to meet the needs of others’. As can be easily inferred, this definition is applicable to the entire life cycle of a product, from its manufacturing to its disposal. Sustainable development fits into the more general concept of Circular Economy (CE) and Circular Manufacturing (CM); these concepts are associated with reusing, recycling and reducing the waste of materials and energy throughout multiple phases. Circular Economy’s goal is to achieve social equity, economic growth and environmental quality. [1]

In the specific case of this project, an interesting definition was given by the French Packaging Association CNE, who released a report in 2015 stating that ‘*In the packaging sector, the circular economy model is about more than just recycling. It handles all stages of a product’s lifecycle, namely: its design, production, distribution and use, but also its recovery. It includes notions such as local integration and proximity*’. [2]

Companies have become increasingly aware of the implications related to the use and production of packaging solutions, and therefore are taking steps towards a more conscious and sustainable selection and usage. According to Klevås [3] there is a strong connection between a product and its packaging, making them affected by each other; moreover, they affect the efficiency of logistics activities, and changes happening to one of them may result in significant optimization of the whole process.

At the Transmission Machining department (DX) of Scania CV AB, Södertälje, optimal packaging solutions are required to deliver high quality components to the customers. Here, gears and shafts are machined and delivered to customers, namely the assembly line in Södertälje (DT), Scania Parts Logistics in Oudsbergen (Belgium) and Scania SLA in Sao Paolo (Brazil).

By high quality it is intended accurate dimensional and surface tolerances as well as rust-free components; to achieve this, it is necessary for the packaging solution to be able to protect the components from impact during transportation while avoiding rust formation at the same time.

Scania’s logistic roadmap seeks to fulfil the standards for Safety, Quality, Cost, Sustainability and Delivery for Industry 4.0.

The scope of this thesis is to develop a general packaging strategy for the components’ flow that stretches from inbound logistic between operations, to finished components in European pallets transported outbound to assembly lines in Södertälje (DT), Brazil (SLA) and to spare parts storage in Belgium (Scania Parts Logistics).

Currently, the Transmission Machining Department’s packaging solution to separate layers of components in H-pallets, consists of a reusable plastic spacer, the MH-0140, used in three different loops, namely DT-Sweden, Scania Parts Logistics and South Latin America. It’s use is associated with a determinate environmental impact and cost, that will be analysed by using a Life Cycle Assessment tool. Furthermore, the department is investigating the possibility of introducing a one-time cardboard solution (SWT 2) to substitute the MH-0140.

Each solution is analysed from an environmental, qualitative and economical point of view to verify the possibility of changing the current reusable plastic spacer with a one-time cardboard one. In the last decade, great effort has been put into developing good packaging strategies, as this affects the company’s financial and logistical performance.
This said, 80% of the components manufactured in the Transmission Machining department go through the Shot Peening process (thoroughly explained in Chapter 3.4.), therefore, to narrow down the scope of this thesis, while being able to consider the majority of the component’s flow, focus will be given on the packaging solution at the end of this process.

Two main research question will be addressed:

1. What is the environmental impact associated with reusable and one-way packaging, and what does their comparison entail?
2. How would the use of a one-time packaging solution impact the performance at the Transmission Department DX in Scania, Södertälje?

The carbon footprint of packaging solutions can vary greatly depending on several factors, including: material, transport, density and end of life (EOL) solutions. For this reason, it is important to perform accurate analysis to assess its impact; this is done by carrying out a Life Cycle Assessment (LCA), a technique used to analyse the impacts associated with all stages of a product’s life cycle. The Scania Packaging Sustainability Tool, released earlier in 2018 in collaboration with IVL Svenska Miljöinstitutet, will be used to run predictions based on the available data.

In addition to investigating the environmental burden of the two packaging solutions, relevance will be given on how a one-way solution would specifically benefit the Transmission Machining department production flow; in particular, aspects such as automation of the packing process, total manning, ergonomics, quality, storage and freight costs will be of main focus.

For clarity, the thesis structure is as follows:

Chapter 2 introduces and deeply explains the methodology used to gather useful data, that is used to perform calculations further in the text. Description of the Scania Packaging Sustainability Tool is outlined.

Chapter 3 gives an overview of the topics that have been reviewed as the foundation to perform the analysis and to contextualize the results.

Chapter 4 presents detailed results, with visual representation of the input and output data. Moreover, a detailed description of the Key Performance Indicators, that have been individualized as the main factors impacting the performance of the production line, is presented.

Chapter 5 presents the main conclusions and offers suggestions for future work.
2. Methodology

In this section, research questions will be addressed, followed by an explanation of the qualitative and quantitative analysis that has been performed to approach the issues presented by the use of the current packaging solution. Here, simple calculations are performed for the reader to have a better understanding on how the numbers used for further calculation have been obtained.

As previously mentioned, the scope of this thesis is to develop a general packaging strategy for the components’ flow that stretches from inbound logistic between operations, to finished components in European pallets transported outbound to assembly lines in Södertälje (DT), Brazil (SLA) and to spare parts storage in Belgium (Scania Parts Logistics).

The challenges novel to this study are the lack of knowledge associated with the definition of the flow of the spacers and the absence of data regarding the previous environmental impact associated with packaging use at Scania CV AB. Therefore, effort has been put into clearly identifying the current packaging flows, to be able to calculate the required data to feed into the Scania Packaging Sustainability Tool to obtain reliable results.

More specifically, the main problems associated with the use of the MH-0140 spacer can be summarized as follows:

• dependence on the use of a volatile corrosion inhibitor paper, to prevent rust formation
• lack of total automation of the line
• quality and rust protection of the components
• operator’s ergonomics
• total manning
• customer adaptability

To tackle these issues, both qualitative (interviews and company visits) and quantitative (data based) methods are used to gather information; a more thorough description of each problem can be found in Chapter 3.5.2. of the Literature Review.

The use a one-time cardboard solution has the potential of greatly influencing and eliminating the aforementioned problems.

First the research questions must be addressed. Based on the needs that have been presented by the Transmission Machining department, it is fundamental to evaluate the environmental impact of the current and potential future spacer, to compare the two solutions; moreover, it is fundamental that a thorough discussion on the benefits and drawback of using a one-way packaging solution is carried out.

2.1. Research questions

• **What is the environmental impact associated with reusable and one-way packaging, and what does their comparison entail?**
  First, an environmental assessment of each packaging solution and for each loop will be performed, followed by a comparison of the sum of the results. Afterwards, their total cost will be addressed and compared.

• **How would the use of a one-time packaging solution impact the performance at the Transmission Department DX in Scania, Södertälje?**
  Automation, quality, ergonomics and total manning are part of the KPIs that will be addressed when discussing the potential benefits of using a one-way cardboard solution.

2.2. Plant and Workshop visits

The shot peening process comprises of four lines:

1. **ASP - Axel (Shaft) Shot Peening**
2. ESP - Enkel Shot Peening  
3. DSP - Dubbel Shot Peening  
4. SP4 - Dubbel Shot Peening

An exhaustive explanation on how the lines work can be found in Chapter 3.4.1. of the Literature Review and the information used to describe them has been gathered through interviews with operators. Problems related to time consuming processes, ergonomics and automation of the line are explained and discussed in Chapter 3.5.2.

2.3. Company visits

As previously mentioned, as part of the qualitative methods, during the course of this Master’s Degree Project, multiple companies have been visited to analyze different packaging strategies and acquire deeper knowledge. More specifically: Volvo, GKN and VIDA.

VIDA Packaging Logistics is a company that offers a wide range of logistics solutions; it is located in Järna, south of Södertälje, and it is a strategic and vital point for the flow (as can be read in the loop description in Chapter 2.5.2.).

The sorting of packaging material incoming from the assembly lines is done at Scania’s CV AB Breakdown Unit building 270, for the loop in Sweden, or at LEADEC FM BV &Co. KG (a provider of logistics services, whose facility is in Eschweiler, Germany) for other loops.

Once sorted at the breakdown unit, 170 MH-0140 spacers are packed into a H-pallet (called a distribution unit – DU) and sent to VIDA. Once delivered, they are put into a washing buffer, after which the spacers are taken out and damaged ones are scrapped; afterwards, 100% of MH-0140 spacers are washed with high pressure warm water, before being packed and stored.

One distribution unit packed at VIDA comprises of 170 MH-0140 and it is ready for use as soon as it is delivered to Scania.

According to the site manager at VIDA, the cost to wash one MH-0140 is 2.9 kr, the cost to scrape each spacer is 0.5 kr and the loading cost is 0.18kr/spacer. These values will be later used to evaluate the costs related to the use of the spacers.

Volvo and GKN packaging strategy do not relate to Scania’s process for the shot peening packaging. In fact, their packaging process is completely manual, hence no useful information could be retrieved.

2.4. Scania Packaging Sustainability Evaluation Tool

One of the major problems that organizations face is lack of standardization. To overcome this, Scania CV AB together with IVL Svenka Miljöinsitutet have developed a common tool for sustainability evaluations. This tool allows to assess different packaging solutions from a sustainability perspective before implementing it, as well as it allows to build knowledge and understanding for how the packaging system affects the environment and what can be done to minimize its negative impact. Moreover, it helps to find improvements in already existing or proposed solution, for instance by considering the several end-of-life options.

Scania CV AB’s Production and Logistics targets are:

- 100% fossil free electricity by 2020
- 33% less energy in industrial operations by 2020
- 50% CO2 reduction from land transports by 2025
- 25% reduction of non-recyclable waste by 2020

To achieve these goals, packaging design is key to improved sustainability.
The packaging sustainability targets are:

-40% CO2 emissions from packaging processes until 2025

-25% material impact

-50% transport impact

-33% energy impact

-25% end of life impact

**Figure 1: 2025 Sustainability targets, Scania CV AB**

To assess the impact of packaging material it is fundamental to identify its life cycle. A general representation could be:

**Figure 2: Life Cycle of packaging materials, Scania CV AB**

For each stage, data is collected for all the inputs and outputs and their effects on different environmental aspects are evaluated [source IVL].

IVL Svenka Miljöinsitutet chose to focus on two impact categories:

1. **Climate Change (GWP - Global Warming Potential)**, which is a pressing and current issue that must be solved
2. **ESP - Environmental Priority Strategy**, a financial evaluation of environmental issues. It includes all types of environmental effects and evaluates them based on the damage they cause. It is a very long-term evaluation of sustainability

The tool that has been developed comprises of 5 different sets of inputs:

1. **Material production** – the impact from material extraction and manufacturing of new packaging material is calculated. To do so, data regarding material and weight is required.
2. **Replenishment rate** – here, the number of components necessary to fill up the loop is entered.
3. **Transport** – as the main function of packaging is to enable the transport of goods, it is of vital importance to pay great attention to its weight and characteristics. As long as fossil fuel is used, added weight means higher use of non-renewable resources and emissions of CO2. Even the smallest change could have a great impact on the total carbon footprint. The tool allows to insert data regarding empty packaging and inbound transport, as well as the mode of transport.
4. **Washing** – water and energy consumption are considered. The total amount of pieces that will be washed annually is entered, as well as the washing location.
5. **End of Life Solution** – or waste management is crucial in assessing the overall impact of packaging. For instance, recycling plastics material gives a credit of -0.8 kg of CO2 per kg of material, whereas incineration adds 1.1 kg of CO2.

