



# CHALMERS

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## **A Calculation Model for Packaging Demand**

**- Calculating the basis for investment for inbound packaging with the variable packaging per car at Volvo Cars**

Bachelor's thesis in Industrial Economics and Manufacturing Technology

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CHALMERS UNIVERSITY OF TECHNOLOGY  
Gothenburg, Sweden, 2016  
Report no. E2016:009

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# Abstract

Volvo Cars handles and plans its own returnable packaging material and the purpose is to serve the suppliers, plants and terminals with packaging material like pallets, boxes and frames. Returnable packaging is made out of durable materials so it can be used several times. To be able to in time serve the production plants with packaging material the company needs to make calculations based on real factors and numbers.

One of the tasks for the department Packaging Operations is to secure the packaging availability. If there is shortage of packaging it can cause a stop in the production line and this is caused because the suppliers are short of packaging to pack their products on, which can cause delays in the production. To prevent this problem, the department has developed a calculation model in Excel to calculate the required packaging in circulation for different time periods and the outcome is an investment sum. This model is based on three variables: production volume, loop time and packaging per car. The last variable defines the amount of packaging needed to manufacture one car model and loop time is the time it takes for one packaging to travel from the terminal to the supplier, from the supplier to the plants and finally back to the terminal before it is sent out again. However, the department saw an opportunity to develop this model with more accurate numbers and data, make it more user-friendly and general so the data and assumptions could be updated easily.

The purpose of this thesis was to improve and verify the original model and the wanted outcome was to develop a new model and make it useful according to two perspectives. The short-term perspective that the model will achieve is to secure packaging availability and make investments in time to always be able to serve the suppliers with packaging. Moreover, the long-term perspective is to plan the cost for future car models and the time span for this is over three years from now. Today there is lack of reliable data at the department to get an understanding if there is enough packaging in circulation and to decide the cost for future car models, so the new model will fulfil both these perspectives.

Using information from an analysis of the original model, requirements for the new model and by making a gap analysis between the original model and the requirements developed the new model. First, the new model consists of two documents, one to calculate packaging per car and the other to calculate the investment sum. Both of the documents are improved and are now more general than the original model, the raw data can be updated easily and the calculations will automatically using the updated data and present it. Another improvement is that the assumptions for example loop time can be regulated at any time and the calculations will adjust to the changes automatically. A user manual exists to facilitate the transfer of knowledge to the concerned department. However, it is a prerequisite that the user has prior knowledge about the organization and processes to also evaluate the outcome's reliability.

There are some improvement potentials and weaknesses to further consider for Volvo Cars. The purpose of this thesis was to develop a model and not to evaluate the numbers used in the model. However, the raw data changes frequently and thus the investment sum. A first step to increase the reliability of the investment sum is to verify the numbers and assumptions. In conclusion, a functioning model is delivered to Volvo Cars, but the numbers need to be evaluated and analysed to be able to trust the investment sum.

Keywords: logistics, Volvo Cars, packaging, packaging per car, loop time, inbound packaging, returnable packaging.

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# 1 Introduction

This chapter starts with a background to the thesis and describes the current problem regarding packaging at Volvo Cars. The purpose, area of application and scope will further be presented to get a good knowledge of the thesis.

## 1.1 Background

Logistics is a complex business area in today's business environment with suppliers around the world which all need to cooperate on different conditions. There is a constant pressure to produce just in time and to reduce the costs to increase the profit margin (Cheng & Lai, 2012). The customers want to have products in time, with a high quality and to an affordable price. All these parameters are important for logistics department to have in mind when planning processes. Within logistics, a more hidden process is the supply of packaging. There are different approaches to handle packaging. The companies can either use returnable packaging or one-way packaging. By using returnable packaging, which compared to one-way packaging can be used multiple times the likelihood increases to reduce the cost over time and also the quality of the products (Wu & Dunn, 1995).

One important task regarding packaging is that it keeps the supply chain together and is fundamental for the supply chain to work. Packaging protects the goods but can also be used to communicate the product (Chan et al, 2005). The ultimate goal with returnable packaging for a company is to maximize the utilization of assets for example packaging materials but also at the same time is able to secure the availability of packaging. Shortage of packaging material will have catastrophic effects on the manufacturing and distribution of finished goods, which if it occurs can be seen as a loss of income (Svanström, 2015).

This thesis will look into the Swedish car company Volvo Cars, and its packaging logistics. The company uses returnable packaging to supply its suppliers and plants with packaging materials. To keep the balance of supply the suppliers with packaging material but not tie up too much capital in packaging a well-reasoned plan is needed to in time serve the manufacturing plants with parts from suppliers. So, Volvo Cars needs a long-term approach to be able to serve the future demand with packaging material and this is what this thesis will support.

## 1.2 Problem Description

Historically, the packaging logistics at Volvo Cars have been handled by AB Volvo to simplify the packaging operations for both partners. However, since early 2014 Volvo Cars is completely responsible for the packaging operation and a new department named Packaging Operation was founded. The new department started basically from scratch, which causes fast decisions and a year later, a lot of progress have been made. Although, the department continue to work on developing routines and working processes, there are room for improvements.

A short-term objective for Packaging Operations is to constantly secure packaging availability. In order to fulfil this objective, packaging investments must be made ahead of time to avoid shortage. The investments shall be based on the forecasted total amount of packaging material required. The existing forecasts are right now not fully reliable and is causing an insufficient view of the packaging demand. The consequence if packaging not is available in the system at the right time and place is catastrophic, and will affect the whole supply chain. The worst-case scenario is an interruption in production caused by insufficient amount of packaging delivered to suppliers. The outcome from this scenario will be less produced cars and will affect the revenue negatively. To avoid this scenario, a short-term objective for Volvo Cars is to secure that packaging is available at any time.

A critical situation and a long-term perspective is when Volvo Cars plans to increase the capacity in the production line, then the amount of packaging material that serves the suppliers will most likely increase as well. Another long-term perspective is to decide the cost for the new car models, where packaging material is one of the cost components. That is why a basis for investment is needed for Volvo Cars to give a good view of both the short-term and long-term perspective.

Volvo Cars has developed a calculation model to calculate the amount of packaging in circulation. This is the amount of packaging that the company owns. The model's aim is to forecast how much Volvo Cars needs to invest in packaging, and act as a basis for investment for both the short-term and long-term perspective.

According to Volvo Cars, the existing data used to determine the variables in the model are not precise and a lot of data is based on assumptions, which cause unreliable results. The existing model is not based on general calculations and the model cannot be updated with current data. Therefore, there is a need at the department to improve the model, so it can be utilized for different outcomes. So, the goal for the new model is to facilitate the working procedure and reduce the manual work.

Furthermore, when planning new investments it is important to have a reasonable basis for the investment. This must be based on reliable data in order to actualize the investment. The problem right now is that this information and data is inadequate and the existing calculation model contains some weaknesses. Therefore, it is important to improve the knowledge of the amount of packaging materials that Volvo Cars has in circulation today, and also in the future. It is particularly important to have this knowledge when the manufacturing volume varies and hence, the amount of packaging varies as well.

### **1.3 Purpose**

The purpose of this thesis is firstly to evaluate an existing calculation model in Excel that shows the amount of required packaging material in circulation for different time periods. Secondly, recreate the model with recommended improvements to reduce the manual work. The aim of the model is to create an accurate basis for investment based on two perspectives. The long-term perspective is to decide the packaging cost for new car model projects and the short-term perspective is to always secure packaging availability.

### **1.4 Area of Application**

The outcome of the model is a recommended investment sum, created to cover the two perspectives, both the long-term and the short-term. The short-term perspective is to always make sure that Volvo Cars has enough packaging and therefore secure the packaging availability for the suppliers. The second usage of the new model is the long-term perspective. Before new car models start their production, Volvo Cars needs to plan packaging investments if the packaging need will increase. To see if the packaging demand is increasing the model must calculate the investment sum for different time periods and then compare different time periods to each other.

The wanted usage of the model is to compare a time period before a new car model has started its production with after the new car model has entered the production. This is to see if the packaging demand at Volvo Cars will increase and therefore be able to make sure to do an investment in time.

The model has to be easy to handle and maintain by the people at the department and take around 15 minutes to utilize. Prior knowledge in Volvo Cars processes and structure are prerequisites for using the model in the intended way. Consequently, this model will not be for public use and only involved people will use it at the Packaging Operations department.

## **1.5 Scope**

In this part, the scope of the thesis will be described. This means to thoroughly explain the boundaries and content that will be both included and excluded in the thesis.

This study is limited to inbound logistics, including returnable packaging in circulation between suppliers, manufacturing plants and terminals. Packaging of finished goods and outbound logistics will not be considered. Also, the model will only look at returnable packaging and not one-way packaging.

At Volvo Cars the packaging material is divided into two groups; standard packaging and special packaging. The data, which the model will be based on, will exclusively focus on a few types of standard packaging. The standard packaging used in the model is affecting the investment calculations in a significant way, in terms of higher volume or price.

In addition, Volvo Cars uses the terms inventory packaging and consumable packaging to distinguish packaging based on expected durability. In this thesis investments regarding packaging inventory, which have an expected lifespan over one year, will be included.

## **1.6 Disposition**

In order to make the disposition of the thesis more comprehensible, the structure of the thesis is presented below. To give the reader a clear picture of how the structure of the report looks, and facilitate the search of information, a brief description of the report's content will be described in this section.

### **Chapter 1 - Introduction**

The first chapter describes the background of the thesis and the problem is identified. Then the purpose of the thesis is presented and a clarification of the applications for the model is made. Finally, the scope of the thesis is described.

### **Chapter 2 - About Volvo Cars**

To get a more comprehensive picture of the company, a short presentation about Volvo Cars and the concerned department Packaging Operations will be presented followed with a further description of the term packaging in circulation and loop time.

### **Chapter 3 - Theoretical Framework**

The theoretical framework presents theories and researches within the field of logistics related to the purpose. Furthermore, returnable packaging and the analysis tools that have been used during the thesis are described. The theoretical framework will be the basis for future analysis and discussion.

### **Chapter 4 – Volvo Cars Data**

In this chapter all the data that have been received from Volvo Cars are described. It includes mostly terms that are used at the company and will be explained to get a more overall knowledge of how the packaging process works at Volvo Cars.

### **Chapter 5 - Methodology**

The approach of this thesis is described in this chapter. The process of making this thesis started of with interviews, observations and theoretical researches, which lead to the analysis of the existing model and data. From the analysis and background research the improvements of the model are made together with a user manual.

### **Chapter 6 - Result - Analysis of the Original Model**

The result of the analysis of the original model is presented in this chapter. From the analysis of the model the requirements of the new model are presented in a software requirement specification and the gaps between the requirements and the original model are presented in a gap analysis.

### **Chapter 7 - Result - New Calculation Model**

Here, the result of the new model is presented and a further more detailed explanation of the two documents and every sheet in the documents are presented. Finally, the improvements, problems and weaknesses of the model are presented.

### **Chapter 8 - Discussion**

In this chapter, the model's problems are discussed and the needed improvements of the model to decide its usefulness and if the model can be presented as a model.

### **Chapter 9 - Conclusion**

The last chapter will include a conclusion of this thesis and if the purpose of the thesis was achieved, and finally a short summary of the needed improvements for further development of the model.

## **2. About Volvo Cars**

In this chapter a short presentation about Volvo Cars and the concerned department Packaging Operations will be presented to get an overall understanding of the company and its processes.

### **2.1 Volvo Cars**

Volvo Cars is a premium segment car manufacturing company of a wide range (Volvo, 2015). The vision is “to be the world’s most progressive and desired premium car brands”. Volvo Cars is one of the world’s most progressive automobile brands with sales in around 100 countries. The largest and most significant markets, which account for 43 per cent of revenue in 2014, were China, Sweden and the U.S. The cars are produced in factories in Torslanda in Sweden, Ghent in Belgium, Chengdu, Daqing and Chongqing in China and Kuala Lumpur in Malaysia (Volvo, 2015).

The very first car was produced in Gothenburg, Sweden in 1927 (Volvo, 2015). Back then the company was AB Volvo and started out as an automobile manufacturing company. Merely one year later, 1928, AB Volvo entered the truck business and until 1999 the company manufactured cars and trucks. In 1999, Volvo Cars became independent from AB Volvo and in 2010 Zhejiang Geely Holding of China acquired Volvo Cars. Volvo Cars and AB Volvo still share the same brand name and sometime cooperate in research and brand-related investments, such as Volvo Ocean Race (Volvo, 2015).

### **2.2 Packaging Operations Department**

This department was founded when Volvo Group Logistics Service (VGLS), which is a part of AB Volvo, cancelled the packaging pool contract in early 2014. Packaging Operations handles the inbound packaging, and work closely with the suppliers to make sure that Volvo Cars’ suppliers always have packaging for their products to send to the manufacturing plants. If not, the products can arrive late to the production, which can cause an interruption in the production line. The other main tasks for the department are to organize the planning, scheduling, distribution, procurement and overall supply chain management of Volvo Cars’ packaging pool.