As previously mentioned, this tool has the purpose to evaluate different packaging solutions before decision making. It must be considered that, due to simplifications in the process, the results are not an absolute truth but a good indication of the environmental footprint. [source IVL]

Once the correct data have been entered into the tool, the total result will be summarized for each packaging solution and visually presented through graphs, enhancing the differences. The lower the impact the better the option.

The Scania Packaging Sustainability Evaluation Tool will be used to assess the impact of the MH-0140 and the SWT 2 spacer for each packaging loop.

Afterwards, an analysis of the sum of the results will be performed and a comparison between the two packaging solutions, based on the Global Warming Potential and the Environmental Priority Strategy, will be made.

### 2.5. Available data storage

Scania CV AB has developed a web-based system, whose mission is to provide standard packaging material for the flow between suppliers and Scania and between Scania units according to customers need.

Here, records of any type of packaging can be retrieved; in particular, important data regarding the MH-0140 have been retrieved:

An average daily demand of 8356 spacers is used in the totality of Scania CV AB; considering a total of 228 work days per year, $8356 \times 228 = 1905168$ spacers are used annually.

In 2018 the transmission machining department DX has ordered a total of 379 300 spacers, for an average daily demand of 1664 spacers. Hence:

\[
\frac{1664}{8356} = 0.1991 \text{ pcs}
\]

\[
0.1991 \times 100 = 19.91\%
\]

**Hence, DX accounts for almost 20% of the total spacers used.**

Considering that 80% of components are Shot Peened, it is assumed that 80% of spacers are here used to pack the components. Therefore, the average **number of spacers used at Shot Peening annually** is:

\[
379300 \times 0.8 = 303440 \text{ pcs}
\]

for a **daily demand** of:

\[
\frac{303440}{228} = 1331 \text{ pcs}
\]

As previously mentioned, a high number of spacers are scrapped every year as they come to their end of useful life. In 2018, the **total number of scrapped spacers** was: 26329.

\[
26329 \times 0.1991 = 5244 \text{ pcs}
\]

**this is the number of scrapped components attributed to DX.**

Those attributed to Shot Peening is:

\[
5244 \times 0.8 = 4195 \text{ pcs}
\]
With these numbers in mind, further calculations can be done.

2.5.1. Replenishment rate

From available historical data the components produced at DX are sent to the customers with the following percentage:

85% = DT assembly line, Södertälje
3% = Scania Parts Logistics, Belgium
12% = SLA assembly line, Brazil

Therefore:

**Number of spacers used in the loop for DT-Sweden:**

\[
303440 \times 0.85 = 257924 \text{ pcs}
\]

**Number of spacers used in the loop for Scania Parts Logistic:**

\[
303440 \times 0.03 = 9103 \text{ pcs}
\]

**Number of spacers used in the loop for SLA:**

\[
303440 \times 0.12 = 36413 \text{ pcs}
\]

After consulting with the responsible for sustainability within Scania’s packaging system, a refill rate per loop has been individualized:

10% for DT, therefore \(257924 \times 0.1 = 25792\) pcs
15% for Parts, therefore \(9103 \times 0.15 = 1365\) pcs
20% for SLA, therefore \(36413 \times 0.2 = 7283\) pcs

The refill rate considers annual scrapped components and increase in demand.

These numbers will be fed into the Scania Packaging Sustainability Tool to calculate the Global Warming Potential and the Environmental Priority Strategy for each type of spacer, in every loop.

2.5.2. Transport

**Packaging Loops**

The Transmission Machining (DX) department has 3 main customers to whom the components are delivered: the assembly line (DT) in Södertälje, Scania Parts Logistics in Oudsbergen, Belgium, and the production line in Sao Paolo, Brazil.

As can be easily inferred, for each destination the packaging material has different loops and therefore it is necessary to break them down for a better understanding. The loop of the MH-0140 spacer is represented in the following pictures and the nomenclature is as follows:

Zerust= provider of the VCI paper
DX= transmission machining department, Scania CV AB, Södertälje, SE
DT= assembly line, Scania CV AB, Södertälje, SE
270= breakdown unit, Södertälje, SE
VIDA= washing and storage pool, Järna, SE
Leadec= storage pool, DE
Antwerp= port, BE
DT – Sweden: of the totality of the components manufactured at DX, 85% are delivered at DT for final assembly. Once the assembly process is completed, all packaging material is randomly put back into a pallet and sent to the breakdown unit in building 270, where sorting of material takes place. Here, operators have an average of 9.5 sec/pallet to empty it; hence it is a high pace process that is greatly influenced by the conditions of the incoming packaging. The flow of components can be found in figure 3.

Scania Parts Logistics: only an average of 3% of the totality of components manufactured by DX is delivered to Scania Parts Logistics in Belgium. As can be seen in the picture, there’s a higher transportation degree which has a major impact on the carbon foot print of each spacer.

Following the unpacking process, all spacers are collected and sent to Leadec, a storage facility in Germany, that will then ship them to VIDA for the washing process before being reused. The flow of components can be found in figure 4.
The last loop, shown in figure 5, and perhaps the most influential from an environmental point of view is the one regarding **South Latin America:**

![figure 5: South Latina America loop](image)

In this loop, a combination of both trucks and container ships are used to transport parts to Brazil, where 12% of the components are sent to the production line in Sao Paolo, for final assembly.

The current MH-0140 spacers are reusable and have an average life time of 5 years; for this reason, all spacers are collected, stored, washed and re-introduced into the loops. This means that, with the exception of the Swedish loop, there is a lot of empty packaging transport over long distances.

Data regarding material, transport, washing and end of life solutions will be calculated for each loop and used to evaluate the Global Warming Potential GWP and Environmental Priority Strategy EPS of the MH-0140 and the SWT 2 spacers, by using the Scania Packaging Tool.

As mentioned, components are delivered to customers by different means of transport (trucks or containers on cargo ships). The kilometers per segment of transportation have been calculated by using google maps (regularly used by truck drivers to estimate travel distances):

<table>
<thead>
<tr>
<th>Transport (km via land)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VIDA-Södertälje</td>
<td>15 km</td>
</tr>
<tr>
<td>Södertälje- Oudsbergen (parts)</td>
<td>1 450 km</td>
</tr>
<tr>
<td>Oudsbergen - LEADEK</td>
<td>75 km</td>
</tr>
<tr>
<td>LEADEK-VIDA</td>
<td>1 405 km</td>
</tr>
<tr>
<td>GöteborgsHamn - Oskarshamn</td>
<td>325 km</td>
</tr>
<tr>
<td>Oskarshamn-VIDA</td>
<td>300 km</td>
</tr>
<tr>
<td>SWT - Södertälje</td>
<td>460 km</td>
</tr>
<tr>
<td>Zerust - Södertalje</td>
<td>435 km</td>
</tr>
<tr>
<td>Södertälje - Anwerpen, BE</td>
<td>1 488 km</td>
</tr>
<tr>
<td>Sao Paolo - Scania Brazil</td>
<td>50 km</td>
</tr>
<tr>
<td>Antwerpen - VIDA</td>
<td>1 513 km</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transport (km via sea)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Antwerpen - Sao Paolo</td>
<td>11 201 km</td>
</tr>
<tr>
<td></td>
<td>6 048 nm</td>
</tr>
</tbody>
</table>
Once the data was collected, the transport kilometer per packaging loop and packaging material is calculated:

- **Empty Packaging Sweden**
  
<table>
<thead>
<tr>
<th>MH-0140</th>
<th>SWT-aPak Cardboard spacer</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 km</td>
<td>460 km</td>
</tr>
</tbody>
</table>

  There is no inbound transport (transportation of packaging WITH components) for this loop.

- **Empty Packaging Scania Parts Logistics**
  
<table>
<thead>
<tr>
<th>MH-0140</th>
<th>SWT-aPak Cardboard spacer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1495 km</td>
<td>460 km</td>
</tr>
</tbody>
</table>

- **Empty Packaging SLA**
  
<table>
<thead>
<tr>
<th>MH-0140</th>
<th>SWT-aPak Cardboard spacer</th>
</tr>
</thead>
<tbody>
<tr>
<td>12779 km</td>
<td>460 km</td>
</tr>
</tbody>
</table>

  **Inbound Packaging SLA via land**
  
<table>
<thead>
<tr>
<th>MH-0140</th>
<th>SWT-aPak Cardboard spacer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1538 km</td>
<td>1538 km</td>
</tr>
</tbody>
</table>

  **Inbound packaging SLA via sea**
  
<table>
<thead>
<tr>
<th>MH-0140</th>
<th>SWT-aPak Cardboard spacer</th>
</tr>
</thead>
<tbody>
<tr>
<td>11201 km</td>
<td>11201 km</td>
</tr>
</tbody>
</table>

This information is used to calculate another set of input data to be fed into the Scania Packaging Sustainability Tool: the **ton\*km**, which is the weight of one spacer (in tons) * the number of annual spacers * the km.

- 0.00117 ton = MH-0140 weight
- 0.00042 ton = SWT 2-aPak spacer’s weight

And

- 257924 pcs = MH-0140 % to DT
- 9103 pcs = MH-0140 % to PARTS
- 36413 pcs = MH-0140 % to SLA
Hence:

<table>
<thead>
<tr>
<th>Empty Packaging Transport (ton*km)</th>
<th>DT</th>
<th>PARTS</th>
<th>SLA (via land)</th>
<th>SLA (via sea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH-0140</td>
<td>9053</td>
<td>15923</td>
<td>67227</td>
<td>477196</td>
</tr>
<tr>
<td>SWT-aPak</td>
<td>49831</td>
<td>5716</td>
<td>7035</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inbound packaging transport (ton*km)</th>
<th>MH-0140</th>
<th>SWT-aPak</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15444</td>
<td>65523</td>
<td>477196</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5544</td>
<td>23521</td>
<td>171301</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 1: Calculation ton*km*

2.5.3. Washing

To abide to the Scania cleanliness demands and standards, it is necessary that the totality of the MH-0140 spacers are washed before being reintroduced in the loop and reused; hence each year an average of 303440 spacers are washed and used for the Shot Peening process alone. In particular, per loop (considering the previously mentioned percentages):

- 257 924 pcs for DT
- 9 103 pcs for PARTS
- 36 413 pcs for SLA

Attributing a specific number of spacers to each loop is fundamental for the calculations of the environmental impact and costs, and to have a clearer mean of comparison between the spacers.

2.5.4. End of Life

Design for Environment or Eco-Design must consider all the stages the product will go through during its useful life, but it must also account for its disposal. The Scania Packaging Sustainability tool offers the possibility to choose between a great number of end of life solutions of which the most commons are: reuse, recycle, incineration with energy recovery and landfill.
3. Literature review and frame of reference

3.1. Design for the environment and Eco-Design

The last few decades have seen an increased sustainability awareness concerning the manufacturing of products and their packaging. Designers and engineers have been working to develop new solutions that consider multiple factors such as resource minimization, reuse, recycle and waste reduction; this thinking and developing process is called Eco-design, and it can be defined as “the incorporation of environmental considerations into any design”. [4]

Eco-design aims to reduce the environmental impact of products by addressing all stages of its lifecycle, to ease its use from manufacturing to disposal, while enhancing its performance and financial value.

3.2. Eco-Design for packaging solutions

In the packaging industry, when designing a new packaging solution focus must be on reducing the resources and hazards as well as enhancing its reuse, recycle and eventual disposal. The key to sustainable packaging is using a wide-ranging approach that includes social, economic and environmental aspects. [5]

The use of eco-design during the development phase of a product, benefits the business/company as a whole: it allows to maximize the use of its resources by adding functionality and effectiveness and it reduces the environmental impact throughout the use and disposal of the product. Manufacturers have adopted a “green mentality”, meaning that they are aware of the responsibility they have for their products, from cradle-to-cradle (or cradle-to-grave).

Moreover, including environmental factors during strategic planning will benefit the company, as it will be able to anticipate regulatory changes and manage potential risks. [4] Farsighted companies, such as Scania CV AB, leader in innovation and sustainability, are recognized worldwide for their environmental policies.

Packaging engineers must be able to enhance the product’s characteristics, while at the same time protecting it from external hazards. For this reason, the connection between packaging and product is very strong, they both affect the logistics, and changes to either of them could optimize or damage the whole process. As mentioned, the logistics is greatly affected, mainly because packaging adds weight to the products and therefore affects its transportation and handling.

According to Koejer, Wever and Henseler [6] there are three major functions of packaging:

1. **Protection** from the environment
2. **Utility** as the function that enables products distribution and use
3. **Communication**

In the specific case of Scania CV AB and the Transmission Machining department DX, packaging solutions are used to safely store, transfer and protect the components from external hazards such as moisture, dust and transportation accidents; therefore, in this thesis only protection and utility will be considered.

There are several barriers when it comes to developing new packaging solutions based on eco-design decision making [4]; among them:

- Lack of motivation:
  due, perhaps, to prosperity and growing market share, factors that might influence decision making based on the fact that the company is “doing well” and therefore might hide the need for a strategic change.
• Poor planning and lack of vision:
  vision can be synonym for long term goals, necessary for a company to grow economically
  and ameliorate its sustainability.
• Poor communication:
  communication is the key for a stable and growing business, when this doesn´t happen
  problems might occur in multiple stages of the development phase.
• Lack of resources:
  good finances are required when heavy investments must be made.

Another interesting term introduced by Holdoway and Hilton [4] is “Fitness for purpose”, meaning that
the packaging must be able to:

• Contain and protect the components, allowing adequate handling, manufacturing, storing and
  distribution
• Ensure high ergonomics
• Comply with customer requirements
• Conform to safety standards and legislations

In addition, for the specific case at the Transmission Department DX, the packaging must also:

• Allow the highest degree of automation to ensure a lower total manning
• Prevent rust formation
• Assure the highest degree of packaging density
• Ensure a high degree of sustainability

A good packaging design will result in reduction of space, transportation and overall costs, while
maximizing its use and expendability.

According to E. D. Georgakoudis [7] the main ideas behind redesigning of packaging solutions are the
following:

1. “To achieve better utilization of vehicle space during transportation”
   A higher degree of utilization would result in lower transportation costs, as there would be an
   increase of carried volume.
2. “To achieve better distribution of the total packaging weight per piece”
   This can occur by achieving an increase in the volume of products packaged
3. “To improve the quality of [secondary] packaging, in order to decrease damage during
   transport or handling operations”

Based on these main principles, Scania has been developing for several years its own packaging
solutions, striving to reach an excellent balance between effectiveness, quality and sustainability.
3.3. Scania’s Packaging Category Definition

To have great control over their packaging and due to the large amount of MH-numbers (packaging that is used by Scania) there is the need to separate those that need storing and should be distributed from the pool, from those that should only be used in closed loops; moreover, there is the need to separate those packaging for internal use from those that should be distributed to suppliers or PRUs (production units). [8]

Hence, the “Divided responsibility of technical documents and distribution flows” table 2, part of the New Category Definition document, released by OISP on 2017-03-24.

<table>
<thead>
<tr>
<th>Cat.</th>
<th>Type of packing</th>
<th>Purchase paid of</th>
<th>Technical development</th>
<th>Design and drawing</th>
<th>Filing of drawing</th>
<th>Owner</th>
<th>Valid flows</th>
<th>Distribution concept</th>
<th>Distribution responsibility</th>
<th>Distribution paid by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard</td>
<td>OID</td>
<td>OISP</td>
<td>OISP</td>
<td>OISP</td>
<td>OISP</td>
<td>Approved by OISP</td>
<td>On supplier request</td>
<td>OID</td>
<td>OID</td>
</tr>
<tr>
<td>2</td>
<td>Special</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Recipient PRU</td>
<td>From supplier to PRU</td>
<td>Closed loop</td>
<td>Dispatched PRU</td>
</tr>
<tr>
<td>3</td>
<td>Special</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Recipient PRU</td>
<td>From supplier to PRU</td>
<td>On supplier request</td>
<td>OID</td>
</tr>
<tr>
<td>4</td>
<td>PRU</td>
<td>Dispatched PRU if not other stated</td>
<td>Dispatched PRU if not other stated</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Dispatching PRU</td>
<td>Between PRUs</td>
<td>Closed loop</td>
</tr>
<tr>
<td>5</td>
<td>KD</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>One-way</td>
<td>One-way</td>
<td>One-way</td>
<td>One-way</td>
</tr>
<tr>
<td>6</td>
<td>One-way</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>One-way</td>
<td>One-way</td>
<td>One-way</td>
<td>One-way</td>
</tr>
<tr>
<td>7</td>
<td>South America</td>
<td>South America</td>
<td>South America</td>
<td>South America</td>
<td>South America</td>
<td>South America</td>
<td>Supplier in Europe, otherwise South America</td>
<td>On supplier request</td>
<td>Supplier in Europe, otherwise South America</td>
<td>Supplier in Europe, otherwise South America</td>
</tr>
<tr>
<td>8</td>
<td>Supplier owned</td>
<td>Supplier</td>
<td>Supplier</td>
<td>Supplier</td>
<td>Supplier</td>
<td>Supplier</td>
<td>From supplier to PRU</td>
<td>On supplier request for closed loops</td>
<td>Closed loops</td>
<td>Open loops ODP, Closed loops</td>
</tr>
<tr>
<td>9</td>
<td>Scania Parts Logistics</td>
<td>Scania Parts Logistics</td>
<td>Scania Parts Logistics</td>
<td>Scania Parts Logistics</td>
<td>Scania Parts Logistics</td>
<td>Scania Parts Logistics</td>
<td>From Supplier to Scania Parts Logistics</td>
<td>On supplier request</td>
<td>Open loops ODP, Closed loops</td>
<td>ODP/Supplier in Europe, otherwise South America</td>
</tr>
<tr>
<td>1</td>
<td>Special</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Respective PRU</td>
<td>Within the PRU</td>
<td>Internal distributed</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Scrapped</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Divided responsibility of technical documents and distribution flows

As can be seen in the table, there are 11 categories that are defined by multiple factors such as type of packing, ownership and valid flows.

In this thesis, two different type of packaging will be analyzed:

3.3.1. Standard packaging

MH-0140: standard packaging, category 1, owned by OISP, purchased by OID, distributed on PRU request.

Dimension: 745x545x3 mm
Weight: 1170 g
Material: 100 % PP

Figure 6: MH-0140, Reusable packaging solution
This type of packaging must conform to Scania’s cleanliness requirements, therefore prior to its use, each spacer must be washed; this process takes place at VIDA Packaging Logistics AB in Järna, Sweden.

3.3.2. One-way packaging

**SWT-aPak spacer**: one-way packaging, category 6, owned by DXLT, purchased by DXLT

- Dimension: 740x540x2 mm
- Weight: 420 g
- Material: 6% VCI paper, 91% recovered paper board, 3% glue

![Figure 7: SWT 2, One-way cardboard solution](https://example.com/swt2_cardboard.png)

3.4. Shot Peening Process

As previously mentioned, the focus of this thesis project will be on the packing process at the Shot Peening line.

3.4.1. Technology and use

The shot peening process can be defined as “*a cold work process used to finish metal parts to prevent fatigue and stress corrosion failures and prolong product life for the part.*” [9] The component is bombarded with small spherical shots that create compression stresses under the dimples caused by the shots; throughout the process, multiple overlapping dimples are formed, and the compression strengthens the metal making it more resistant to fatigue, heat, cracks and erosion from cavitation.

![Figure 8: Kurtiss-Wright, Application of Shot Peening Process, digital image](https://example.com/shot_peening_process.png)
This process is used to strengthen manufactured components and it often is the last step before assembly. At the department of Transmission Machining at Scania, Södertälje, several types of gears and shafts are manufactured and 80% of the totality of the components go through the shot peening process.

The production line, figure 7, comprises of the following steps:

![Production Line Diagram](image)

*Figure 9: Production Line, Transmission Machining Department, Scania CV AB*

More specifically, the Shot Peening process at Transmission Machining DX is divided in four different lines:

1. **ASP – Axel (Shaft) Shot Peening:**
   this line has manual packing and unpacking of components, but automated loading and unloading for the shot peening process; the line is composed of two conveyors, onto which the components are fed manually by the operator that performs a superficial quality check before the washing process takes place. After the shafts are washed, they get shot peened and finally washed one last time before being manually packed. For these components, a special category 3 spacer is used, hence this line will not be considered for further investigations.

2. **DSP – Dubbel (Double) Shot Peening:**
   a fully automated line that has the possibility to be loaded and unloaded manually if necessary. Two conveyors allow the components to go through four different processes (verification of occurred grinding process, washing, shot peening, washing) before being packed by an KUKA robot into an H-pallet according to a predefined pattern associated with the articles’ number.