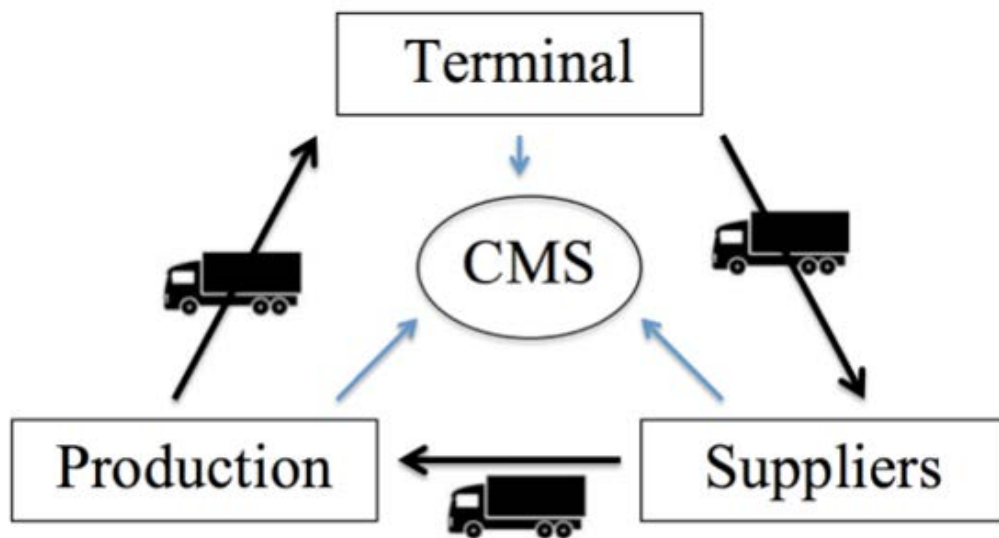
The department also works for a long-term perspective, to see how much packaging that is needed to invest in the future, when future cars are going into production. The long-term approach is low, and the company has problems with planning investments because of lack of knowledge. This thesis will help the department with a long-term basis for investment. The short-term will also be included, that the department always can guarantee enough packaging in the current packaging pool to supply their suppliers with packaging and not interrupt the production.

### **2.3 Packaging in Circulation**

Packaging in circulation is the amount of packaging Volvo Cars actually owns. The packaging circulates between the suppliers, plants and terminals. There are three terminals located in Gothenburg, Skövde and Gent. The packaging terminals supply packaging material to about 1200 suppliers located mainly in Europe. At the terminal the packaging is released from the plants and some packaging types are washed and repacked into bundles before the trucks are loaded with packaging and sent out to the suppliers again. The suppliers then pack their products on the packaging to send to the production plant, which then send the packaging back to the terminal. The packaging goes around in this circulation continuously.

During the circulation of packaging all the information about where the packaging is in location is reported into the information system Container Management System (CMS). CMS connects suppliers, terminals and manufacturing plants with information about packaging materials.

First, suppliers make a notification in CMS about what kind of packaging material, the amount and when the packaging materials are needed. This notification must be done before a certain point. According to Volvo Cars, the process is unreliable and many suppliers order more packaging materials than actually needed. Secondly, the closest terminal receives a notification from CMS and delivers the packaging to intended supplier. Suppliers send the goods using the ordered packaging to the manufacturing plants which in turn register received packaging materials in CMS and subsequently send it back to the terminals. An existing problem with this process is the lack of forecasting demand for packaging materials, which in the worst case can result in shortage. So, for CMS to work perfectly and always secure packaging availability, a packaging material forecast is needed to in turn make investments in time.



**Figure 2.1:** Packaging in circulation

## 2.4 Loop time

Loop time is a term used at Volvo Cars and the meaning of the term in packaging purpose is the time it takes for the packaging to circle one loop. It is the time it takes for the packaging to do a whole loop in the circulation. The circulation starts from a terminal, to the suppliers, to the manufacturing plant and back to the terminal. Included is also the time packaging is stored at the terminal before it is sent out again. The loop time is different for different packaging types, as it does not take the same time for pallets to circle as it does for boxes. The loop time is also different for Volvo Cars Customer Services (VCCS) where the spare parts are stored and used for after sales. This means that the packaging is stored longer, because the packaging flow and demand is lower than for the actual production.

## **3. Theoretical Framework**

This chapter will start with some general theory about supply chain and logistics to get an overall view of the subject. The chapter will then continue to explain some theory about packaging, analysing tools and also definitions of relevant terms that will further be used in this thesis.

### **3.1 Supply Chain and Logistics**

Supply chain describes a network of partners, which all work together with the goal to satisfy the customers with a product or service. Supply chains tend to be complicated and frequently constitute multiple organizations and activities to collaborate. Furthermore, logistics is included in the supply chain concept and according to the authors Harrison and van Hoek, logistics is defined as “the task of coordinating material flow and information flow across the supply chain”. The first thing to coordinate is the material flow, and this is the movement of physical goods from suppliers to the customers. The second parameter is the information flow, which helps to plan and control the material flow (Harrison & van Hoek, 2008).

An organization possesses a competitive advantage if it is better than its competitors. It is possible to increase an organization’s competitive advantage through logistic activities. Quality-, time- and cost advantages are all important parameters. High quality within logistics can be referred to avoiding defected goods, faulty quantities and items. Time advantage can be achieved by deliver faster than competitors and obviously lowering the cost will have a positive effect (Harrison & van Hoek, 2008).

Logistics can be divided into inbound logistics and outbound logistics. Inbound logistics is the material and information flow from suppliers to the manufacturing process. While outbound logistics is the flow to the customer (Cheng & Lai, 2012). As described in the scope, this thesis will only include inbound logistics.

### **3.2 Packaging**

Packaging's traditional function is to protect the product to avoid losses and defected goods along the supply chain and to the final consumer (Williams et al. 2008). Frank Albert Paine defines packaging’s fundamental functions as protecting, containing, preserving and communicating the product (Paine, 1981). Packaging does not only protect the product from its external influences but can also protect the surrounding environment from the product. Obviously, all products must be packed in order to provide easy handling, warehousing and transport.

#### **3.2.1 Packaging Types**

Packaging can be categorized into three types, these are primary, secondary and tertiary packaging (Chan et al, 2005). Primary packaging is the packaging that is in direct contact with the product, often also the packaging the customer sees and uses. Secondary packaging is designed to contain several primary packaging and this part is often thrown away when the product is opened. Tertiary packaging uses a large number of secondary and primary packaging for transportation and the packaging can be placed on for example a pallet or a container. This thesis will focus on tertiary packaging types because these are the easiest to reuse between the suppliers to the manufacturing plants (Chan et al, 2005).

### **3.2.2 Returnable and Reusable Packaging**

Returnable and reusable packaging is a common term to describe packaging that can be used several times before it is scrapped. The packaging prevents waste, reduces greenhouse gas emissions and support source reduction (Jason Bullock, 2002). Reusable packaging can be different types of packaging, for example containers, pallets and plastic boxes. In comparison, one-way packaging is discarded after being consumed only once (Kroon and Vrijens, 1994).

A returnable packaging system affects the planning of transport networks and it will become more complex. The lead-time will extend because of the transportation time back, the extra-required space of storing and also the cleaning of the packaging (Wu & Dunn, 1995). It may seem like returnable and reusable packaging increase the logistics cost because of the added equipment handling and storage space. But, since the suppliers charge extra for the packaging, the total cost for packaging in the supply chain is reduced since returnable packaging is used several times even though capital is tied up in packaging (Wu & Dunn, 1995).

### **3.3 Software Requirement Specification**

A software requirement specification (SRS) is a tool utilized prior to developing a new software product or program. The requirement specification has multiple benefits and helps to communicate and confirm an agreement between the customer and the supplier and will state the outcome of the product. Furthermore, another benefit is that a SRS possibly reduces the development work and fewer misunderstandings and redesigns occur and can be discussed and omitted early in the project cycle. Since the SRS describes the product's outcome and requirements, this can simplify the understanding for existing but also new users. The SRS can also be used as a basis for the user manual (The Institute of Electrical and Electronics Engineers Inc, 1998).

The structure of a SRS is not fixed, instead it depends on the context and the most important thing is that the customer and supplier confirm the SRS (The Institute of Electrical and Electronics Engineers Inc, 1998). In this case, a SRS report template will be used and this report contains general information about the model. Furthermore, it also contains information about the software requirements, user requirements, safety requirements and naturally the requirements for the model.

### **3.4 Gap Analysis**

A gap analysis is an analysing tool used to compare the current state; where you are, and the desired state; where you want to be. The outcome will be a gap, called the performance gap and shows the gap between the current state and the desired state (Franklin, 2006). The ultimate goal is to close the gaps (Doyle, 2011). It is important to not have an already set solution in mind at the time a gap analysis is performed because this will limit the analysis and impair the potential solution (Franklin, 2006). Moreover, the planned desired state often develops new ideas and products based on the unfulfilled needs.

### **3.5 Model**

A model is a representation or an image of a part of the reality. Common for all models are that they are simplifications of realities (Allwood, 1989). A model in this thesis means an abstraction based on the image or representation of usually fairly complex phenomena, such as a business or an information system. Abstraction means that in relation to a concrete situation chosen to regard a certain phenomena while ignoring others. A model's aim is to simplify a draft in relevant situations that is of interest (Allwood, 1989).



To create a model, there are a few things the model needs to consider and fulfil (Allwood, 1989).

1. The model shall be accurate, which means it cannot include phenomena that is not included in the model.
2. The model shall be without contradictions both internally and externally. This means it may not represent a certain appearance, and what is represented in the model should be compatible with other relevant information.
3. The model should demonstrate proper completeness, which means no phenomena that are relevant from the perspective foreground should be excluded.
4. The model should be simple and foreseeable. This is a model's simplicity and transparency requirement.

Models are never perfect and need to be corrected and maintained. It is therefore desirable that the model and modelling method include components that facilitate the continuous evaluation of results and the procedures for change and development of the model when required (Allwood, 1989)

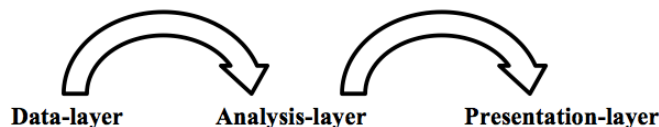
### 3.6 Excel and Layers

The software used in this thesis to develop the model is Microsoft Excel 2013 and it is a spreadsheet software program used to organize and analyse data. In the industry, this is the most common analysing tool and organizations often use the excel spreadsheet to make decisions. Excel has the potential to do complex analysis of large amount of data.

According to the authors Alexander and Walkenbach, a convenient strategy to analyse a lot of data is to divide the model into three layers (Alexander & Walkenbach, 2010). The first layer is the data layer, this is used to collect all the extracted raw-data so it appears in a standardized way. Some raw data can be exported from different programs into an Excel document. No modifications should be made in the data layer and as a result, Excel can always make calculations even if the raw-data is updated. Though, it is important that the raw data is exported in a standardized way (Alexander & Walkenbach, 2010).

The calculations are done in the second layer named the analysis layer and the data used in this part is often linked to the data layer. In the analysis layer it is important to have general calculations, so when new data is input, the model will still deliver a correct outcome without any adjustments (Alexander & Walkenbach, 2010).

The final layer is the presentation layer and in this layer it should be possible to make adjustments of the assumptions and also most importantly show the result calculated through the model (Alexander & Walkenbach, 2010).



**Figure 3.1:** An effective data model separates data, analysis, and presentation layer.

### **3.7 80/20 Rule**

The 80/20 rule was developed by an Italian man named Vilfredo Pareto and is a common term to describe the famous distribution, the Pareto Principle. The purpose of the principle is briefly to describe the phenomenon that for example 20 per cent of the customers will often make 80 per cent of the sales. Therefore, it is more economical to focus on those 20 per cent (Lavinsky, 2014). This distribution can be used in multiple business areas and also within logistics. In this thesis Volvo Cars uses the 80/20 rule to distinguish and choose packaging material included in the calculation model.

## 4. Volvo Cars Data

Volvo Cars utilizes a lot of its own terminology to explain internal data and events, and it is of importance to recognize those in order to understand the model and its concept. The three variables of the model will first be presented. Additionally, there are also internal software programs and all of these will be further declared in this section. The source of the information in this section is Packaging Operations and is gathered through discussions with the department.

### 4.1 Packaging Per Car

Packaging per car is a term and measurement used by Volvo Cars to describe the packaging quantity required to manufacture one car model. This measurement is calculated by first looking at data about the part numbers included in the car model. The important data are “part numbers quantity” per car, unit load, load carrier and additional packaging types. Unit load describes the quantity of parts that fits the packaging, for example part number “XX” is packed on a pallet and it fits 20 XX on the pallet, then 20 is the unit load. Moreover, load carrier is a code name used to inform what kind of outer packaging used to transport the goods. For example, B3 is equal to a plastic box of size XY and is packed on a pallet.

### 4.2 Packaging Types at Volvo Cars

Volvo Cars uses different types of packaging, both standard packaging and special packaging. The packaging is mainly decided and created from a perspective to protect the goods, but at a low cost. Some car parts are more sensitive than others and therefore different packaging is being used.

In this study standard packaging is the main focus and the following packaging types are included in the model; pallets, frames, lids, boxes and combitainers.

Pallets are the most common packaging type, and it is simply planks spiked together used to carry goods. Another task for the pallets is to store other packaging types on in the terminals and while transportation. The advantages with a pallet are that it is easy to handle, to transport and the low price. Volvo Cars uses pallets in different sizes and the most common pallet is the L-pallet (see figure 4.1). Other types of the pallets used in the calculation model are K- and F-pallets, these look the same as an L-pallet but has other measurements.



**Figure 4.1:** L-pallet

The next packaging type used in the model are frames and these are placed on top of a pallet (see figure 4.2), and several can be placed on each other to prevent goods to fall off the pallet. Furthermore, lids are also used to protect the content on the pallet from falling off and are placed on top of the top frame. Every pallet has its own frame and lid in the correct size. The purchase price for both frames and lids are low compared to other packaging types.



**Figure 4.2:** Frame for a L-pallet

Boxes are made out of plastic and smaller parts are often placed in this packaging type (see figure 4.3). There are many different sizes of boxes and the boxes are always placed on L-pallets and the amount that fits on a pallet is dependent on the size of the box. The lifetime of a plastic box is longer than for a pallet.



**Figure 4.3:** Box

Combitainer is a combination of a pallet and a container (see figure 4.4). These are not as common as the other packaging types but they are starting to be used more frequently by the suppliers and the purchase price is much higher compared to the rest.



**Figure 4.4:** Combitainer

### 4.3 Pecca Cost Estimation

Pecca Cost Estimation is a calculation program to estimate the cost for a car. This is often done before a car model has entered the production line. All the parts included in the car model are added in this calculation with the price per part, so the total cost for the car can be calculated. This program is used to collect all the part numbers that are included in one car and the amount of parts that are used in the car model, for later on calculating the variable; packaging per car.

### 4.4 FLIT

FLIT is a software program and Volvo Cars uses it to document and decide packaging data. The program contains information about all the part numbers and suppliers. Also, how the parts are packed and which packaging that is used to deliver the goods in a safe way. In this thesis, the most useful data from FLIT is load carrier, unit load and data about the inner packaging. To be clear, the load carrier describes the outer packaging. For example, the load carrier code B1 shows that it is a L-pallet with one type of box on it. Then the inner packaging information shows the amount of boxes needed to deliver the article. There are different FLIT documents for different production plants, so there is one document for part numbers used in the production in Torslanda and another document for the production in Gent.

### 4.5 EOP/SOP/NWC

Nearly every year a few old car models discontinue the production and new car models enter the production line. At Volvo Cars this phenomenon is called end of production (EOP) and start of production (SOP). In the beginning of the production the production amount is low, the volume then increases. Before the car models end the production the produced volumes often decrease before it stops producing totally. Different car models overlap each others SOP and EOP because several car models are in the production at the same time and they start their production at different times, one curve represents one car model (see picture 4.5).

The production peak between the SOP and EOP, and it is the moment when the produced volume is the highest. This is called normal week capacity (NWC) and this is the volume Volvo Cars wants to produce and the highest amount, the top of the curve in the picture below.

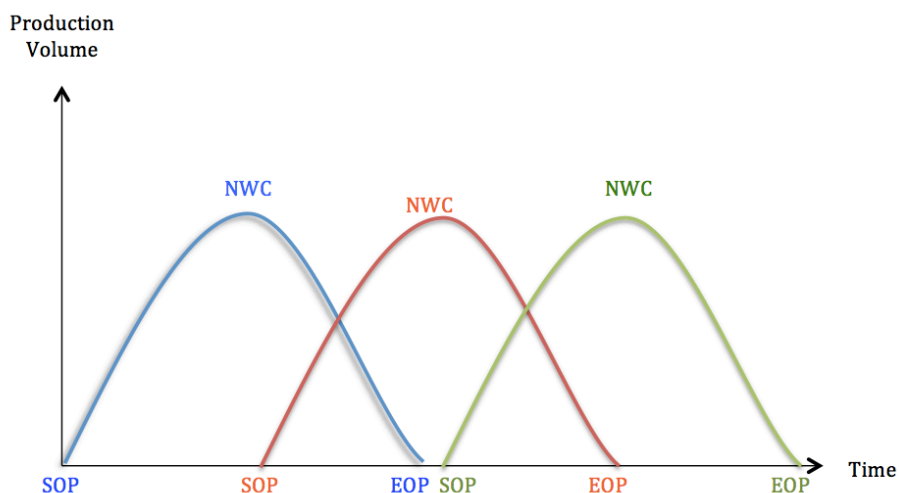


Figure 4.5: SOP/EOP/NWC



## 5. Methodology

The principal task of this chapter is to describe the methodology of the thesis in a detailed way, so it would be possible to repeat the process over again.

### 5.1 Process of the Methodology

To begin with, the thesis will be based on both an empirical and a theoretical research. The empirical study will be performed by conducting interviews and by making observations with the purpose to gather meaningful data to improve the calculation model. Furthermore, the theoretical research will be based on existing literature within logistics, packaging and Excel-knowledge. From the empirical and theoretical researches an analysis of the original model is done. And from the analysis of the model the requirements and gaps between the model and the requirements are produced. A development of the original model, and finally an analysis of the new and improved model is made. Below is a picture of the process of the methodology, and further in this chapter the methodology is described more detailed.

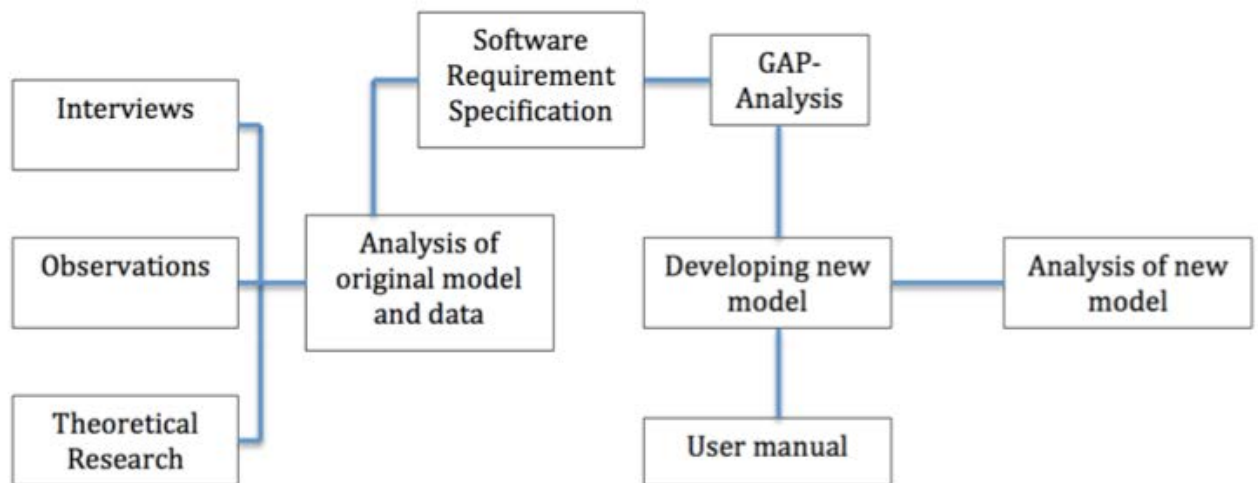


Figure 5.1: The process of the thesis

### 5.2 Semi-Structured Interviews

To start off with and to get a better understanding about the company, working processes and routines, a qualitative research via interviews has been performed. The problem itself was stated in an understandable way, however, the model is based on certain assumptions and to understand every detail, interviews have been a helpful tool. Interview questions and topics have been planned ahead of every interview occasion, but spontaneous questions have been asked as well. This kind of interview method is called semi-structured interview and is compared to a structured interview a less strict approach to conduct an interview. The information in Volvo Cars Data is gathered through interviews, but sometimes the interview sessions turned out to be more like discussions. The questions were decided before every meeting with the department, but more questions were added during the meeting.

### **5.3 Observations**

An observation is also a qualitative research method used to gather information. In the thesis, observations of the processes in the packaging terminal have been performed. The packaging flow in the terminal was observed and an insight how the terminal handles the packaging. Most of the packaging materials in the calculation model were demonstrated to get a better understanding of the area. The observations have been made to get a better understanding of the organization as a whole, and increase the holistic view.

### **5.4 Theoretical Research**

The literature study will assist to analyse the calculation model just like to recommend improvements. A theoretical framework within the stated subject area will also increase the knowledge, on one hand, which will be used to solve the problem on the other hand to get a better understanding of the subject. The theory will be based on articles and also academic literature. It is important that the sources are verified and reliable, that is why the key part of the literature is taken from the library's database. Moreover, the study fields packaging logistics, analysing methods and Excel-knowledge will mainly be the fundamental to the theoretical study.

### **5.5 Analysis of the Original Model and Data**

In the beginning, it is important to analyse and be critical to the original model and data. This data will be used as a foundation to the updated model, so it is important that this part is reliable. Before any improvements are done, the model is analysed from different perspectives to get a good picture of the original model.

The first analysing tool is a software requirement specification (SRS), which is used to confirm the outcome of the future model between Volvo Cars and "the writers". It is important in an early stage to be united on the wanted outcome, so the model will fulfil its purpose (The Institute of Electrical and Electronics Engineers Inc, 1998). After the outcome is communicated between the partners, the existing model is evaluated in Excel to find advantages and disadvantages. Then, the time can be allocated to focus on areas in the model, which need to be enhanced.

A gap analysis is the second tool used to analyse the present state and later describe the targeted state with the intention to find the gap between those. At this point, when the present state and targeted state are examined it is easy to locate where improvements must be accomplished (Franklin, 2006).

### **5.6 Development of a New Model**

Based on the SRS and the gap analysis, improvements of the original model will be made to complete a new model to fulfil the requirements and the purpose of the thesis.



## **5.7 User Manual**

The last step is to create a user manual, because it is important to make sure to pass on the knowledge to the customer. This process will be performed simultaneously as the improved model is developed. The manual will describe how to use and maintain the model because otherwise the model has no function in the future.

## **5.8 Analysis of the New Model**

When the improved and new model is finished, an analysis of the new model will be done. By analysing the changes, improvements and the appeared problems with the new model, further improvements can be recommended to improve the model additionally.



# 6. Result - Analysis of the Original Model

The result chapter will be divided into several sections and to begin with, the analysis of the existing calculation model will be presented and will end up with strengths and weaknesses with the model. The next section will describe the results of the software requirement specification and the requirements themselves. Furthermore, the outcome from the comparison of the original model and the requirements will be presented as a gap analysis.

## 6.1 Analysis of the Original Model

An important process and also the base for the new calculation model were to analyse and understand the original model. The original model was delivered in two Excel documents from Volvo Cars. One of the Excel documents calculates the variable packaging per car and the second document calculates an estimated investment sum for 2016 based on weekly demands.

w1635-w1643	EMB 1	EMB 21	EMB 71	EMB 2	EMB22	EMB 72	780	840	EMB 750
VED									
VEP									
ISP									
Total number packaging									
Number of production days									
Emballage per day									
Loop days									
delta VCT/VCG									
VCCS w1605 -- w1613									
VCCS w1635 -- w1643									
Loop days									
Delta VCCS									
Investment summary	115%								
Total	0	0	0	0	0	0	0	0	0
purchase price	X	X	X	X	X	X	X	X	X
Outgoing need	EMB 1	EMB 21	EMB 71	EMB 2	EMB22	EMB 72	780	840	EMB 750
Daily need	looptid	looptid	looptid	looptid	looptid	looptid	looptid	looptid	looptid

Sheet2 Volume program weekly Volume program monthly VOLume program Engine Sheet1 2016 2017\_temp 2018\_temp 2017

**Figure 6.1:** Original model

The figure above shows an example of the original model and a calculation of the investment sum for year 2016, and this calculation is based on weekly demands. All data have been excluded because of confidentiality. EMB “X” is the name of the packaging types. Here, you can see that the weeks are fixed, for example w1605-w1613 cannot be changed. The information and meaning of the headers in the document will not be further explained in detailed. From now on, the weaknesses and strengths with the original model will be presented.

The first thought about the packaging per car document is that it is not general and does not include general formulas, there are mostly just numbers entered in the cells. So, this excel document cannot be applied to different or new car models, neither to different time periods.

Specific errors in the calculation will not be further explained, but a few major faults were identified. One of them calculates the frames in a wrong way and translates the load carrier incorrectly. For example the packaging code L 1 means a L pallet with one frame, but the calculation used two frames. The numbers in the parentheses are the name of the packaging, and will further be used in this way. This error will calculate the frame incorrectly and in the end the sum of the frame for that specific car model will exceed the actual number of frames.

Another major fault was detected in the presentation of packaging per car for frame (22) and lid (72), both of them have the same amount of packaging need for every car. This was discussed with the department and according to the responsible person it seemed unlikely.

Moreover, the second document created by Volvo Cars calculates the investment sum only based on the weekly production volume forecast. The model itself will not be described in detail and the focus in the section is only to present the significant outcome of the analysis of the model and its strengths and weaknesses. This document was as the other document not general and could not be updated with new raw data in a convenient way. Also, the Excel document sometimes included formulas but sometimes the numbers were just copied, so when the original data was edited this did not follow to the connected cells in Excel.

One speculation is that the model only calculates two fixed time periods based on what Volvo Cars thought was regular production volumes. The first time period that Volvo Cars chose was before end of production started, to know how the production volumes and the packaging demand were before some car models discontinued the production. The second time period that was later compared to the first, was after start of production, this was the point when new car models had entered the production and also were produced in a regular volume. With regular volume it means that the production has reached a normal and originally planned capacity for the specific car model. A problem with this logic is that during some weeks in those time periods the plants are closed due to vacation or similar and this affects the investment sum.

Furthermore, some minor calculation errors were detected, but did not have much impact on the investment sum. The structure and design of the model was somehow confusing, and it was difficult to understand what was really calculated. The model could not be understood by anyone without prior knowledge. Although some calculations and reasoning were hard to understand, it was possible to understand the concept of the model in the end.

The strengths and weaknesses of the model were helpful to decide the requirements for the new model, and especially the disadvantages where improvement potentials could be identified. Some weaknesses discovered in the model were: no or weak automation in the model, not general in the way that you could not update or add raw data later, not able to choose different time periods, messy calculations, errors in the calculations, only based on two week spans and no yearly calculations included.