3. **ESP – Enkel (Single) Shot Peening:**
   this line has automated packing and unpacking but has the possibility to be run manually. It is composed of two conveyors onto which the parts are fed automatically before going through an optical quality check that verifies that the grinding process (that takes place at a previous line) has been done. As for the previous lines, the components go through washing before being automatically loaded into the shot peening machine, after which they undergo another washing phase. Finally, the components are packed by an KUKA robot into an H-pallet, according to a predefined pattern that depends on the articles’ number.

4. **SP4 – Dubbel Shot Peening:**
   A fully automated line, that doesn’t have the possibility to be loaded and unloaded manually. The line works exactly as the DSP.
Depending on the production line, one or two types of media are used:

**SK-G3 0,30 HV640**  
**SK-G3 0,70 HV 640**

*Figure 10: Shot Peening Media, Transmission Machining Department, Scania CV AB*

Depending on the size of the shot peening media, different residual stresses are induced on the surface, influencing its ability to plastically deform. Through Single Shot Peening (ESP) an increase of 29% in strength is obtained, whereas in the Double Shot Peening (DSP, SP4) it can increase up to 40%.

For a better understanding refer to figure 8, 9, 10.

This process is done to increase the strength of the flank and bottom land of the gear, parts that are more prone to rupture due to fatigue stresses.

*Figure 11, 12: Gear, Transmission Machining Department, Scania CV AB*

*Figure 13: Nomenclature of a gear, digital image,  
<https://mechanicalpages.blogspot.com/2013/06/nomenclature-of-gear.html>  
21*
As previously mentioned, 80% of the components’ flow goes through shot peening, therefore this will be the focus area for this thesis. In particular, the packing process that takes place at DSP, ESP and SP4, where currently MH-0140 spacers are used in an (almost completely) automated process, will be analyzed.

3.4.2. Washing process

Each gear in the Shot Peening lines goes through two washing phases: the first one to remove any trace of grease, oil and dust due to previous machining stages, the second one after shot peening to remove the dust produced during the process.

Both of them use BONDERITE C-NE 10640 washing media, a special neutral cleaner that has the specific characteristic of preventing rust formation.

Figure 14: Washing media

Figure 15: Washing Machine, Shot Peening Line, Transmission Machining Department, Scania CV AB
3.5. Packaging solution for gear manufacturing at Scania CV AB, Södertälje

3.5.1. Current state

It can be said that the production line for the Shot Peening process of gears in Södertälje has a high degree of automation; inbound components, coming from the hard machining process, are delivered stacked in multiple layers in H-pallets.

Used to separate each layer is an MH-0140 green spacer, previously described. For a better understanding of the inbound and outbound flow refer to figures 16, 17, 18:

![Figure 16: Packing flow, Shot Peening Line, Transmission Machining Department, Scania CV AB](image1)

The packing and unpacking process is automated, performed by an KUKA robot.
Once the H-pallet is delivered, an operator manually opens the lid and sends the pallet inside the work cell, where a robot proceeds to unpack the components and positions them on the shot peening line, as well as it removes the MH-0140 spacers and stacks them into an empty pallet close by.

Once the pallet is empty, it is sent through automated conveyors, to a second step that comprises of the operator manually preparing it for the packing process. The operator positions a VCI plastic bag as shown in figure 16, and black lateral spacers for the bag not to be torn by the robot during the process.

Now the pallet is ready to be sent into the cell a second time for the components to be packed.

![Figure 19: Packaging solution prior to the packing process, Shot Peening Line, Transmission Machining Department, Scania CV AB](image)

A second KUKA robot unloads the shot peened components from the conveyor belts and places them into the pallet following a predefined pattern, according to the article’s number. There are 4 different patterns:

- Rak
- Tärning
- Omlott
- Förskjutet

![Figure 20 (a), (b), (c), (d): Gear predefined patterns, Shot Peening Line, Transmission Machining Department, Scania CV AB](image)
The robot separates each layer with a MH-0140 spacer, to which a VCI paper has been manually attached. To have a better understanding of the packaging “layers” a quick sketch of the section of a pallet has been drawn:

![Section of a Distribution Unit with components](image)

*Figure 21: Section of a Distribution Unit with components*

The use of a Volatile Corrosion Inhibitor paper is fundamental in the packing process, as it prevents rust formation while the pallet is being stored and/or during its transport to the customer. The VCI paper is supplied by ZERUST and its chemical properties and function will be further analyzed in Chapter 3.6.
3.5.2. Problems

Applying the VCI paper to the MH-0140 spacers is a time consuming and non-value adding operation that requires a high manning degree and an average of 3.5-4 hrs/shift dedicated depending on multiple factors such as: the line (ESP, DSP, SP4), the article that is being processed and therefore the number of parts per layer. Moreover, according to the workshop operators, due to the high production rates and short cycle times, it is often necessary to request help from operators on other lines to speed up the task, resulting in the lines remaining unattended.

The workstation and the tools used can be seen in the following pictures:

Figure 22 (a), (b), (c): Workstation

Multiple problems can be individualized:

- **Lack of automation:** the necessity to manually stick the VCI paper to each spacer, doesn’t allow a full degree of automation of the lines.
- **Lack of ergonomics:** as can be seen in the pictures, the operator sitting on the chair must bend over into the pallet to reach for components and he/she must constantly turn around to reach for the tape.
- **Time consuming:** it is a repetitive task that requires up to 4hrs/shift.
- **Dependence on cleanliness of the spacer:** to conform to Scania’s cleanliness demands, each spacer must be washed prior to its use, but dust deposits in the workshop might affect the process and the tape can easily detach.
• **Effectiveness:** on average 3 papers/hr partially or fully detach from the spacer. This is due to mainly two factors: the cleanliness of the spacer and the robot handling. The robot must “shake” the spacer to separate it from the one below, causing the paper to detach or in other cases causing the spacer to fall on the floor into the robot cell (figure 20), and therefore requiring an operator to stop the line and pick it up.

![Image](image1.png)

*Figure 23: Example of disruption in the work cell*

• **Influence on the breakdown unit:** applying tape to fix the VCI paper to the spacer causes big disruptions at the breakdown unit in building 270. Operators have less than 9.5 seconds per pallet to sort the packaging material; this restricted time often forces the operators to stop the line to fully remove the tape before sending the MH-0140 to VIDA (washing facility).

• **Tape residues on MH-0140:** at times, residues of tape go through the washing process at VIDA and are afterwards transferred to the components.

• **MH-0140 residues and chips on the components:** due to the unpacking and handling process at the assembly line, gears are often dragged onto the surface of the spacer before being lifted; this causes plastic chips to detach and stick to the gears (figure 21), making it extremely difficult for the vision cameras used for quality control to detect the correct geometric and surface tolerances.

![Image](image2.png)

*Figure 24: MH-0140 chips found on the gears*
An example:
There are 100 spacers/pallet.

Article 1500145 runs on line SP4. For this article there are 4 pieces/layer, 6 layers, for a total of 24 parts/pallet. Assuming a batch of 30 pallets, and given a cycle time/pallet of 12 mins:

6*30= 180 spacers that will be used for this order of articles

180/100=1,8 >2 pallets of spacers necessary

12*30=360 mins minutes to through 30 pallets (360/60=6 hr)

20” is the minimum time required to stick 1 VCI paper to 1 plastic spacer, therefore

20*180= 3600 sec= 3600/60= 60 mins= 1h minimum required to attach the VCI to the spacers just for this one article.

3.5.3. Potential future state
To overcome the drawbacks of using the MH-0140, a one-way cardboard spacer has been developed by aPak, SWT and Scania. It’s composition and dimensions have been described in section 3.3.2.

The main characteristic is the volatile corrosion inhibitor embedded in the material, eliminating the need for VCI paper and the process of applying it to the spacer, allowing to save time and reduce total manning, to increase the degree of automation and ergonomics by eliminating a manual process, to enhance quality and customer adaptability.

All of these points will be discussed and analyzed in chapter 5, after performing a Life Cycle Assessment of both MH-0140 and the SWT 2 cardboard spacer.
3.6. Rust formation and VCI protection

3.6.1. Causes and damage

Rust formation is an oxidation process that occurs whenever a metal surface is exposed to a moist or wet environment and in order for it to take place the presence of oxygen and water is necessary. Rust is an iron oxide with a typical red and brown color distinguishable with the naked eye. It is a corrosion process that eventually results in damage and breakage of the components it affects.

Moreover, if components are exposed to a salty environment (such as seawater or salt spray) the corrosion process will take place at a much higher pace.

The rusting of iron is an electrochemical process that starts with the transfer of electrons from iron to oxygen[10]. The iron is the reducing agent that frees electrons, while the oxygen is the oxidizing agent that gains them; the rate at which this process develops is affected by water and electrolytes (found for instance in salt).

![Image](http://hyperphysics.phy-astr.gsu.edu/hbase/Chemical/corrosion.html)

Figure 25: Corrosion as an electrochemical process, digital image. <http://hyperphysics.phy-astr.gsu.edu/hbase/Chemical/corrosion.html>

The formation of rust on metallic surfaces is one of the major threats for high quality components; more specifically, the Transmission Machining department must take this process greatly into account when developing packaging solutions, as components will be stored for an unknown period of time before assembly.

3.6.2. VCI packaging

For these reasons, the current packaging solution at the Shot Peening line involve using a VCI plastic bag (see fig ch. 3.5.1) and a VCI paper. VCI stands for Volatile Corrosion Inhibitor and it is a type of corrosion inhibitor used to protect ferrous components against corrosion and oxidation. [11]

The principle on which volatile corrosion inhibitors act is simple: they slowly release a corrosion preventative compound into a sealed airspace, actively preventing corrosion by forming strong bonds with a metal surface. According to Zerust Excor [12] “the VCI layer that forms is invisible, dry and does not affect the physical properties or functionality of the metal in any way. The protected metal can be painted, treated and/or sued straight out of the Zerust package without further cleaning.”. Both VCI bag and paper used by the Transmission Machining department is from Zerust Excor.
Corrosion and rust formation can occur at any step into the production process:

![Diagram of corrosion inhibitor process](https://omnituff.com/and-you-still-may-not-understand-what-it-is-vci/)

Figure 26: The corrosion inhibitor process, Omni-tuff, digital image, <https://omnituff.com/and-you-still-may-not-understand-what-it-is-vci/>

More specifically, if rust formation occurs during the manufacturing process, prior to shot peening, this will not affect the components properties, but it is of major importance to prevent it afterwards. For this reason, VCI bags and paper are only used to pack components at the end of the shot peening line.

Nowadays, the inability to know beforehand the destination of the pallet, whether it will stay in Sweden or be shipped to Belgium or Brazil calls for the necessity to pack each pallet with the same procedure and amount of packaging material. If this weren’t the case, the packing process could be customized based on the destination, but this topic is out of the scope of this thesis.