However, there were also some advantages and positive inputs, for example the important variables like loop time, production volume and packaging per car were predetermined by the department, and also general formulas to calculate the investment sum. The original model worked and calculated an investment sum, but there were some errors in the calculations. The outcome of this analysis is the foundation to the requirements and later the new model.

## **6.2 Software Requirement Specification**

The second result and the base for the improvements of the model is the software requirement specification (SRS). The process of coming up with requirements started with a software requirement specification template and with help from that it ended up in a SRS report. Through semi-structured interviews and conversations with Volvo Cars, the requirements were determined. The questions for the interviews were decided prior to the interview occasion. Volvo Cars had an idea that the calculation model should be more general and work for future time periods as well. This issue was discussed and an important function according to Volvo Cars is to be able to change assumptions afterwards and at the same time synchronize the calculations in the model.

The full SRS report will not be covered in this thesis, however it can be seen in the appendices (Appendix 1). The reason why the SRS report will not be included is because it contains more

operational information to the customer. The first chapters of the SRS report explain the purpose of the model, the intended audience and users, product functions but also the operating environment. This is to get a thorough background to the requirements and understand all the parts included in the model and to gather them in one place. The SRS report will be delivered to Volvo Cars along with a user manual, to improve the user-friendliness and carry on the knowledge to the customer.

Finally, three requirements were found and they describe what the model should be able to do. The model was then developed to meet and fulfil the requirements. Below are the three requirements presented:

- The model should update the presentation layer automatically when the raw data is updated.
- The model should update the presentation layer automatically when assumptions are updated
- The model should show an accurate investment sum based on both a weekly- and yearly demand.

The first and second requirements will make the model more general and the model should automatically synchronize to get an updated outcome based on new raw data and assumptions. In this way, the customer can by itself choose assumptions based on current state and update the raw data with actual numbers. By doing this the model will be more general and the formulas will work even if more raw data or assumptions are added. This will make the model useful even in the future and since the focus is to develop a working model and not focus on the numbers this is significant.

Furthermore, the last requirement handles the two outcomes, the model should be able to both calculate an investment sum based on a weekly basis and a yearly demand. The weekly calculation covers 60 weeks of production volumes and will secure the packaging availability in a short-term perspective. The yearly calculation includes current production volumes until six years into the future and represents the long-term perspective. To get an accurate investment sum the user should be able to choose time periods, this will improve the accuracy in the investment sum. The accuracy of the model will increase if the variables are reliable. Packaging per car is the only variable that is included due to time limitation, but the calculation of the variable will increase the accuracy. So, depending on the desired outcome the user must use either the weekly or the yearly model.

### **6.3 Gap Analysis of the Original Model and the Requirements**

The next step in the process includes a gap analysis, and it was also prepared before the actual calculation model was developed. The gap analysis compares and finds the gap between the original model and the requirements determined in the SRS. In this way, it was easy to understand and decide which parts that would need extra focus to in the end correspond with the requirements. It is unnecessary to develop the model from the start if some parts are already achieving its purpose. The first thing to analyse was the existing model and to take advantage of the useful outputs like the weaknesses and advantages. These were then compared to the requirements and the gaps could be identified. The gaps will be presented below.

As explained before in the analysis of the existing model part, there were some faults made by Volvo Cars in the calculation of packaging per car. This will affect the investment sum and make it less reliable. Packaging per car was the only variable that could be evaluated and recalculated and that is also within the scope of the thesis. So, to achieve the requirements to calculate an accurate investment sum this gap had to be closed. The decision is that the variable needs to be calculated not only to get a more correct output but also to fulfil that the model is the main purpose not the numbers.

Both the original packaging per car and the model document were as described before not general enough to operate with new raw data or to be updated. Two of the requirements include the phrase to “automatically update” the presentation layer when new data is added or updated. This gap is therefore important to focus on to be able to create a model that can be used further.

The original model does not include an investment sum based on the yearly production volumes and this is a requirement for the new model. Therefore, this part must be added to the new model. Another thing to improve with the new model is to make it possible to change or add assumptions, and as with the raw data this must be synchronized automatically with the investment sum. Overall, the calculations and formulas in Excel must be accurate to fulfil the last requirements and avoid the calculation errors in the original model.

## 7. Result - New Calculation Model

This chapter will begin with a general introduction to the new improved model and the construction of the model. Moreover, the design of the model will be described briefly but not too detailed because the wanted outcome of this thesis is to create a model, so the calculations and formulas done in Excel will not be presented in detail. However, the general formulas and reasoning will naturally be included. So, after the introduction to the model and its sheets in Excel, some of the calculations will be described to understand how the model works.

The new model is divided into two documents, the first document calculates the variable packaging per car and this chapter will begin with a description of the calculations. The second document will be described after the packaging per car section, and it calculates the recommended investment sum and there are three variables that are needed in this document, packaging per car, volume and loop time. The reason why the model is divided into two documents is because it simplifies the structure of the document to have them split, and because of the data size. The model will become too big to have it as one document. See picture 7.1 of how the two documents are connected.

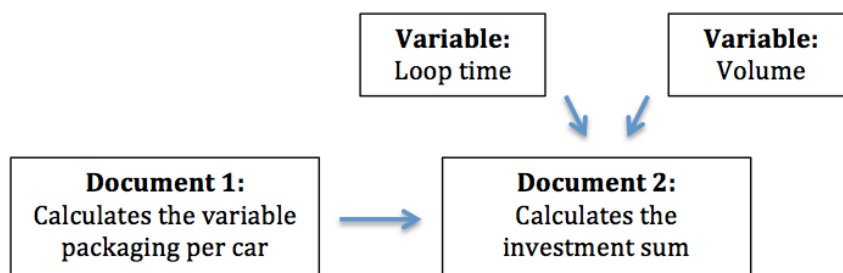
Before the making of the model, it was decided together with Volvo Cars that the model was going to be presented for 6 years ahead. Therefore the model is only designed for 6 years forward and only the cars models that are produced during these years are included in the calculation.

Three layers construct the model; data layer, analysis layer and presentation layer. The different layers together form the model. The first layer is the data layer and it only consists of raw data. Data is downloaded from different software programs in a standardized way so it is possible to update, and the model will then automatically synchronize with the rest of the document.

The second layer is the analysis layer. These layers consist of calculations and formulas based on the raw data to calculate the numbers shown in the presentation layer. These calculations are calculated in a general way so it should not be necessary to edit these sheets, even when new data is included or updated in the model. However, if the raw data is constructed in a different way, the analysis layer must be updated to match the new raw data.

In the presentation layer the model's outcome is shown. Whenever new raw data is updated and added to the model, also the numbers in the presentation shall be. In the presentation layer for the investment sum there are options to choose different time periods.

The model has also a sheet with only assumptions. This because of that the assumptions change and need to be updated during the Volvo Cars lifetime. So, when assumptions change the whole model will update as well, therefore the assumption has its own layer.



**Figure 7.1:** The connection between the two documents.

## **7.1 Model - Packaging Per Car**

In this model there are three variables that have been important. These are volume, loop time and packaging per car. It was decided that loop time was out of scope and the production volume is collected from a volume program, and therefore is only packaging per car needed to be verified and recalculated.

The first document calculates the variable packaging per car. The variable is presented for every car model that is currently produced and for all the planned car models for six years ahead. The calculation is based on raw data that is collected from FLIT and Pecca Cost Estimation. From the raw data it can be calculated how much packaging one car model needs. The calculations are calculating for 19 different packaging types.

In this chapter there will be a description of every sheet in the packaging per car Excel model and how the model is calculating the variable packaging per car. Also, the improvements that were made in the new model and the problems that arose with the model will be presented in this chapter.

### **7.1.1 Description of the Sheets**

There will now follow an explanation of every sheet to get a better knowledge about the document. Under the sheet name there will be an explanation of the purpose.

#### **7.1.1.1 Cost Estimate - (Raw data document)**

This raw data sheet is exported from Pecca Cost Estimation and shows different car models. There are multiple car models in the Cost Estimate sheet and sometimes a filter is needed to separate the car models. The important information that is needed from this sheet is the part number because it describes all the parts that are included in the car model, and the amount of parts that are used in one car model. From this sheet this information is collected to sync together with the rest of the document.

#### **7.1.1.2 FLIT-VCT - (Raw data document)**

This is also a raw data sheet and as the name mentions it is exported from FLIT. The data used from this sheet is part number, load carrier and unit load. The part number from Cost Estimate sheet is compared to the part number in FLIT to collect the other information from FLIT. This FLIT sheet is for the plant in Torslanda and is only used to calculate packaging per car for the car models produced in Torslanda.

#### **7.1.1.3 FLIT-VCG - (Raw data document)**

This sheet fulfils the same functions as the sheet above except for that it is for the plant in Gent. The different sheets are used for different car models, depending on if they are produced in Gent or Torslanda.

#### **7.1.1.4 CAR VCT- (Analysis layer)**

Together with the data collected from FLIT and Pecca Cost Estimation does this sheet calculate the variable packaging per car for the 19 different packaging types. Part numbers and sys part/car need to be transferred from Pecca Cost Estimation manually to this sheet, and description of that can be find in the User Manual in Appendix 2.

From the part number from Pecca Cost Estimation, VLOOKUP is used to collect load carrier, unitload, qty and emb to this sheet. With knowledge of how much packaging that is needed in load carrier and how many of the parts that is used for one car model, the Excel model calculates how much packaging every part needs by dividing the number of part with unit load.



This sheet then calculates the sum for all the parts that is included in one car model to get the total amount of how much packaging a specific car model requires. The calculation formula is:

$$\text{Sum} \left( \frac{\text{Parts used in one car}}{\text{Unit load}} \right) = \text{packaging per car}$$

All the numbers for the chosen packaging types are added together and the answer shows how much of the specific packaging that is required to produce a specific car model. This calculation is only necessary to do once, when new car models need to be entered in the model.

See picture 7.2 below of the analysis layer, the blue cell shows the amount packaging needed for one car model, the variable packaging per car. All the part number's data have been excluded because of confidentiality and the numbers are not correct.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
1													0,000425	0,25	0,25	0,25152	0,752402	0,25152	0,0051	
2		SYS																		
3	PARTNO.	PARTS/CAR	Loadcarr.	Unitload	Pallets	Frame	Q1	EMB1	Q2	EMB2	Q3	EMB3	EMB 1	EMB 21	EMB 71	EMB 2	EMB22	EMB 72	780	
4	1	B 1	6000	B	1	1	780						1,38889E-05	0	0	0	0	0	0	0,000167
5	1	Y 5	22	Y	5	1	9133						0	0	0	0	0	0	0	0
6	1	K 3	4	K	3	1	21	1	71				0	0,25	0,25	0,25	0,75	0,25	0	0
7	1	B 1	6000	B	1	1	780						1,38889E-05	0	0	0	0	0	0	0,000167
8	1	B 1	750	B	1	1	780						0,000111111	0	0	0	0	0	0	0,001333
9	1	K 2	60000	K	2	60	100	1	62				0	0	0	1,67E-05	3,33E-05	1,67E-05	0	0
10	1	K 2	12000	K	2	60	100						0	0	0	8,33E-05	0,000167	8,33E-05	0	0
11	1	K 2	54000	K	2	60	100	1	62				0	0	0	1,85E-05	3,7E-05	1,85E-05	0	0
12	1	K 1	30000	K	1	30	100	1	62				0	0	0	3,33E-05	3,33E-05	3,33E-05	0	0
13	1	K 1	30000	K	1	30	100	1	62				0	0	0	3,33E-05	3,33E-05	3,33E-05	0	0
14	1	B 1	10000	B	1	1	780						8,33333E-06	0	0	0	0	0	0	0,0001
15	1	K 2	36000	K	2	60	100	1	62				0	0	0	2,78E-05	5,56E-05	2,78E-05	0	0
16	1	K 2	60000	K	2	60	100	1	62				0	0	0	1,67E-05	3,33E-05	1,67E-05	0	0
17	1	K 2	24000	K	2	60	100	1	62				0	0	0	4,17E-05	8,33E-05	4,17E-05	0	0
18	1	K 1	7500	K	1	30	100						0	0	0	0,000133	0,000133	0,000133	0	0
19	1	K 2	15000	K	2	60	100	1	62				0	0	0	6,67E-05	0,000133	6,67E-05	0	0
20	1	K 2	9000	K	2	60	100	1	62				0	0	0	0,000111	0,000222	0,000111	0	0
21	1	K 2	2100	K	2	60	100	1	62				0	0	0	0,000476	0,000952	0,000476	0	0
22	1	K 1	24000	K	1	30	100						0	0	0	4,17E-05	4,17E-05	4,17E-05	0	0
23	1	K 1	7500	K	1	30	100	1	62				0	0	0	0,000133	0,000133	0,000133	0	0
24	1	K 1	21000	K	1	30	100	1	62				0	0	0	4,76E-05	4,76E-05	4,76E-05	0	0
25	1	K 1	15000	K	1	30	100	1	62				0	0	0	6,67E-05	6,67E-05	6,67E-05	0	0
26	1		0										0	0	0	0	0	0	0	0
27	1		0										0	0	0	0	0	0	0	0
28	1	K 1	6750	K	1	15	100						0	0	0	0,000148	0,000148	0,000148	0	0
29	1	B 1	300	B	1	1	780						0,000277778	0	0	0	0	0	0	0,003333
30	1	K 2	42000	K	2	60	100						0	0	0	2,38E-05	4,76E-05	2,38E-05	0	0

Figure 7.2: Packaging per car

### 7.1.1.5 CAR VCG - (Analysis layer)

This sheet fulfils the same function as the one above. This one should instead be used if the car model is produced in Gent. This sheet then collects information from FLIT-VCG instead of FLIT-VCT. Therefore, it is very important to know where the car is produced so the correct sheet is used for the calculations.

### 7.1.1.6 Assumptions - (Assumption layer)

In this sheet all the assumptions are made. The boxes are always shipped on a L-pallet, so when calculating how many boxes that are needed for one car model, a small part of a L-pallet is always added to the calculations as well, to not forget this small amount of packaging.

The amount of boxes that are packed on a L-pallet is different from every supplier, and this data of how many boxes that are shipped are missing. Therefore, an assumption about how many boxes that are packed on one pallet are made. This to find out how big part of the L-pallet that is needed for one part that is packed in a box.

The assumption is that in average there are stocked 4 boxes of type 840 on a pallet, 12 boxes of type 780 on a pallet and 24 boxes of type 750 on a pallet. The model looks up if there are any

boxes used in that part number and if there is, the model adds one-quarter, one-twelfth or one twenty-fourth to the L-pallet.

### **7.1.1.7 Packaging Per Car – (Presentation layer)**

This sheet presents the packaging per car numbers that have been calculated. It is the variable packaging per car that connects this document with the other one. So when updating packaging per car the numbers need to be copied manually to the other document which in turn calculates the investment sum.

### **7.1.2 Calculations - Packaging Per Car**

This document's purpose is to calculate the variable packaging per car. Volvo Cars had calculated the variable in the original model, so this data was evaluated and the defaults with the calculations were found and corrected in the new model.

A recalculation of packaging per car was made in a more general calculation way so that new raw data could be updated in the model and then the whole model would update with current numbers. The ideal was to get the packaging per car more exact and correct calculated.. There will now follow an explanation of how the model calculates the variable.

In the recalculation of packaging per car the first step was to collect all the part numbers and the amount of each part number that is included in one car model. These were collected manually from Pecca Cost Estimation and transferred to a separate sheet, Car-VCT or Car-VCG depending if the car is produced in Torslanda or Gent. To read a more detailed description of the process of how the part numbers are transferred see User Manual that describes the document and the calculation process more detailed. (Appendix 2)

A search based on the part numbers that was collected from Pecca Cost Estimation was made in the Excel-document. The model searched in the sheet where FLIT data was located, and then collects unit load and load carrier that have the same part number as the one the search is based on.

The load carrier describes what type of packaging the parts are packed on and unit load is how many parts there is in one load. Together with unit load and the number of parts used for the car model, the packaging need for every part was calculated for every different packaging type. The formula becomes:

$$\frac{\text{Parts per car}}{\text{Unit load}} = \text{how much of packaging one part need.}$$

This formula calculates how big part of the packaging one part takes, and then this step is repeated for every part number. The model finally sums every part's packaging need. After the sum is calculated for all the part numbers, the total will become packaging per car for the 19 different packaging types. The formula looks a little bit different for different types of packaging, but the general formula is the one explained above. A more detailed description about the calculation can be found in the User Manual (Appendix 2).

### **7.1.3 Improvements - Packaging Per Car**

In this chapter the improvements that were made with the model are described. The current model is calculating in a more general way, such that the model is divided into three layers. The layers make the model easy to update with new raw data, without making any changes in the calculation. And also that the same model can be used for all different car models, without making any changes manually in the model except for updating with new raw data.

In the new model improvements in the calculation were also made. Before there were some defaults in the calculation that now were corrected, and some small packaging that was ignored in the calculation that now was included, like the boxes that actually needed a little part of a L-pallet. This improvement made the variable packaging per car became more exact.

Another improvement that was made together with Volvo Cars was that some additional packaging types were added. This because of the 80/20 rule that is applied in the calculation. The most common packaging types had been selected in the original model in hope that they stand for the biggest demand. The ideal was that these packaging types together stand for 80 per cent of the investment demand and therefore the 20 per cent could be added in the investment sum to add the excluded packaging.

To get a more correct view according to Volvo Cars, three new packaging types were included in the model because there were thoughts that these were as common as the other ones. The ideal was that all 19 different packaging types together would become 80 per cent of the packaging demand, and 20 per cent could be added to the investment sum. However, it has not been verified if these packaging together constitute 80 per cent, this is only an estimation made by Volvo Cars.

### **7.1.4 Problems Updated Packaging per Car-Model**

When calculating packaging per car it was noticed that FLIT, the document where unit load and load carrier were collected from, is updated all the time. This is because the part numbers that are used for the old car models that already are in production have changed because of new suppliers and changes in the article. Therefore, the old part numbers cannot be found in the new FLIT document. This affected the calculations such that the new FLIT could not be used when calculating packaging per car for the old car models. To solve this problem, an old FLIT list was merged together with the new one to have all the part numbers located together in the same FLIT list. So, when the model is searching for the part numbers all of them could be found. However, this is not a problem for the new car models, because packaging per car should only be calculated once and in the future the newest FLIT list will work.

When making the model, one requirement was to get the model more general, and that was done except for pasting the part numbers from Pecca Cost Estimation. A problem was notified that the part numbers needed to be filtered out manually to see one car model. This because several car models were located in the same Pecca document, and the model could not filter out the car models automatically. Consequently, the user needs to manually filter out the right car and then copy and paste the part number to the sheet Car-VCT or Car-VCG.

Another problem was that the model does not update automatically with the other document that calculates the investment sum. So, the user needs to copy the numbers manually that represent packaging per car into the other Excel document.

To sum up, the model calculates the variable packaging per car, the weakness with the model is that the automation, some manual work is needed in this document and it is mostly because of raw data that causes these problems.

## **7.2 Model - Investment Sum**

To begin with, this section will first describe the document in Excel in general and later move on to explain the calculations more in detail. The investment sum is calculated in the second document in the model and the purpose is to present and calculate a recommended investment sum for packaging. The document is designed to fulfil the requirements that were described earlier in this thesis.

The model is designed to be able to choose different time periods, based on both weekly and yearly production volumes. The production volumes for weeks cover a forecast of 60 weeks, compared to the production volume for years, which cover six years. The calculation is based on three different variables; volume, loop time and packaging per car. Packaging per car is the variable that connects this document with the one described earlier.

Below follows a description of every sheet, and a description of how the calculations are made. Finally, some improvements with the new model will be described together with weaknesses and new areas to focus on for further improvements.

### **7.2.1 Description of the Sheets**

There will now follow an explanation of every sheet to get a better knowledge about the document. As described earlier, a convenient way to organize an Excel model is to have different layers. The layers in this model are raw data layer, analysis layer, presentation layer and assumption layer. A more detailed description of the sheets with Excel-formulas can be found in the User Manual (Appendix 2).

#### **7.2.1.1 Volume Week-Raw – (Raw data document)**

This sheet shows the forecasted production volume and this is how many cars that are produced every week, up to 60 weeks ahead. Car model, week and manufacturing plant are the most important information in this document and will be further used in the analysis layer. The sheet tab is coloured red to easier recognize the raw data sheets.

#### **7.2.1.2 Volume Week Engine-Raw – (Raw data document)**

This sheet is also raw-data and shows 60 weeks of engine demand and in this sheet week and engine types are the data that will be further used. VED and VEP are the engine types included in this document.

#### **7.2.1.3 Volume Year-Raw– (Raw data document)**

Planned production volumes based on years for Gent and Torslanda exist in this sheet. Even though the production volumes cover more than 6 years, it is only this time period that will be used in the model. This sheet also adds together car models with similar names to make the calculations easier. For example, V40 and V40 CC are added together, because there are only packaging per car data for V40.

#### **7.2.1.4 Packaging per Car (Raw data document)**

The sheet called packaging per car connects the two different Excel documents with each other. The sheet shows all the existing and planned car models, and the packaging need each car model requires of every different packaging type. The packaging per car sheet also shows engines and its packaging information but these numbers are just estimated and are not based on actual calculations.

### **7.2.1.5 Volume Week Engine- (Analysis layer)**

In this sheet the packaging amount for engines per week are calculated by multiplying weekly need with packaging per car data for engines. The result shows every packaging type included in the model and the engine demand for packaging every week.

### **7.2.1.6 Volume Week-Cars- (Analysis layer)**

The rows in packaging per car document – car models, does not include cross country (CC)-models, an average of for example V40 and V40CC is calculated and is entered under only packaging per car for V40. Therefore, it is impossible to match Volume week-row where all models including CC-models exist with the packaging per car. So, in this sheet the volume for for example V40 and V40CC are added together.

### **7.2.1.7 Volume+Basic- (Analysis layer)**

In this sheet the weekly volume and packaging per car are added together. The data used to calculate this is packaging per car and volume week-cars. The result from this shows how many of every packaging type that is required every week.

### **7.2.1.8 2016-2021 (Analysis layer)**

These sheets are calculating the required packaging in circulation for the years 2016-2021 and are based on production volumes for years. The sheet collects data from “volume year-row” and synchronizes with the “presentation yearly” by doing some calculations. For every packaging type and every car model the model calculates the packaging need based on production volume, SOP/EOP/NWC, packaging per car and production days. Normal week capacity (NWC) is used as a volume for car models with SOP during the specific year. These numbers are summed and packaging need for engines and VCCS are added. In the end, the different loop times depending on packaging type are added to the calculation. The outcomes from this calculation are “Total number of required packaging in circulation EOP” and “Total number of required packaging in circulation SOP”. These are connected to the “presentation yearly” and in that sheet it is possible to choose time periods to compare to each other.

### **7.2.1.9 Assumptions - (Assumption layer)**

In this sheet it is possible to change assumptions at any time and these will automatically sync with the calculations. Assumptions included are: produced ratio between VED and VEP engines, loop time for VCCS, pallets, boxes and combitainers, production days per week and year, price per packaging, percentage value to include “not included packaging” and the actual amount of each packaging type that already exist in the packaging pool. If these assumptions change, a new number can be entered in this sheet. Below is a more detailed explanation of every assumption.

First, an important variable for the calculation of required packaging in circulation is loop time and this number will be assumed based on past experiences. A fixed number for the different packaging categories pallets, boxes and combitainers will be used to simplify the calculations.

Another assumption is the engine volume for the calculation based on the yearly production volumes. This assumption is made because of deficient knowledge about the future demand for engines types. It is possible for the user to choose how much percentage of VED and VEP that are used for the investment sum based on yearly volumes.

Volvo Cars assumes that Volvo Cars Customer Service (VCCS) utilizes a per cent value of the total sum of packaging required for both the Torslanda- and Gent-factory. A different loop time will also be used for VCCS.

This assumption describes simply the amount of days the production in the plant is on going. The plants are closed during some weeks every summer, around Christmas and other celebrations.

### 7.2.1.10 SOP-EOP - (Assumption layer)

This sheet is also a kind of assumption. Here is all the information about the car models' start of production (SOP) and end of production (EOP). Also, a car model's normal week capacity (NWC) is also given for cars with a start of production date. These are needed in the yearly calculation.

### 7.2.1.11 Presentation Weekly - (Presentation layer)

In this sheet the investment sum will show up based on weekly production volumes. The numbers are collected from the analysis sheets and can be checked there too. The user chooses two time periods to compare and the investment sum, both compared to the current number of packaging in the packaging pool and the time periods compared to each other. See picture 7.3 below of the presentation layer-weekly the green cells show the investment sum, all the data has been excluded because of confidentiality.

	B	C	D	E	F	G	H	I	J	K	L
How many weeks?		6									
Choose time period 1	w1607	w1608	w1609	w1610	w1611	w1612	-	-			
Choose time period 2	w1637	w1638	w1639	w1640	w1641	w1642	-	-			
	EMB 1	EMB 21	EMB 71	EMB 2	EMB22	EMB 72	780	840	EMB 750	400	
Period 1 - Cars	0	0	0	0	0	0	0	0	0	0	0
Period 2 - Cars	0	0	0	0	0	0	0	0	0	0	0
Period 1 - Engines	0	0	0	0	0	0	0	0	0	0	0
Period 2 - Engines	0	0	0	0	0	0	0	0	0	0	0
Period 1 - VCCS	0	0	0	0	0	0	0	0	0	0	0
Period 2 - VCCS	0	0	0	0	0	0	0	0	0	0	0
<b>Sum Period 1</b>	0	0	0	0	0	0	0	0	0	0	0
<b>Sum Period 2</b>	0	0	0	0	0	0	0	0	0	0	0
<b>Current in SAP</b>	0	0	0	0	0	0	0	0	0	0	0
Price/packaging	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr
Investment demand	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
<b>Total invest. Demand</b>	<b>0 kr</b>										
<b>Last timeperiod compared with second time period</b>											
Price/packaging	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr	0,00 kr
Investment demand	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
<b>Total invest. Demand</b>	<b>0 kr</b>										

Figure 7.3: Presentation layer weekly.

### 7.2.1.12 Presentation Yearly– (Presentation layer)

This is the second presentation sheet and it is based on yearly production volumes. It is possible to choose time periods to compare to each other or to compare to the current numbers in the packaging pool. The packaging need for all the years are shown to see when the peak volume is. See picture 7.4 below of the presentation layer-yearly the green cell shows the investment sum, all the data has been excluded because of confidentiality.