![Diagram of PLC: Product Life Cycle](image)

Figure 27: Corrosion stages
3.7. Life Cycle Assessment – LCA

Life Cycle Assessment is a concept that has been developed to conduct a detailed examination of the life cycle of a product or process; LCA is defined as “a technique to assess environmental impacts associated with all the stages of a product’s life from cradle-to-grave”. [13]

This method allows to grasp the environmental impact of production and consumption, necessary to evaluate and improve performances in the industry; in many cases, it is used to carry out a comparison between two products or processes to enhance their characteristics and find the best solution for their improvement without shifting the impact to other fields. [14]

The International Organization for Standardization (ISO) has released several international standards on the topic of LCA and the main series is the ISO 14040, followed by technical reports ISO 14041, 14042 and 14043 that have been incorporated into the ISO 14044 document. According to the ISO 14040, Life Cycle Assessment is a “compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle”. And it is added that “A product system is a collection of unit processes connected by flows of intermediate products which perform one or more defined functions. [...] The essential property of a product system is characterized by its function and cannot be defined solely in terms of its final product.”

As previously mentioned, one of the main purposes for performing a life cycle assessment is to support the choice of different options, by evaluating the environmental consequences of these options. To assess the impact, it is necessary to use a model that is relatively simple in order to keep the analysis feasible.

In the specific case of this thesis project, Scania CV AB and more specifically the department of Supply Chain Network (OI) have developed, together with IVL Svenska Miljöinstitutet, the Scania Packaging Sustainability Tool. It is an LCA tool that, by feeding input data into the model, allows to obtain two output information: The Global Warming Potential – GWP and the Environmental Priority Strategy - EPS.

According to Keith P. Shine [15] the GWP is an established method for comparing the climate effects of emissions of different greenhouse gases. It is widely used to compare the impact of CO2 with non-CO2 greenhouse gases, and in 1990 the IPCC (Intergovernmental Panel on Climate Change) appointed the GWP as a metric of choice. The scale used is CO2-equivalents.

The IPCC has defined the GWP as “the time-integrated radiative forcing due to a pulse emission of a given gas, relative to a pulse emission of an equal mass of CO2” and it has been seen to have fewer embedded assumptions and it is easy to understand the behavior of numerical values. [15]

Furthermore, according to IVL [16], the Environmental Priority Strategy – EPS is a “methodology which makes environmental costs more visible early in the product development phase.” Moreover it “aims to facilitate the change from a reactive to a proactive product development strategy with regards to environment and sustainability”.

There are four main stages in a life cycle assessment:

1. Goal definition and scoping
2. Inventory analysis
3. Impact analysis
4. Valuation
3.7.1. Goal definition and scoping

In this section it is defined how big a part of a product life cycle will be taken in assessment and for what reason.

In the specific case of this thesis project, whose primary scope is to assess and compare the environmental burden of two different spacers (namely the MH-0140 and SWT 2), the whole life cycle, from its raw material composition to transport and end-of-life solutions will be considered.

**System boundaries diagram**

![System boundaries diagram](image)

*Figure 28: System boundaries*

3.7.2. Inventory analysis

Here, the inventory analysis gives a description of material and energy flows within the product system and especially its interaction with the environment, consumed raw materials and emissions to the environment. [13]

![Material and Energy Flows](image)

*Figure 29: Material and Energy Flows*
The data collected by the IVL is used to calculate the Global Warming Potential and Environmental Priority Strategy of the materials, the transport (the mode and fill rate), the pooling (washing facilities location, water and energy consumption) and of the end of life solution.

3.7.3. Impact analysis
In this thesis the two main impact categories are the Global Warming Potential – GWP, calculated in terms of CO2 tons-eq, and the Environmental Priority Strategy – EPS.

Assigning an emission of a given substance into a given environmental impact depends on the properties of a given substance. It involves the conversion of LCI results to common units and the aggregation of the converted results within the same impact category.

3.7.4. Valuation
This is a normative step where a reflection and analysis of results is carried out. Interpreting the results is a process that involves critical reviews, determination of data sensitivity and result presentation. [13]
4. Results and Discussion

The results can be divided in two groups:

- The first results give an understanding of the **environmental impact** attributed to the packaging material, based on five set of inputs: Material Composition, Replenishment Rate, Transport, Washing, End of Life. Results are given in terms of Global Warming Potential, measured in CO2-eq, and the Environmental Priority System, a monetary evaluation.

- Secondly, a **cost analysis** is performed considering the total yearly cost of:
  - the annual refill
  - manning required for sticking the VCI paper
  - the flow
  - scraping the spacers
  - the VCI paper

After addressing and explaining the results in detail, an analysis of the Key Performance Indicators (KPIs) is carried out in Chapter. These KPIs have been individualized as the main factors impacting the performance of the production line.

**4.1. Environmental Impact of MH-0140 and SWT-aPak spacers**

Previously calculated data is inserted in the Scania Packaging Sustainability Tool, and a Life Cycle Assessment is conducted for each loop. Here, three packaging materials are assessed (in the Description/MHnr tab) and in Chapter 5.1. the impact of the MH-0140 and VCI paper will be summed and compared to that of the SWT 2 spacer.

All results found in the columns named **GWP** and **EPS**, are calculated using data previously collected by the IVL Svenska Miljöinstitutet (see Chapter 2.4.)

The first set of inputs, that comprises of the material of the spacers, remains constant throughout all calculations:

![Figure 30: Material input](image)

The replenishment rate of the MH-0140 spacers is calculated as 10% for the DT-Swedish loop, 15% for Scania Parts Logistics and 20% for SLA, assumptions based on transportation distances, mode of transport (truck or container ship) and available data concerning scrapped parts.

Although the replenishment rate for the MH-0140 is relatively small, it is fundamental to understand that the amount of VCI paper is based on the total number of spacers used in one year.

**4.1.1. LCA: DT-Sweden loop**

By considering the calculations made in Chapter 2, the following data have been uploaded to the Life Cycle Assessment tool and the specific impacts are as follows.
The replenishment (10%) and material impact:

![Material impact total](image)

**Figure 31: Annual material replenishment**

The transport impact:

![Empty packaging and inbound transport](image)

**Figure 32: Empty packaging and inbound transport**

As can be seen, there is no inbound transport; this means that there is no transportation of packaging with components that could have a relevant impact on the emissions.

The washing impact:

![Washing type](image)

**Figure 33: Washing type**

As previously mentioned, a one time cardboard solution does not require any type of washing process; hence, savings are made both in terms of water and energy consumption, as well as transport, as the components will not have a return flow to the washing facility (VIDA).

The End of Life solution impact:

![End of Life solutions](image)

**Figure 34: End of Life solutions**
Noticeable in the previous table, is the negative value obtained in the calculations. It signifies that there is a credit in the emissions, meaning that the type of end of life solution selected benefits the environment by reusing or redistributing the by-product of the materials and processes.

Since for every MH-0140 spacer, one VCI paper is used, their total impact is added and compared to the SWT 2 spacer. The final result and comparison are:

<table>
<thead>
<tr>
<th></th>
<th>GWP</th>
<th>EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH + PAPER</td>
<td>46071</td>
<td>11713</td>
</tr>
<tr>
<td>SWT</td>
<td>52394</td>
<td>29059</td>
</tr>
</tbody>
</table>

Table 3: GWP and EPS numerical results

To better understand the results, a quick reminder of the definition of GWP - Global Warming Potential as an established method for comparing the climate effects of emissions of different greenhouse gases, and of the EPS - Environmental Priority Strategy as a financial evaluation of environmental issues, might be necessary.

From the graphs, it is clear that the one-time cardboard spacer (SWT 2) has both a higher Global Warming Potential (by 6323 tons CO2-eq) and a higher Environmental Priority Strategy, hence for the packaging loop in Sweden the best solution would be to use the MH-0140 spacer.

As will be discussed in further detail in Chapter 5, the ideal scenario would be to use the MH-0140 spacers without the VCI paper; currently, this cannot be done, as the use of two MH-0140 spacers might cause the sealed environment inside the gear to develop rust. Further tests are required to gather a sufficient amount of data to have a reliable source for strategic decisions. Of the many discussions about how this data could be collected, perhaps one pallet each week could be packed without VCI paper, stored for a definite amount of time and afterwards analyzed for presence of rust or damage.
4.1.2. LCA: Scania Parts Logistics loop
As the input categories do not change, the calculated data and its impacts do.

The replenishment (15%) and material impact:

![Figure 36: Annual material replenishment](image)

Transport impact:

![Figure 37: Empty packaging and inbound transport](image)

As can be noted, for the Scania Parts Logistics loop both empty packaging and inbound transport are present. Interesting is the much higher impact of the empty packaging transport for the MH-0140, due to its return flow.

Moreover, the weight of the spacers (1170g for the MH-0140, 420g for the SWT2) play a major role when considering fuel consumption and its related emissions.

Washing impact:

![Figure 38: Washing type](image)

As for the previous loop, no washing is involved when considering the SWT2 spacer.
End of Life Solution impact:

Figure 39: End of Life solutions

Total impact:

<table>
<thead>
<tr>
<th></th>
<th>GWP</th>
<th>EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH + PAPER</td>
<td>4 540</td>
<td>1 215</td>
</tr>
<tr>
<td>SWT</td>
<td>2 529</td>
<td>1 227</td>
</tr>
</tbody>
</table>

Table 4: GWP and EPS numerical results

Figure 40: GWP and EPS results

Maintaining the same axis scale as in the previous loop, gives a clear understanding of the overall much lower impact that the Scania Parts Logistics flow has. Nevertheless, a difference in almost 2000 tons CO2-eq is present, making the SWT 2 cardboard spacer a much more environmentally friendly solution. When comparing the Environmental Priority System results, the difference is insignificant, therefore it can be discarded.

4.1.3. LCA: South Latin America loop
Finally, the loop that involves transoceanic transport is assessed. Here, transportation is calculated first for the truck transport via land, then for the transport of empty packaging and inbound packaging via sea.

It is important to consider that currently very little information is available on the return flow of the MH-0140 spacers, therefore:

- the preferred method for the end of life solution is a scrapped flow for the MH-0140 spacers, and a combination of recycling, landfill and incineration for the cardboard spacers
- the empty packaging return flow, via sea, might be subjected to high variations
The replenishment (20%) and material impact:

Figure 41: Annual material replenishment

The replenishment rate has been calculated to be minimum 20%, but, as previously mentioned, very little information is available on the return flow, therefore the percentage could increase significantly, resulting in a higher environmental impact and environmental cost.

Transport impact:

Via land

Figure 42: Empty packaging and inbound transport via land

Via sea

Figure 43: Empty packaging and inbound transport via sea

The weight of the spacers and the empty packaging return flow have the greatest impact on the GWP, resulting in the one-time cardboard solution being highly more efficient and environmentally sound.
Washing impact:

![Washing impact chart]

Figure 44: Washing type

End of Life Solution impact:

![End of Life solutions chart]

Figure 45: End of Life solutions

Total impact:

<table>
<thead>
<tr>
<th></th>
<th>GWP</th>
<th>EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH + PAPER</td>
<td>42 002</td>
<td>11 444</td>
</tr>
<tr>
<td>SWT</td>
<td>11 979</td>
<td>5 592</td>
</tr>
</tbody>
</table>

Table 5: GWP and EPS numerical results

![GWP and EPS results chart]

Figure 46: GWP and EPS results

As can be inferred from the graphs, the MH-0140 spacer has an extremely higher Global Warming Potential, by more than 30000 tons CO2-eq. Moreover, the Environmental Priority System of the MH-0140 is higher as well, resulting in the cardboard spacer being without any doubt the best packaging solution for this loop.
Results are hereby summarized for a clearer understanding:

<table>
<thead>
<tr>
<th></th>
<th>MH-0140 + VCI PAPER</th>
<th>SWT 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWP</td>
<td>ESP</td>
</tr>
<tr>
<td>Sweden</td>
<td>46070</td>
<td>11714</td>
</tr>
<tr>
<td>Scania Parts Logistics</td>
<td>4540</td>
<td>1216</td>
</tr>
<tr>
<td>South Latin America</td>
<td>42002</td>
<td>11444</td>
</tr>
</tbody>
</table>

*Table 6: Summary of GWP and EPS numerical results per loop*
4.2. Cost analysis
The calculations of the costs attributed to the spacers differs for each loop:
(values have been calculated in excel, therefore approximations have been made. An overview of the
excel sheets can be found in Appendix A)

4.2.1. DT-Sweden loop

For the MH-0140 spacers:

257924 pcs/y = annual number of spacers used
25792 pcs/y = annual refill rate
420 pcs/y = annual scrapped parts

the cost of one spacer is 29 kr/pc, hence the total cost for annual refill is $748000 \frac{kr}{y}$

Additional costs are:
2.9 kr/pc = washing and pooling cost
0.86 kr/pc = cost of handling one spacer at the breakdown unit
0.0186 kr/pc = transportation cost 270-VIDA
0.18 kr/pc = loading cost at VIDA

Therefore, the total cost of the MH-0140 flow is $1021000 \frac{kr}{y}$

Considering the scraping cost to be 0.5 kr/pc the total annual cost for scraping the spacer is $210 \frac{kr}{y}$

1.11 kr/pc = cost of VCI paper
for a total annual cost for VCI paper of $286000 \frac{kr}{y}$

550000 kr/y = annual salary for one operator
825000 kr/y = total cost for sticking the VCI paper
2.72 kr/pc = cost of sticking one VCI paper
For a total annual manning cost of $701000 \frac{kr}{y}$

Adding the different cost gives a total annual cost of $2757000 kr$

For the SWT-aPak spacers:

257924 pcs/y = annual number of spacers used
8.49 kr/pc = cost of one spacer (with transport included)
0.97 kr/pc = cost of handling one spacer at the breakdown unit

therefore, the total annual cost for refill is $2190000 \frac{kr}{y}$

and the total annual cost of the SWT-aPak spacer flow is $251000 \frac{kr}{y}$

For a total annual cost of $2441000 kr$
4.2.2. Scania Parts Logistics loop

For the MH-0140 spacers:

9103 pcs/y = annual number of spacers used
1365 pcs/y = annual refill rate
630 pcs/y = annual scrapped parts

the cost of one spacer is 29 kr/pc, hence the **total cost for annual refill** is 40000 \( \frac{kr}{y} \)

Additional costs are:
2.9 kr/pc = washing and pooling cost
0.86 kr/pc = cost of handling one spacer at the breakdown unit
0.18 kr/pc = loading cost at VIDA

Therefore, the **total cost of the MH-0140 flow** is 36000 \( \frac{kr}{y} \)

0.5 kr/pc = scraping cost

Hence the **total annual cost for scraping** the spacer is 315 \( \frac{kr}{y} \)

1.11 kr/pc = cost of VCI paper

for a **total annual cost for VCI paper** of 10100 \( \frac{kr}{y} \)

550000 kr/y = annual salary for one operator
825000 kr/y = total cost for sticking the VCI paper
2.72 kr/pc = cost of sticking one VCI paper

For a **total annual manning cost** of 25000 \( \frac{kr}{y} \)

Adding the different cost gives a **total annual cost of 111500 kr**
For the SWT-aPak spacers:

9103 pcs/y = annual number of spacers used
8,49 kr/pc = cost of one spacer (with transport included)
0.97 kr/pc = cost of handling one spacer at the breakdown unit

therefore, the total annual cost for refill is $77000 \frac{kr}{y}$

and the total annual cost of the SWT-aPak spacer flow is $9000 \frac{kr}{y}$

For a total annual cost of 86000 kr

For the MH-0140 spacers:

36413 pcs/y = annual number of spacers used
7283 pcs/y = annual refill rate
840 pcs/y = annual scrapped parts

the cost of one spacer is 29 kr/pc, hence the total cost for annual refill is $211000 \frac{kr}{y}$

Additional costs are:
2,9 kr/pc = washing and pooling cost
0,86 kr/pc = cost of handling one spacer at the breakdown unit
0,18 kr/pc = loading cost at VIDA

Therefore, the total cost of the MH-0140 flow is $143500 \frac{kr}{y}$

0,5 kr/pc = scraping cost
Hence the total annual cost for scraping the spacer is $420 \frac{kr}{y}$

1,11 kr/pc = cost of VCI paper
for a total annual cost for VCI paper of $40500 \frac{kr}{y}$
550,000 kr/y = annual salary for one operator
825,000 kr/y = total cost for sticking the VCI paper
2.72 kr/pc = cost of sticking one VCI paper

For a total annual manning cost of 99,000 \( \frac{kr}{y} \)

Adding the different cost gives a total annual cost of 494,400 kr

**For the SWT-aPak spacers:**

36,413 pcs/y = annual number of spacers used
8.49 kr/pc = cost of one spacer (with transport included)
0.97 kr/pc = cost of handling one spacer at the breakdown unit

therefore, the total annual cost for refill is 309,000 \( \frac{kr}{y} \)

and the total annual cost of the SWT-aPak spacer flow is 354,000 \( \frac{kr}{y} \)

For a total annual cost of 344,400 kr

---

**Figure 48: Cost results**

As can be seen in all three graphs, the cost of the MH-0140 spacer is always higher when compared to the SWT-aPak. More details will be given in the Comparative Analysis Chapter 4.3.

4.3. Comparative analysis

4.3.1. Total Environmental Impact

So far, calculations and analysis of the Global Warming Potential and the Environmental Priority Strategy for each loop has been carried out, and the results can be summarized as follows:

- for the DT-Sweden loop, the optimal solution is to use the MH-0140 spacers with the VCI paper
- for the Scania Parts Logistics loop, the optimal solution is to use the SWT 2 spacers
- for the South Latin America loop, the optimal solution is to use the SWT 2 spacers
In taking a step forward, and analyzing the cumulative results of each loop, interesting results are obtained:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>GWP</th>
<th>EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH + PAPER</td>
<td>92 613</td>
<td>24 373</td>
</tr>
<tr>
<td>SWT</td>
<td>66 902</td>
<td>35 878</td>
</tr>
</tbody>
</table>

*Table 7: Summary of GWP and EPS cumulative results*

As can be interpreted from the graphs, the MH-0140 spacer has a much higher Global Warming Potential (by 25 711 tons CO2-eq), but a lower Environmental Priority Strategy.

Neither the GWP nor the EPS have a higher priority over each other, making it a matter of individualizing which of the two factors has to be tackled first. Nowadays, reducing global warming is considered to have the highest priority, hence the graph on the left should be addressed first.

This indicates that the use of a one-time cardboard solution, specifically the one developed in collaboration between SWT and aPak, that has VCI chemicals embedded in its fibers, is the ideal solution and the one that should be adopted in order to reduce the impact on global warming.

One might argue that since the majority of components and spacers are used in the DT-Sweden loop, it would be ideal to keep using the MH-0140 spacers for it, and to use the SWT 2 spacer for the other loops. This assumption is correct, but there currently isn’t the possibility for the system to know where the pallet will be shipped after its packing phase, therefore all pallets must be packed the same way.

Moreover, as the use of the MH-0140 spacers is dependent on the VCI paper, this solution wouldn’t take nor solve the problem of the 3 to 4 hr/shift spent by the operators to stick the VCI paper. If data showing that no rust problems occur in the sealed environment were available, the argued solution would be ideal. A more in depth analysis and discussion will be carried out in Chapter 6.
4.3.2. Total cost
Following the costs results that have previously been calculated for each loop, considering the totality of the spacers (303440 pcs) used at the Shot Peening line the cumulative results are:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>total MH-0140</td>
<td>3 362 900,00</td>
</tr>
<tr>
<td>total SWT</td>
<td>2 871 400,00</td>
</tr>
</tbody>
</table>

*Table 8: Summary of total costs*

*Figure 50: Comparison of cumulative costs results*

The numbers show that using the MH-0140 spacers have on average a higher cost per year; therefore, the use of a one-way cardboard spacer would allow Scania CV AB to save a total of roughly 490 000 kr/y.

Hence, the use of a one-time cardboard solution would be both more environmentally friendly and less costly.
4.4 Discussions
So far, the processes, problems and costs involved with the use of both types of spacers have been addressed. Scania CV AB relies on a concept called SPS – Scania Production System, whose steps, pillars and priorities can be seen in figure 51:

![Figure 51: SPS-Scania’s Production System](image)

In order to comply with the Scania Production System parameters, considerations regarding the use of the MH-0140 and SWT 2 must be made.

A brief summary of the main results:

- **From an environmental point of view, the use of a one-way cardboard solution is ideal, as it has a lower carbon footprint and lower impact on global warming.**
- **From an economic point of view, a one-way cardboard solution would allow Scania to save roughly 490000 kr yearly.**

Moreover, the aforementioned problems linked to the use of the MH-0140 spacer are:

- Dependence on the use of a volatile corrosion inhibitor paper, to prevent rust formation
- Lack of complete automation of the line
- Quality and rust protection of the components
- Operator’s ergonomics
- Total Manning
- Customer adaptability

These and other problems will be discussed in greater detail.

4.4.1. Automation
The Shot Peening line at the Transmission Machining department is considered to have a high degree of automation as the unpacking and packing processes are performed by robots.