	EMB 1	EMB 21	EMB 71	EMB 2	EMB 22	EMB 72	780	840
Choose time period 1 2016 EOP	0	0	0	0	0	0	0	0
Choose time period 2 2017 EOP	0	0	0	0	0	0	0	0
Investment sum per packaging	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr	0 kr
Investment demand	0 kr							
Current	0	0	0	0	0	0	0	0
2016 EOP	0	0	0	0	0	0	0	0
2016 SOP	0	0	0	0	0	0	0	0
2017 EOP	0	0	0	0	0	0	0	0
2017 SOP	0	0	0	0	0	0	0	0
2018 EOP	0	0	0	0	0	0	0	0
2018 SOP	0	0	0	0	0	0	0	0
2019 EOP	0	0	0	0	0	0	0	0
2019 SOP	0	0	0	0	0	0	0	0
2020 EOP	0	0	0	0	0	0	0	0
2020 SOP	0	0	0	0	0	0	0	0
2021 EOP	0	0	0	0	0	0	0	0
2021 SOP	0	0	0	0	0	0	0	0
Hösta värdet	0	0	0	0	0	0	0	0

Figure 7.4: Presentation layer yearly

### 7.2.2 Calculations - Investment Sum Weekly

This section will explain how the investment sum based on weekly production volumes was calculated and how it is presented in the presentation layer. All the sheets used to calculate the investment sum are explained above. The first thing to do in the model is to calculate packaging in circulation based on the volumes for weeks. The raw data layers are all connected to analysis layers and which in turn are connected to presentation layer. The following formula was used to calculate the required packaging in circulation:

$$\text{Volume} * \text{Packaging per car} * \text{Loop time} = \text{Packaging in circulation}$$

The first variable in the formula is volume and the unit for volume has to be in days. Therefore, the weekly volume must be divided by “production days/week” and this number can be found in assumptions. Packaging per car is the second variable and this data is gathered from the packaging per car sheet and this data must be calculated before this document is used. The final variable is loop time, and to decide an accurate number for this is out of scope for this thesis, so the loop times are decided in the assumption sheet.

The formula above is used to calculate the required packaging in circulation for every packaging type. The final investment sum is calculated by comparing two time periods to each other. The time periods are between one and eight weeks and only weeks for 60 weeks ahead can be chosen. The user has to choose the time periods depending on the wanted outcome. In order to calculate the investment sum an average number of the packaging in circulation for both time periods are calculated.

The recommended investment sum will be displayed based on two different comparisons. If the required packaging in circulation for the different packaging types for the second time period is greater than the numbers of the first time period. Then the investment need will be displayed for

every packaging type and also added together to show the total investment sum. The difference in packaging in circulation between the time periods is multiplied by the price per packaging and that is what becomes the investment sum.

First time period < Second time period → investment sum displayed

The other comparison is the required calculated packaging in circulation and the existing packaging amount in the packaging pool. There is no need to make packaging investments if there is enough packaging in the pool at the specific moment.

Packaging in the pool < Time period → investment sum

The investment sum in both cases is multiplied with a percentage value to include the rest of the packaging type that are not included in the model. This number can be changed in the assumption sheet.

### 7.2.3 Calculations - Investment Sum Yearly

In the second presentation layer, the investment sum based on yearly production volumes is determined. The calculations are similar to the prior calculation of “investment sum weekly”, but there are minor changes. The biggest change is the process to calculate the volume variable, but also how the time periods are decided. To get a more detailed explanation with all the steps, see the User Manual (Appendix 2). The following formula is used to calculate the required packaging in circulation:

$$\text{Volume} * \text{Packaging per car} * \text{Loop time} = \text{Packaging in circulation}$$

However, there are some more aspects to take into account regarding volume in this case. Because SOP/EOP/NWC affects the process of calculating the required packaging in circulation. SOP/EOP/NWC can be changed in the assumption sheet called “SOP-EOP”. When a new car model enters the manufacturing plant the volume cannot be calculated as an average for the whole year, this number is too misleading and inadequate. The solution used in this model is to use NWC and this means that the planned production volume per week when the car model is more stable in the production process will be used. Normal week capacity is based on weeks and the formula to calculate packaging in circulation requires the unit per day, so NWC needs to be divided by “production days per week ” and this assumption can be changed in the assumption sheet. Now the volume for SOP can be calculated in a more accurate way, and when multiplying with packaging per car and loop time the result is packaging in circulation.

On the other hand, when a car model will discontinue to be produced the volume must be calculated in another way. EOP shows the week the car model will stop its production and this week is used to decide the amount of days the car model is actually produced during that year. For example, if EOP is week 2, the amount of days the car model is produced is then 10 days based on current production days per week (2\*production days per week). A disadvantage and a future problem that affects the investment sum is that the EOP week is uncertain and sometimes the production volumes increase during the last weeks and sometimes the volumes decrease. This is hard to anticipate, and especially for car models with an EOP a couple of years from now. To get a more accurate investment sum it is important that the user has enough information to forecast this. However, the production volumes are updated all the time and it makes it hard to forecast this even for a user with good knowledge.

$$\frac{\text{Production Volume for a year}}{\text{EOP} * \text{Production day for a week}} = \text{Volume EOP}$$



For the car models with a continuous production during the year, the calculation is more simple. The total production volume is divided by “production days per year” and this is also just an assumption and can be changed at any time if the production days increase or decrease.

In the yearly presentation layer it is not possible to compare weeks. In this case, the comparison use “packaging in circulation before EOP” and “packaging in circulation after SOP”. This is to see if there is an increase of packaging demand when the new cars models enter the production and the old car models leave the production. So, for every year it is possible to choose either “packaging in circulation before EOP” or “packaging in circulation after SOP”. But it is not always the user wants to compare these to each other for just one year, therefore it is possible to choose for every year and also to compare to the current number of packaging in the packaging pool.

After the volume and later the required packaging in circulation are calculated for all six years and the time periods for the years. The user can choose time periods or the current number of packaging depending on the wanted outcome. The investment sum is decided by checking if the first time period’s packaging in circulation for every packaging type is lower than the second’s, and if it is the difference for every packaging type will be multiplied with the price per packaging type. If the investment sum per packaging type is greater than zero these numbers will be added together and show a total investment sum. Finally, a percentage value is added to the total investment sum to include all packaging types that are not included in the model. This percentage value is based on the 80/20 rule, and the value can be changed in the assumption sheet.

## **7.2.4 Improvements - Investment Sum**

In this section the improvements with the new model will be described and the foundation for this is to compare the new model to the requirements, and if they were fulfilled and if the gaps can be closed.

The first two requirements explain that the new model should be more general in a way so the raw data and assumptions can be updated and then the presentation layer and outcome will change too. As described earlier when the sheets and calculations are explained the concept of the model works even when the raw data is updated. But it is important that the raw data is standardized and looks the same way as the raw data did that were used when developing the new model. The model is easier to use and update when the new model consists of different layers. The same applies for the assumption sheet, it is easy to change the assumptions and add more assumptions if it is necessary.

The last requirement says that the investment sum should include both weekly and yearly production volumes. Right now, the investment sum based on weekly demands can be found in the “presentation weekly” sheet and the investment sum for production volumes for years can be found in the “presentation yearly” sheet.

To improve the user-friendliness the design of the documents have been improved with input from Volvo Cars. The following examples show some design improvements made in the new model. To be able to identify the different layers the sheets are coloured to match the colour for the layer type. In this way it is easy for the user to look for example red coloured sheet tabs, which are the raw data layers. Another design improvement is the presentation layer. It is easy to identify the important cells, which need attention because these are all coloured. Also in the presentation layer a description box is added to help the user to understand the document without having to read the full user manual.

### **7.2.5 Problems with Updated - Investment Sum**

The new model is improved in many ways but there are still many things that can be further improved but some things will just be weaknesses with the model. To begin with, when the user choose time periods in the “presentation weekly” it is important that the user first check the raw data for production volumes for weeks. Because some weeks the production is closed in either Torslanda or Gent. If a closed production week is included in the time period it will affect the average for packaging in circulation for that time period. So, when a closed production week is used the investment sum will be misleading.

As described before, the production volume for car models with EOP is hard to forecast and will affect the investment sum. The model calculates the volume based on EOP, but it is a weakness for the trustworthiness of the model and this is because of uncertainty in data.

The model is developed from the standardized raw data that were given from Volvo Cars. This means that the model only works if the data keeps being standardized in the same way. However, the concept of the model will continue to work but some sheets might need to be added or changed.

### **7.3 User Manual**

The model is easy to use because of its construction with layers. When the raw data layer is updated everything is update as well, and the user only needs to look in the presentation layer where the outcome is shown. But, the user still needs a manual to use the model, to get a more deeply knowledge about the model and how it works. That is why a manual was created to facilitate the use of the model with explanations.

The User Manual explains the model in a detailed level with clarification of all the sheets, which formulas the sheets use, how the model works, how to use it, how to maintain and a detailed explanation of the manual work that is needed in the model. The complete User Manual will not be included in this thesis, however it can be seen in the appendices (Appendix 2).

## **8. Discussion**

The discussion will start with an evaluation, to see if the model achieves its purpose and fulfil the requirements. Then it will include recommendations for Volvo Cars, how the company can continue to work on the model and its data.

### **8.1 Characteristics of a Model**

According to Allwood there are four points of what qualifies a model (Allwood, 1989). The model in this thesis qualifies a model because it fulfils the four points that Allwood mentions. The first point is about that the model should not bring up appearances in the model that are not calculated. And this is something that is applied in this model neither. The model is simple in that way that only the assumptions and raw data that are actually used in the model are included. If any more assumptions want to be included in the calculations in the moment, as an error factor, it will not become a model anymore.

The second point is that the model should not benefit anyone internal or external. The original model had many defaults in the calculations that benefited the department packaging operations that actually made the investment sum higher. The calculations in the new model are general and more exact and therefore do not benefit any part.

The third point is that the model should demonstrate proper completeness. Which means that the model should not exclude anything that is relevant for the model. This model excludes some things like the model does not include every packaging type, just 19 of them are included. But this does not make a major difference in the calculation because the excluded packaging types are used very rarely, and there is a factor instead that includes these excluded packaging types. The last point is that the model should be simple and foreseeable, and this new model is both very simple and foreseeable. In conclusion, the new model fulfils every point and can classify as a model.

### **8.2 Compare to Purpose and Requirements**

The first step in this thesis according to the purpose is to evaluate and validate the original model. By doing this the requirements for the new model were decided and also that the variable packaging per car were going to be recalculated. The calculation of packaging per car improved the accuracy for the investment sum and by using the different layers the calculation reduced the manual work and the raw data can be updated in a convenient way.

The performed improvements in the model are linked to the requirements and the complete model is now more general in terms of that the raw data and assumptions can be updated at any time. The theory about the layers was utilized to both reduce the manual work and also increase the automation. Even if there are weaknesses with the data and assumptions in the model and there exist potential improvements, the purpose and requirements are fulfilled.

### **8.3 Unreliable Raw Data**

A problem that was identified during the thesis was that the raw data received from Volvo Cars was not always correct. For example FLIT could not be used for the old car models because it was a continuously updated document that actually caused a lot of problem.

Another unreliable data is SOP/EOP, these numbers are not exact because there is not knowledge in advance of exact when they end and start their production, and some car even

increase their production before they end and this affects the calculations a lot. Therefore the number of packaging in circulation can vary greatly. This causes an overview error that makes the model not reliable because of its data. The model is general and there is no need to calculate by hand, but because of the doubtful numbers that is entered, the model's outcome can be very doubtful as well.

## **8.4 Recommendations and Reliability**

As described in the prior chapter, the investment sum can be very misleading if the user utilizes the model in a wrong way. Examples on factors that can affect the outcome are the time periods in “presentation weekly”, the assumptions and also the variable packaging per car. Based on factors that possibly make the investment sum misleading and what assumptions that affect the outcome the most, some recommendations for the user will now be presented. All of these recommendations will not affect the model itself, but it is recommended that Volvo Cars works on improving the data so the model can be further used and achieve its requirement of calculating a reliable investment sum.

Most important, the user must have good knowledge about the company, the department and also be able to interpret the numbers based on historically events. The reason why the responsibility lies on the user is because a lot of assumptions need to be decided by the user prior to using the model. The user also needs to evaluate if the numbers are reliable. Therefore, the first recommendation is that the user should use “presentation weekly” instead of “presentation yearly” when it is possible. The calculation of “presentation weekly” is based on fewer assumptions and is therefore more reliable and reflects the reality better. However, it is important to remember the weaknesses with the “presentation weekly” and always check the production volume if the plants are closed or not. The greatest weakness with the volume for the years is how to calculate an average volume for the car models and this makes the outcome less exact.

Another recommendation is to continue to go over the assumptions to get actual numbers that reflect the reality. Nowadays one of the variables, loop time is just an estimated number based on historical facts made by the department. In the future, the loop time will most likely decrease as the department work towards more efficient work processes. A more accurate loop time will both make the investment sum more reliable but also help the department to plan future packaging demand as the knowledge of when the packaging should be available for the suppliers will be improved. So, the department should focus on determining the actual loop time.

Moreover, VCCS is another assumption that needs to be evaluated. Right now VCCS’s packaging demand is calculated by taking a percentage value of the total packaging demand. However, this percentage value is also just an assumption and has not been verified.

One of the variables is packaging per car and this is as mentioned before calculated in the first document. An existing problem with that calculation is that data from Pecca does not exist for some coming car models. Then the department at Volvo Cars has estimated the packaging per car data for those car models. Packaging per car is not only important for this model, it is used to further plan future processes at the department. Because of that a recommendation is to always update packaging per car when new car models exist in Pecca.

A recommendation is that Volvo Cars should look up the 80/20- rule of the packaging types. Now an estimation of the most common packaging types that Volvo Cars think stand for 80 per cent of the investment sum is selected and calculated for in the model. Only these 19 types are included in the calculation. If Volvo Cars wants more exact numbers, the 80/20 rule needs to be validated or the calculation needs to calculate for all the packaging types, and not only the ones Volvo Cars think is the most common.