As previously mentioned, the current packaging solution to separate layers of components in an H-pallet, complies of a MH—0140 spacer to which a VCI paper is manually attached by the operators, a task that can take up to 12 hrs every day (4hrs per shift, for three shifts a day). This operation, thoroughly
described in Chapter 3.5.2., among many other problems, impedes for the line to have a higher degree of automation.

The use of a one-time cardboard spacer with embedded VCI, would eliminate this time consuming and non-value adding process, allowing to free up time from the operators. Moreover, its use would decrease stop times, currently due to the VCI paper detaching from the MH-0140 spacers up to three times per hour.

To verify if the cardboard spacer can be used for the packing process, the SWT 2 spacer has been therefore tested on the Shot Peening line. A full H-pallet of the heaviest gears produced has been packed; it comprises of 5 layers, 6 gears per layer, for a weight of 11 kg per gear. Therefore, the weight distributed on each spacer is 66 kg on the upper layer, to a maximum of 330 kg on the lowest one.

While testing the packing process at the end of the Shot Peening line, it has been observed that:

- the KUKA robot can handle the SWT 2 spacer the same way as it can handle the MH-0140 spacer
- the spacers do not stick together while in the H-pallet
- the robot’s vision camera does not have problems when handling the spacers, nor the gears

The pallet has been stored for four weeks, and afterwards sent to HASA (the assembly line for the main shaft); During the unpacking process several interesting points have been observed by the operators:

- the spacers do not break or deform under the gears’ weight
- the components do not show any sign of rust, nor damage caused by the spacer
- the lighter weight of the spacer has a strong impact on the ergonomics of the process, as well as allows to have a quicker sortation of the packaging material due to the lack of tape and VCI paper
- the use of the SWT 2 spacers avoids residues and chips of MH-0140, often found on the gears due to the components being dragged out of the pallet

Hence it can be concluded that the use of the SWT 2 spacers would have an extremely positive impact on the assembly line.

In addition to the Shot Peening line, the SWT 2 spacers have the potential to be used in the Bin Picking process. Their lower weight and the lack of VCI paper would allow the collaborative robots to ease and speed up the process. To verify if the vision camera installed on a collaborative robot has any problems when handling the spacers or the components, a test has been performed at Scania’s Smart Factory. The results show that the COBOT has no problems handling the spacers during the pick-and-place test run; in fact, the lack of reflecting surface that characterizes the SWT 2 spacers, makes them a much better candidate for this process.

As previously mentioned, there is a lack of data regarding the physical process that takes place inside the gear, when placed between two MH-0140 spacers without a volatile corrosion inhibitor solution. Currently, there is the assumption that rust formation occurs due to a higher degree of humidity that might develop in the aforementioned closed environment.

This might be true during summer, when the humidity rate is higher, and the components are stored for a longer period due to inactivity of the production lines. Further tests should be performed throughout the year in order to verify if, with lower humidity rates and shorter time in the storage, substantial differences can be observed.

To tackle this, a great amount of data must be gathered over a prolonged time span. To do so, the components should be packed and stored with the current procedure, with the only exception of removing the VCI paper. Pallets should be stored, and samples should be analyzed at different times.
intervals to verify when and how the rusting process takes place. A sufficient number of components should be packed in order to have a reliable pool of data.

If data showing that no rust problems occur in the sealed environment were available, two separate flows (one using the MH-0140 spacer for the DT-Sweden loop, the second one using the SWT 2 for the remaining two loops) could be put in place to minimize to an even greater extent the environmental impact, but it is out of the scope of this thesis.

4.4.2. Total manning

Currently, each line is operated by one operator, whose role is to assure for the line to run smoothly with as little interruption as possible; moreover, the operator is responsible for preparing the pallet of 100 (or more) MH-0140 spacers and VCI paper, necessary for the robot to separate the layers. As mentioned, this is a time consuming and non-value adding process that can be eliminated with the introduction of a one-way cardboard spacer, with embedded volatile corrosion inhibitor.

Due to the high volumes and short cycle times, one operator is often not sufficient to prepare all the required spacers, hence the need for backup from operators on other lines; this entails that the lines remain unsupervised and that any problems will be delayed to when the operator will return. The efficiency of the line will drop, and production rates will decrease.

Up to four hours per shift are used for this process, that adds up to an average of 12 hours (1.5 shifts) a day. The average annual salary for an operator is 550 000 kr, hence 825 000 kr is the cost associated with the physical act of taping the VCI paper to the spacers. As can be easily inferred, and as can be seen in the previous results, the use of a one-way cardboard solution would significantly decrease total manning and the associated costs.

Not only the use of a one-way spacer would alleviate the burden at the shot peening line, it would also affect the packaging breakdown process in building 270. Here, the task of removing the tape from the spacers would come missing, allowing a smoother and quicker sortation of packaging material, increasing productivity by greatly decreasing stop times.

4.4.3. Ergonomics

SHE - Security Health and Ergonomics is at the top of the priorities of the Scania Production System, and the use of the MH-0140 has repercussions on the ergonomics of the processes involved with its use.

Specifically, at the shot peening line the process of taping the VCI paper requires the operator to bend into the pallet, take out the spacers and position them at a comfortable height; afterwards, the operator sitting at his chair is required to turn his bust by 90 degrees, reach for the tape and the paper, turn back and complete the task before repositioning the spacer in the pallet. Repeating this process for an average of 444 spacers per person every day has important health and ergonomics repercussions.

Concerning the process of emptying the pallets and sorting packaging material at the breakdown unit in building 270, the presence of tape on the MH-0140 spacers makes it necessary for the operators to bend into the pallets and over the spacers to remove the tape, which, very often is a hard and time-consuming operation. With less than 9.5 seconds to empty one pallet, very often the operators are forced to stop the line in order to be able to fully remove the tape.

In both scenarios, the use of a one-time cardboard spacer would allow to remove ergonomically unsustainable operations.
4.4.4. Customization and Customer Adaptability
The current design of the packing process, using the MH-0140 spacers, does not allow to have any type of special packaging which entails a lower density degree and the absence of customization.

On the contrary, the use of a one-time cardboard solution would enable the use different solutions based on customers´ requirements. Moreover, the possibility of developing special patterns would allow to increase the packing density, therefore making better use of the pallets´ volume. Increasing the packing density means that a higher number of components can be packed in one pallet, therefore the transportation would be more efficient and its costs per gear reduced.

The use of special or customized packaging would possibly require a redesign of the handling process for the spacers, hence different grippers or vacuum tools. This topic is out of the scope of this thesis, but it certainly is an important aspect for future developments.

4.4.5. Quality Assurance
Quality, of components and services, is the second most important priority in the Scania Production System; it must be embedded in all processes and tasks carried out daily.

Specifically, as previously mentioned, it is necessary for the components that are packed at the Shot Peening line, to be protected against rust formation, dust and damage inflicted by transport. When comparing the use of the two spacers, it is clear that the absence of the washing phase in the use of the SWT 2 spacer, allows to remove the threats of grease, oil or remaining tape presence that often characterizes the use of the MH-0140 spacers.

Moreover, the presence of embedded VCI in the spacer, allows a more uniform distribution of the chemical compounds inside the VCI bag and the pallet enhancing rust protection, especially in the sealed environment inside the gear.

According to the experts at the Quality Assurance department in Södertälje, the use of a one-way cardboard solution has the potential to reduce the quality check times, due to the reduced number of components that develop rust.

4.4.6. Rust Protection
This topic has been extensively covered in Chapter 3.6. Rust formation is considered to be the major threat to the manufactured components, specifically during its storage and its transport. In particular, components that are shipped to Belgium or South Latin America are those that require a higher degree of protection, due to the long transport time and to the temperature variations they must withstand.

Currently, the VCI bag and VCI paper allow to have a sufficient degree of protection, with a uniform distribution of chemicals between the layers of the pallet. The same degree of protection would be guaranteed by the use of the SWT 2 spacer, as its fibers are embedded with VCI chemicals and therefore its diffusion would be uniform throughout the pallet.

4.4.7. Storage and Freight Costs
An average of 57 pallets (each composed by 3 collars, for a total of 170 MH-0140 spacers/pallet) are present in the storage daily.

Due to the constraints imposed by the robot cell at the Shot Peening line, it is possible to only use H-pallets with two collars (refer to picture in chapter 3.5.2.), hence 100 MH-0140 spacers. Thanks to the reduced thickness of the SWT 2 spacers, each H-pallet, composed by two collars, can be filled with 150 SWT 2 spacers.

Currently, as all MH-0140 spacers must be washed before their use, VIDA Packaging Logistics provides pooling and storage. The closeness of VIDA to Scania’s production facilities in Södertälje,
allows the Transmission Machining department to place daily orders and having them delivered in a short amount of time, for the production to run smoothly.

To date, with the current distribution unit (DU) comprising of 1 H-pallet, 3 collars and 1 lid, for a total of 170 MH-0140 spacers/DU, 2232 DUs are handled every year, for an average of 186 units/month.

Assuming the possibility to remove and change the constraints at the Shot Peening line, it would be ideal to use H-pallets with 3 collars at the robot packing station, as this would entail a decrease in logistic transport and costs, but an increase in density and productivity.

Hence with a collar height of 197 mm

**MH-0140 (thickness 3mm)**

\[
\frac{197 \times 3}{3} = 591 \text{ mm}
\]

\[
\frac{591}{3} = 197 \rightarrow 170 \text{ MH - 0140 spacer}
\]

with a margin of 197-170=27; 27*3=81 mm= 8.1 cm

**SWT 2 (thickness 2mm)**

\[
\frac{197 \times 3}{2} = 295 \text{ spacers (without margin)}
\]

\[
\frac{(591 - 81)}{2} = 255 \text{ spacers (with an 81 mm margin)}
\]

therefore, an H-pallet with 3 collars could be filled with 255 cardboard spacers.

Assuming to change or remove the constrains at the shot peening line, it would be therefore possible to handle a total of 1488 distribution units per year, for an average of 124 every month. As can be easily inferred, this would allow to greatly reduce external transport, as well as internal logistics, increase density, reduce storage and freight costs, while increasing overall safety.

Table 9 shows the past, current and potential future number of yearly Distribution Units, depending on the number of collars.