In conclusion, Volvo Cars needs to start verifying the following assumptions and variables to get a more reliable investment sum; packaging per car, loop time, VCCS and the 80/20-rule. There are several things to do to get a more reliable outcome, but it is important to weigh the cost to the benefits. The model is only to give a hint of the future packaging need and to be able to plan ahead of time for new packaging investments.

## **8.5 Limitations of the tool**

The model was in most ways more general, except for the Pecca document in Excel. The user has to use a filter to decide the car model and the goal was to make this part automatized as well, but Excel which is the software program used to develop the model did not have a command to solve this. So, the software program acts as a limitation for achieving the requirements fully. It has not been investigated if this step is possible to program in another software program and it is up to Volvo Cars if it beneficial. Another limitation with Excel is that it cannot handle big documents and the solution was to separate the model into two documents.

## **8.6 Usefulness of the New Model**

The new model compared to the old one is still more useful even though its unreliable data and assumptions. The old model was not general enough and could not therefore be updated with new data to get a correct and current view. The new model can always be updated and therefore be modern all the time, and always give out numbers based on the current data. This makes the model more useful than the old model.

The new model has also all the assumptions in a separate sheet, so these can be changed. In the old model the assumptions could not be changed, and this is a major improvement because of that the assumptions never have been checked that they actually are correct. So when they are improved, the model's outcome will become more correct.

The model has options and this makes the new model more trustful because of that the user can look up investment sum for different time periods, and then compare them by itself to later on come up with a more correct investment sum. To compare many different time periods to see the change in investment sum, for example during a year, makes the user to get a holistic perspective. The old model could only deliver one sum for one time period, and the user then had no knowledge of how it looked the rest of the year.

To sum up, the new model is more useful than the old one because of its generalization, assumption sheet and that the model has option opportunities. However, will always the data that is input in the model make a big difference for the outcome of numbers, but the model itself are correct and give the user a good view of the investment sum because of its choice for options and assumptions.



## **9. Conclusion**

The model fulfils its purpose and a lot of improvements have been done to reduce the manual work and increase the automation. The design of the model is completely new and now consists of several sheets which all are connected to different layers depending on the purpose of the sheet. Volvo Cars can easily update the raw data and assumptions so the outcome will synchronize automatically, and the user manual describes the model in detail, so it makes the model easy to use and update and if necessary.

There is however some variables and assumptions that need to be more reliable for the model to be really useful. These affect the outcome of the model and when these are verified the model's numbers will also be more reliable as will the model. A recommendation for Volvo Cars is to use the weekly volume demand to calculate the packaging investment sum and secure packaging availability in a short-term perspective. The long-term perspective can only be used to give a hint of the future situation, but cannot be trusted fully with today's numbers.

Finally, the model fulfils its purpose but there are several improvement areas to make the model better and more reliable.





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# **Appendix 1**

## **Software Requirements Specification**

**For**

**A Calculation Model for packaging demand**

- Calculating the basis for investment for inbound packaging with the variable packaging per car at Volvo Cars

**Prepared by Evelina Ericsson and Emma Rosenkvist**

**8/12-2015**

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# 1. Introduction

This section will describe the purpose of the calculation model and the intended audience. Furthermore, the model and background to the model will be presented to get a good foundation for the requirements.

## 1.1 Purpose

The purpose is to evaluate and validate an existing model and later come up with improvements to reduce the manual work and increase the automation. The model will be created in Excel 2013 and it will calculate the packaging demand for different time periods. The model will be used by the packaging operation department at Volvo Cars to both, in time plan new packaging investments as well as to always secure packaging availability.

## 1.2 Intended Audience

This document intends to communicate the outline of the model, and the requirements that the model needs to fulfil. The main audience is Volvo Cars and Packaging Operation department at Volvo Cars. However, the SRS is part of a thesis work and will also be used by Chalmers University of Technology. For the best comprehension, read the SRS from the beginning to understand the general information about the model.

## 1.3 Product Scope

The model will be developed in Excel 2013 and this software program has its advantages and disadvantages. The purpose with the model is to calculate an investment sum based on the packaging quantity in circulation. The investment sum will be used to inquire capital from higher departments. Furthermore, the goal is to improve an existing model developed by the Packaging Operation department at Volvo Cars. The future model will generate less manual work and increase the automation. Also, new and more accurate data will be added to improve the model.

Existing parameters for the model are packaging per car, manufacturing volume and loop time. The data accuracy differs and is dependent on time periods. Therefore, the closer in time, the better and more exact the result will be. The first time span is from current to 60 weeks ahead, and the volume is based on a weekly demand. The second time span is based on yearly demand and includes the following year up to six years. Depending on the reliability of the volumes the quality of the investment sum will differ.

More in detail, the model will be broken down into three layers in Excel. The first layer is where all the raw data will be updated and this will be divided into multiple sheets. The model is based on raw data regarding production volume weekly/yearly and shows every car model/engine and the planned manufacturing volume every week/year. Another raw data is supplier and part number information from FLIT and PECCA. FLIT and PECCA are software programs used to gather packaging information from the suppliers and parts included in every car model. This data will further be used to calculate the parameter; packaging per car. Moreover, the second layer is the analysis part and in these layers all the calculations will be performed. The user should not have to change anything in this layer, instead the presentation layer will show the result and other important information. In the presentation layer it is possible to choose time span for the intended investment period. There will also be a sheet where assumptions can be edited and one to show packaging per car and these are not included in the data/analysis/presentation layers. The benefit with this layout is that the raw data will hopefully synchronize with the rest of the document when it is updated.

## 2. Overall Description

To increase the knowledge even more about the model, this chapter will explain some general facts that lead to the requirements.

### 2.1 Product Perspective

This section will describe the reason why the model first was created and the usage area for the model. Packaging Operations was founded during 2014 and therefore the department has a lack of routines and well-organized processes. Previous investments have been based on a percentage value and have not been based on real data. This model will improve the routines within the department and also improve the accuracy of the investment sum.

The model will be a base for new packaging investments, for both short term and long term investments. For the model to work, raw data needs to continue to be standardized and exported to an Excel file.

### 2.2 Product Functions

In this chapter the major functions of the model will be summarized, further detailed information will be provided later. The model will result in a recommended investment sum based on different time periods. So, the model will be divided into two parts, one will calculate based on weekly demand and the second on yearly demand. To be able to get the investment sum, the raw data must be updated first and the user will perform this manually.

The first choice for the user is to decide two time spans based on weeks and the basis for this is the weekly demand programme for 60 weeks. The second choice is to compare two years or the same year depending on when new car models enter or exit the production. Also, the user needs to update the assumption sheet. Afterwards, the investment sum will automatically be calculated. In general will the calculation be based on that the quantity of different packaging types per car model will be multiplied with the planned manufacturing volumes and later also with the loop time. These numbers show the quantity of packaging types that needs to be in circulation. The investment sum is calculated by comparing two time periods with each other and if the later time period is larger than the first the company needs to do an investment. The investment sum is based on the difference in packaging material from the time periods multiplied with the price for every packaging type.

As mentioned earlier, the model will be broken down into three parts. The data layer's function is to contain all the raw data. So, by updating the raw data the calculations made in the analysis layer will synchronize and the new result will be shown in the presentation layer. There should be no need to edit the analysis layer, however, some events can occur and not be foreseen by the formulas used in the model. It is the user who will be in charge of the presentation layer and manually change time span to get an investment sum based on that time period. Also, it is the user's responsibility to choose a time span when the production rate is regular and not includes vacation weeks etc. This is so the comparison will show based on the two parameters; packaging per car and manufacturing volume and not include other factors as vacation weeks.

## **2.3 Users**

The most important user of this model is the “director” of the Packaging Operation department. That person will use the outcome of the model to plan new investments and to inquire capital to future packaging investments. To some extent the user must have good knowledge about the company, processes and be able to make own assumptions based on prior experiences.

## **2.4 Operating Environment**

The model is developed in Excel 2013 for windows, but it will most likely work in future and past Excel versions too.

## **2.5 Design and Implementation Constraints**

The Excel documents include a lot of data and analysis, which require computer with high performance and memory. However, the documents are too large to handle inside one, and are therefore separated into two documents. The first calculates the packaging per car and the reason why it is so large is because it is based on supplier information for every car part. The second document is not large in size but it contains of many linked formulas, which slows it down.

Manufacturing volumes and packaging per car are confidential data and is included in the model. This data have been delivered but have not been verified and some errors may occur. (fel I FLIT)

## **2.6 User Manual**

To help the user to utilize the model by its fullest potential, a user manual exists. It includes a detailed explanation of the documents and every sheet. To further help the user some comments will be included in the Excel sheets.

## **2.7 Assumed Factors**

Packaging per car is one of the parameters in the model and the raw data is based on supplier information and sometimes this information does not exist until three-four(?) years before the planned production start. In this case, an assumption based on previous models will have to be made.

The raw data is constantly changing, however, at the time the model will be used the latest update will be used. In some cases, if the rows and columns change the analysis parts need to be updated too. Mostly, the data is based on a look up value and not rows/columns.(?)

The model is developed in Microsoft Excel and this is the most common spreadsheet right now, but this might change in the future. The concept of the model can be used in whatever spreadsheet or even manually.

# **3. Functional Requirements**

This chapter will more in detail describe the functional requirements for the model. These are the requirements that must function for the model to work in the planned way.

## **3.1 The model should update presentation layer when RAW DATA is updated**

The first functional requirement describes that the presentation layer will be updated automatically when new raw data is added or updated. This will reduce the manual work by the user and reduce the time spent on the model. So, the first step is to update all the raw data. This is of high priority, since the model will not work without raw data.

This requirement heavily rely on the analysis layers, that the formulas are entered in a correct way and do not show error messages that will mess up the presentation layer. The raw data is linked to the analysis part, where the calculations are made based on packaging per car, manufacturing volume and loop time.

The raw data sheets will be converted to tables in Excel, so if more data is added than the last row the table will extend to fit the new raw data. In this way the model will be more general and will work with future raw data as well.

If the raw data is imported in a wrong way, the first indication is that the presentation layer will not present an investment sum and the text in some cells will say: N/A, error, ref etc.

The user needs to export raw data (how to collect the raw data is not a part of the model), to later import or copy to the correct Excel sheet. See the user manual for more detailed information on how to update the raw data. It is important to put the raw data in the right sheet, otherwise the analysis part will not work properly.

### **3.2 The model should update the presentation layer when ASSUMPTIONS are changed**

The user must fill out the assumption sheet, since a lot of formulas contain assumptions that have to be entered by the user. The assumption sheet is already filled out from the start, but the numbers might change and the user has to enter new numbers for the investment sum to be as accurate as possible. The data that are assumed will automatically sync with the presentation layer. The priority is medium, since the model still will work with the old assumptions but not be very exact. So, the model will not cover to decide numbers on assumptions, this have to be done by the organization in another project.

All the assumptions based on numbers are entered in the same sheet, so it will be possible to change afterwards. A requirement is that the calculations will synchronize and automatically be updated inside the formulas. So, in the end the investment sum is based on the current assumptions.

The assumptions and how they actually are calculated will be further described in the user manual and the thesis report will describe the theory behind it. If the assumption numbers need to be edited, just go to the assumption sheet and remove the old numbers and write new ones. The calculations should be updated automatically.

### **3.3 The model should show an investment sum based on both weekly- and yearly demand**

The ultimate goal for the model is to end up in an investment sum, so if this fails, the model fails too. This is therefore of high priority. However, this functional requirement depends hugely on previous steps. The investment sum will be presented in the currency Swedish kronor. It is possible to choose if the investment sum will be based on the raw data from weekly volumes that cover up to 60 weeks ahead or yearly volumes for six years. The investment sum based on the weekly demand will be more accurate.

The user has to enter weeks or years to compare to each other. If the later period is greater than the first period, a recommended investment sum will be displayed. In addition to choose time period, the user can choose to compare with the current packaging quantity registered in the system.

## **4. Other Non-functional Requirements**

Safety Requirements: To be sure to always keep a copy of the model and make a copy of the model before using it.

Security Requirements: To make the document more secure, a password can be used to be able to see the data in Excel.



## **Appendix 2**

# **User Manual**

This User Manual describes the calculation process, the sheets, assumptions and limitations of the model for Volvo Cars Packaging Operations. It is recommended that the user read and understand this manual before using results of the model for any purposes. If any questions regarding the model contact the creators Emma Rosenkvist or Evelina Ericsson.

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# 1. Introduction

To be able to understand the model and to use it by its fullest potential, some information about the structure of the model is necessary. The following text will describe the model, the two different documents, the content in every sheet, how the document is calculating and how to use the document.

The model exists in two Excel documents. The first document calculates “packaging per car”. That document calculates the amount of different packaging types required to manufacture different car models. Moreover, the second document called “packaging investment model” calculates the total packaging amount in circulation based on different time periods, both weeks and years. The result is a recommended investment sum.

The document should be easy to use, and if it is difficult to understand the model, the user can always read the comments in the document or in this user manual. There are also some textboxes in different sheets with descriptions.

## 2. Layers

The model is divided into three layers; data layer, analysis layer and presentation layer. First a general description of every layer will be presented, followed by a more detailed explanation of every sheet for the different documents.

### 2.1 Data layer: (Red)

The data layers only consist of raw-data. It is data downloaded from different software programs in a standardized way so it is possible to update, and the model will then automatically sync with the rest of the document. To find the raw data in the Excel document, look for “raw” in the sheet name and the sheets’ colour is red.