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DUs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MH-0140 2 collars</td>
<td>3793</td>
<td>2232</td>
<td>2232</td>
</tr>
<tr>
<td>MH-0140 3 collars</td>
<td></td>
<td>2529</td>
<td></td>
</tr>
<tr>
<td>SWT 2 collars</td>
<td></td>
<td></td>
<td>1488</td>
</tr>
<tr>
<td>SWT 3 collars</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 9: Yearly Distribution Units*
Figure 52: Comparison of current and potential future distribution unit

Figure 53: Graphic distribution of current and potential future distribution units
The implications of using a one-way cardboard solution with embedded volatile corrosion inhibitor, reflect positively on a wide range of key performance indicators; a graphic representation of the discussions carried out in Chapter 6 can be summarized as follows:

<table>
<thead>
<tr>
<th></th>
<th>MH-0140</th>
<th>SWT 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automation</td>
<td>![good]</td>
<td>![bad]</td>
</tr>
<tr>
<td>Total Manning</td>
<td>![bad]</td>
<td>Very high</td>
</tr>
<tr>
<td>Ergonomics</td>
<td>![good]</td>
<td>![bad]</td>
</tr>
<tr>
<td>Customization and Customer adaptability</td>
<td>![bad]</td>
<td>Very low</td>
</tr>
<tr>
<td>Quality Assurance</td>
<td>![good]</td>
<td>![bad]</td>
</tr>
<tr>
<td>Rust Protection</td>
<td>![good]</td>
<td>![good]</td>
</tr>
<tr>
<td>Storage and Freight costs</td>
<td>![good]</td>
<td>![good]</td>
</tr>
</tbody>
</table>

*Table 10: Visual representation of KPI performances*

- ![good] good
- ![moderate] moderate
- ![bad] bad

As can be easily inferred by the table, major positive outcomes would follow the transition to a one-way cardboard solution with embedded volatile corrosion inhibitor. Not only it would positively impact the production of the Transmission Machining department (DX), but also departments such as the Assembly line and the Breakdown unit would see an increase in productivity and reduction of waste.
5. Conclusions and Future Work

The analysis and comparison of the use of two different packaging solutions, that has been conducted in this thesis, has a clear outcome.

Numbers show that, due to the high degree of transportation and uncertainty of the end of life for the MH-0140 spacers, the use of a one-way packaging solution would be ideal. Not only it allows to significantly reduce the environmental impact associated with its use, but also costs calculations show that it would allow Scania CV AB to reduce the expenses associated with packaging material.

Specifically, the use a one-way cardboard solution would allow to reduce the carbon emission by 25711 ton CO2-eq and therefore reduce the global warming potential associated with its use, as well as Scania CV AB would save a total of 490000 kr/y.

Moreover, after analyzing and discussing the Key Performance Indicators that characterize the production line, it is clear that the adoption of a one-way packaging solution would greatly increase productivity, by achieving a higher degree of automation of the lines, lower overall costs and an increase in quality and safety.

The use of a one-way solution opens up the possibility of developing new packaging solutions, to have greater dialogue and collaborations with customers and to shift the focus to integrate sustainability into daily activities.

The clear outcome of this thesis research gives the opportunity to research and investigate the potential next steps that can be taken to increase the productivity of the Transmission Machining department of Scania CV AB in Södertälje.

As previously mentioned, the implementation of the use of a one-way cardboard spacer would allow to increase the number of special packaging, to increase density and meet customers’ requests, among many other benefits; this entails that special handling tools would be necessary in order for the robot to be able to properly handle the spacers. It can be easily inferred that development will be necessary to increase productivity and have a fully automatic packing process.

While analyzing the benefits that the use of a one-way cardboard solution would entail, it is clear that the storage and freight costs would greatly diminish, as well as external an internal logistics. In order to reach maximum productivity and automation, a necessary future development would be to change or remove the constraints at the shot peening line, enabling a 3 collars pallet to be used inside the robot cell, and to verify if any constraints affect the robot handling process.

Scania’s CV AB production and logistic roadmap heading into the future, has clear goals:

- system control and information transparency
- real time emissions and follow up
- traceability
- sustainability for packaging

To be able to work towards these goals, digitalization, optimization and automation must be at the core of any development project.

A potential future suggestion would be to develop and implement a system, through MDB – Model Based Design, that would allow packaging developers to select specific components from the database and receive immediate feedback regarding density and pattern of components per layer, as well as the selection of the best packaging material and its environmental impact. Ideally, initially the system would work with predefined patterns fed manually into the database, but with the use of machine learning and AI the system (or machine) would “train itself” to develop new non-existing patterns and packaging solutions to optimize the process and increment productivity.
Thanks to the outcome of this thesis, the Transmission Machining department will switch to the use of a one-way cardboard solution and will invest in further development towards digitalization and environmental sustainability.
### Appendix A

**Cost calculations DT-Sweden Loop**

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DT</strong></td>
<td></td>
</tr>
<tr>
<td>303,440 pcs/y annual MH-0140 use</td>
<td></td>
</tr>
<tr>
<td>257,924 pcs/y annual MH-0140 use @DT</td>
<td></td>
</tr>
<tr>
<td>25,792 pcs/y annual refill rate</td>
<td></td>
</tr>
<tr>
<td>420 pcs/y annual scrapped parts</td>
<td></td>
</tr>
<tr>
<td>29 kr MH-0140 cost</td>
<td></td>
</tr>
<tr>
<td><strong>Total yearly cost of annual refill</strong></td>
<td>748,000</td>
</tr>
<tr>
<td>2.9 kr/MH-0140 washing cost</td>
<td></td>
</tr>
<tr>
<td>0.86 kr/MH-0140 cost of handling 1 spacer @270</td>
<td></td>
</tr>
<tr>
<td>0.0186 kr/MH-0140 transportation cost per spacer from 270 to VIDA</td>
<td></td>
</tr>
<tr>
<td>0.5 kr/MH-0140 cost of scraping 1 spacer @VIDA</td>
<td></td>
</tr>
<tr>
<td>0.18 kr/MH-0140 loading cost at VIDA</td>
<td></td>
</tr>
<tr>
<td>3.96 kr/MH-0140 flow cost per MH-0140 (washing, DU handling, transport)</td>
<td></td>
</tr>
<tr>
<td>1.11 kr/VCI paper cost of 1 VCI paper</td>
<td></td>
</tr>
<tr>
<td>550,000 kr/y salary 1 operator per year</td>
<td></td>
</tr>
<tr>
<td>825,000 kr/y total cost for sticking the VCI papers</td>
<td></td>
</tr>
<tr>
<td>2.72 kr/spacer cost of sticking one VCI paper</td>
<td></td>
</tr>
<tr>
<td><strong>Total cost of sticking VCI paper @DT</strong></td>
<td>701,000</td>
</tr>
<tr>
<td>2.10 kr/y total yearly cost for scraping</td>
<td></td>
</tr>
<tr>
<td>1,021,000 kr/y total yearly cost of MH-0140 flow</td>
<td></td>
</tr>
<tr>
<td>286,000 kr/y total yearly cost of VCI paper</td>
<td></td>
</tr>
<tr>
<td><strong>Total yearly cost MH-0140</strong></td>
<td>2,757,000</td>
</tr>
<tr>
<td>6.49 kr SWT-aPak spacer cost (with transport included)</td>
<td></td>
</tr>
<tr>
<td>2,190,000 kr/y total yearly cost of annual refill</td>
<td></td>
</tr>
<tr>
<td>0.97 kr/SWT cost of handling 1 DU @270</td>
<td></td>
</tr>
<tr>
<td>0.97 kr/SWT flow cost per SWT (DU handling)</td>
<td></td>
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<tr>
<td>251,000,00 kr/y total yearly cost of SWT flow</td>
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<tr>
<td>2,441,000 kr/y total yearly cost SWT-aPak spacer</td>
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</tbody>
</table>

**MH-0140**

**SwT**
## Cost calculations Scania Parts Logistics loop

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (kr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual MH-0140 Parts</td>
<td>9,103.00</td>
</tr>
<tr>
<td>Annual refill rate</td>
<td>1,385.00</td>
</tr>
<tr>
<td>Annual scrapped parts</td>
<td>630.00</td>
</tr>
<tr>
<td>MH-0140 cost</td>
<td>29.00</td>
</tr>
<tr>
<td>Total yearly cost of annual refill</td>
<td>40,000.00</td>
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<tr>
<td>Washing cost per MH-0140</td>
<td>2.90</td>
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<tr>
<td>Cost of handling 1 spacer @270</td>
<td>0.96</td>
</tr>
<tr>
<td>Transportation cost per spacers from 270 to VIDA</td>
<td>kr/MH-0140</td>
</tr>
<tr>
<td>Cost of scraping 1 spacer @VIDA</td>
<td>0.50</td>
</tr>
<tr>
<td>Loading cost at VIDA</td>
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<tr>
<td>Flow cost per MH-0140 (washing, DU handling)</td>
<td>3.94</td>
</tr>
<tr>
<td>No transport included (transport of return flow is missing)</td>
<td></td>
</tr>
<tr>
<td>VCI paper cost</td>
<td>1,11.00</td>
</tr>
<tr>
<td>Salary 1 operator per year</td>
<td>550,000.00</td>
</tr>
<tr>
<td>Total cost for sticking the VCI papers</td>
<td>825,000.00</td>
</tr>
<tr>
<td>Cost of sticking one VCI paper</td>
<td>2,72.00</td>
</tr>
<tr>
<td>Total cost of sticking VCI paper @PARTS</td>
<td>25,000.00</td>
</tr>
<tr>
<td>Total yearly cost for scraping</td>
<td>315.00</td>
</tr>
<tr>
<td>Total yearly cost of MH-0140 flow</td>
<td>36,000.00</td>
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<tr>
<td>Total yearly cost of VCI paper</td>
<td>10,100.00</td>
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<tr>
<td>Total yearly cost of MH-0140</td>
<td>111,500.00</td>
</tr>
<tr>
<td>SWT-aPak spacer cost (with transport included)</td>
<td>8,49</td>
</tr>
<tr>
<td>Total yearly cost of annual refill</td>
<td>77,000.00</td>
</tr>
<tr>
<td>Cost of handling 1 DU @270</td>
<td>0.97</td>
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<tr>
<td>SWT flow cost per SWT (DU handling)</td>
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<tr>
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### Cost calculations South Latin America loop

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<tr>
<td>35.413</td>
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<tr>
<td>annual MH-0140 @SLA</td>
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<tr>
<td>7.283</td>
<td>pcs/y</td>
</tr>
<tr>
<td>annual refill rate</td>
<td></td>
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<tr>
<td>840</td>
<td>pcs/y</td>
</tr>
<tr>
<td>annual scrapped parts</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>kr/MH-0140 cost</td>
</tr>
<tr>
<td>2.9</td>
<td>kr/MH-0140</td>
</tr>
<tr>
<td>cost of handling 1 spacer @270</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>kr/MH-0140</td>
</tr>
<tr>
<td>3.9</td>
<td>kr/MH-0140</td>
</tr>
<tr>
<td>1.11</td>
<td>kr/VCI paper</td>
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<tr>
<td>8.49</td>
<td>kr/SW-T-0Pak</td>
</tr>
<tr>
<td>0.07</td>
<td>kr/SW-T</td>
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</tbody>
</table>
References


12. ZERUST, *Corrosion Protection*.