### 2.2 Analysis layer: (Grey)

The second layer is the analysis layer. These layers consist of calculations and formulas to reach the result/presentation. These calculations are calculated in a general way so it should not be necessary to edit these sheets, even when new data is included in the model. These sheets use information from the raw data and calculate the numbers shown in the presentation layer. However, if the raw data is constructed in a different way, the analysis layer must be updated to match the new raw data. The analysis sheets are coloured in grey.

### 2.3 Presentation layer: (Green)

In the presentation layer the models outcome is shown; the recommended investment sum. In this sheet only the presentation numbers are shown and not any of the calculations. Whenever new raw-data is updated into the model, also the numbers in the presentation shall be.

### 2.4 Assumption layer: (Yellow)

This sheet have all the assumptions, this is just because the assumptions should be easy to change, because they affect the calculation a lot.

## 3. Document-Packaging per car

### 3.1 Introduction to the document

This document calculates the parameter “packaging per car”. The parameter is presented for every car model that is currently produced and for all the planned car models for 6 years ahead. The calculations are based on raw-data that is collected from FLIT and Pecca Cost Estimation. From that, data can be calculated to decide how much packaging one car model needs. The calculations are calculating for 19 different packaging types that constitute 80% of the most used packaging types.

### 3.2 Description of the Sheets

There will now follow an explanation of every sheet to get a better knowledge about the document. Under the sheet name there will be an explanation of what the sheet is needed for, if its raw data etc.

#### 3.2.1 Cost Estimate – *(raw data document)*

This raw data sheet is exported from Pecca Cost Estimation and shows different car models. There are multiple car models in the Cost Estimate sheet and sometimes a filter (column M; “CM name”) is needed to separate the models. The important information that is needed from this sheet is the part number “PARTNO” (column Q) and how many parts that are used in one car “SYS PARTS/CAR” (column Y). From this sheet this information is collected to sync together with the rest of the document.

#### 3.2.2 FLIT-VCT - *(raw data document)*

This is also a raw data sheet and as the name mentions it is exported from FLIT. The data used from this sheet is: the part number (PARTNO, column F), the load carrier (column W), unit load (column X) and Qty 1-3 and Emb 1-3. The part number from cost estimate sheet is compared to the partnumber in FLIT to collect the other information.

This sheet is for the factory in Torslanda and is only used when calculating packaging per car for the car models produced in Torslanda.

#### 3.2.3 FLIT-VCG - *(raw data document)*

This sheet fulfils the same functions as the sheet right above except that it is for the factory in Gent. The different sheets are used for different car models, depending on if they are produced in Gent or Torslanda.

### **3.2.4 CAR VCT-** (*Analysis layer*)

Together with the data collected from FLIT and Pecca, this sheet calculates the parameter “packaging per car” for all the packaging types. Partnumbers and sys part/car needs to be transferred from Pecca manually to this sheet, and description of that comes further below.

From the part number from Pecca, VLOOKUP is used to collect Load carrier, Unitload, Qty and Emb. With knowledge of how much packaging that is needed in unit load and how many of the part that is used in one car, the model calculates how much packaging every part needs and summarize it for all the parts that is included in one car to get the total amount of how much packaging one car need. The calculation formula is:

$$\text{sum} \left( \frac{\text{SYS PARTS/CAR.}}{\text{Unit load}} \right) = \text{packaging per car}$$

All the numbers for the chosen packaging types are summarized and the answer shows how much of the specific packaging that is needed to produce one car. This calculation is only necessary to do once, when new car models need to be entered in the model.

### **3.2.5 CAR VCG** – (*Analysis layer*)

This sheet fulfils the same function as the one above. This one should instead be used if the car model is produced in Gent. This sheet then collects information from FLIT-VCG instead of FLIT-VCT. Therefor, it is very important to know where to car is produced so the right sheet is used for the calculations.

### **3.2.6 Assumptions-** (*Assumption layer*)

In this sheet all the assumptions are made. The assumptions are about the boxes and how many boxes that is packed on one pallet.

### **3.2.7 Packaging per car** – (*Presentation layer*)

This sheet presents the “packaging per car “ that has been calculated. It is “packaging per car” that connects this document with the other one. So when updating “packaging per car” the numbers needs to be copied manually to the other document that calculates the investment sum.

### 3.3 How is the model calculating

In the calculation of “packaging per car”, the model is based on the part numbers included in every car model. All the part numbers that are included in one car is collected from Pecca Cost Estimation, and how many parts that is used in one car as well. From FLIT unit load and load carrier is collected to calculate “packaging per car”. Below comes a more detailed description of how the model calculates.

When the part numbers and sys part/car is transferred to the sheet CAR-VCT or CAR-VCG the model then calculates automatically “packaging per car”. Depending on where the car is produced the part numbers and sys part/car are transferred to CAR-VCT or CAR-VCG. But first the part numbers needs to be converted from text to numbers. A description of how this is done is presented in the chapter “how to calculate packaging per car” below.

Now a description of how the model calculates and what formulas that have been used will follow. The model search together with VLOOKUP in FLIT-VCT if the part numbers is in CAR-VCT or it search in FLIT-VCG if the part numbers is in the sheet CAR-VCG. The model collects Unit load, Load Carrier and Qty 1-3 and Emb 1-3 that have the same part number as the one the search is based on.

The Load Carrier describes what type of packaging the parts a packed on. Together with Unit load and “sys parts/car” the packaging need for every part was calculated for every different packaging type. The formula becomes different for different packaging types. The formula for pallets, boxes, lids and combicontainer is;

$$\left(\frac{SYS PARTS/CAR.}{Unit load}\right) = \text{how much packaging a part number needs}$$

This step is repeated for every part number.

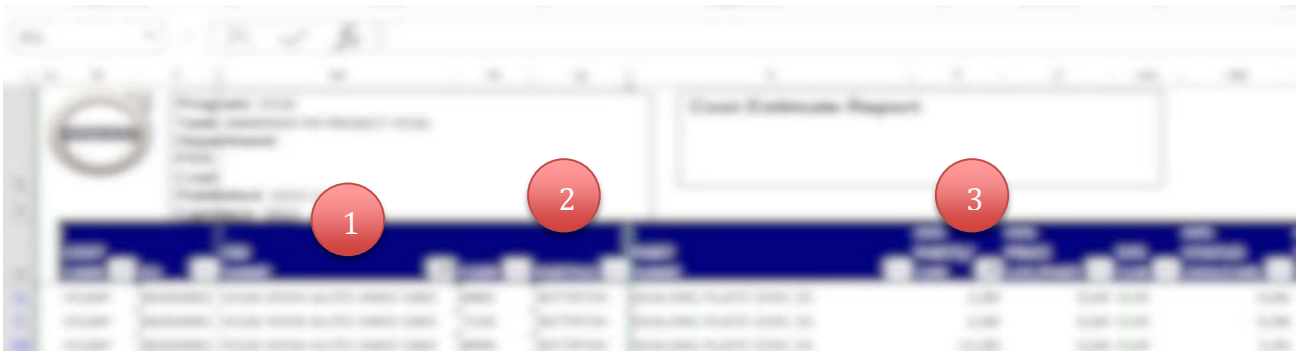
As mention above, it is the load carrier that says if the parts are packed on pallets and what type of pallet and how many frames. For example a L-pallet is described as “L 2”. It means that one L-pallet is used and 2 frames. Several frames can be used. When calculating the packaging need for frames the formula is;

$$\left(\frac{Parts per car * number of frames}{Unit load}\right) = \\ = \text{how much packaging of frames one part need}$$

The calculation for boxes is more complex because they are shipped on a pallet. The model first looks if there are any boxes in column 8, 10 and 12. If there is written out any boxes codes, in this case the boxes are 750, 780 and 840, the model then use the same formula as for pallets. However, an assumption is that boxes are always packed on a L-pallet. There are always a different amount of boxes in every shipment and therefore assumptions have been made. In average there are stocked 4 boxes of type 840 on a pallet, 12 boxes of type 780 on a pallet and 24 boxes of type 750 on a pallet. The model looks up if there are any boxes used in that part number and if there is, the model adds one-quarter, one-twelfth or one twenty-fourth to the L-pallet.

The model finally summarizes every part’s packaging need. When summarize for all the part numbers, the total will become packaging per car for 19 different packaging types.

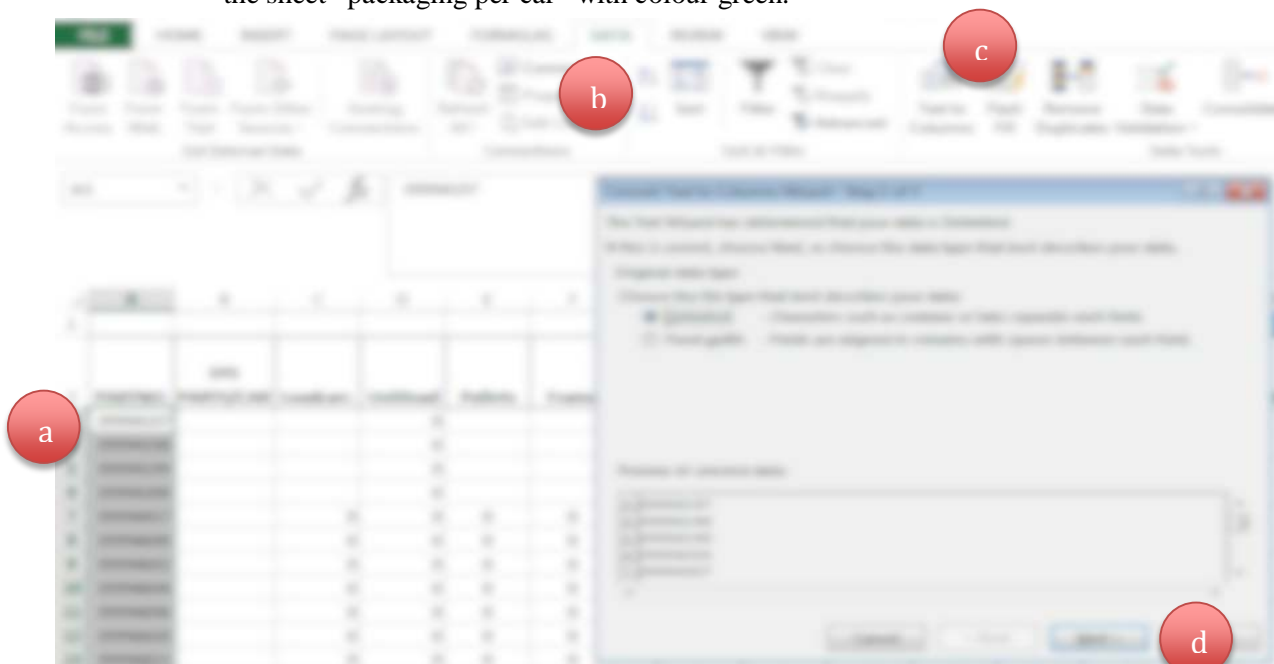
To sum up, the model calculates the packaging need of one part number. The calculation looks different for different packaging types, and there are 19 different packaging types in this model. The model then summarizes all the packaging need for every part for every different packaging type. The outcome is packaging per car.



### 3.4 How to calculate packaging per car

There are some things that need to be done manually in this model. The first thing is about how to get the part numbers from Pecca Cost Estimation imported to the sheet “CAR-VCT” or “CAR-VCG”. The following description will explain how to do this and how to get the outcome “packaging per car”.

1. Import new FLIT-VCT and FLIT-VCG to update if necessary.
2. Import the raw data from Pecca and put it in the sheet Pecca Cost Estimation.
  - 1 a. Put on the filter and select which car you want to calculate “packaging per car” for. This can be selected in column named “CM NAME” in column M. See number 1 in picture above.
  - 2 b. Now mark all the part numbers in column Q (see 2 in picture above) and copy, then paste it in the sheet “**CAR-VCT**” or “CAR-VCG” depending on where the car is produced. Place it in column A (See a in picture below)
  - 3 c. Before finishing do the same with Sys part/car (see 3 in picture below) that is in column Y and copy into column B in sheet “CAR-VCT” or “CAR-VCG” depending on where the car is produced.
3. The last step is to transform the part numbers in sheet CAR-VCT/VCG from text to numbers.
  - a. Start with marking all the part numbers that you just pasted to the sheet CAR-VCT or CAR-VCG. (see a in picture below)
  - b. Go to the tab DATA (see b in picture below)
  - c. Press Text to Columns (see c in picture below)
  - d. There will now come up a textbox. Just press next on every step until finish. (see d in picture below)
4. The model will now calculate “packaging per car” by itself and it will be presented in the sheet “packaging per car” with colour green.





## **4. Document - Packaging investment model**

### **4.1 Introduction to the document**

This document's purpose is to present and calculate a recommended investment sum for packaging. There is an ability to choose different time periods, based on both weekly and yearly production volumes. This document covers only 6 years ahead and therefore are only the data for 6 years included as well. The document is based on 3 different parameters; volume, loop time and packaging per car. Packaging per car is the parameter that connects this document with the one described earlier.

Below follows a description of every sheet, and finally a description of how to use the document and also how to update some of the information in the document.

### **4.2 Description of the Sheets**

There will now follow an explanation of every sheet to get a better knowledge about the document. Under the sheet name there will be an explanation of what the sheet is needed for, if its raw data etc.

#### **4.2.1 Volume week-raw – (*raw data document*)**

This sheet shows how many cars that are produced every week, up to 60 weeks ahead. Car model, week and manufacturing plant are the most important information in this document. When importing new raw-data it is important to only paste data for the plants in Gent and Torslanda.

#### **4.2.2 Volume week-engine-raw – (*raw data document*)**

This sheet is also raw-data and shows 60 weeks of engine demand and in this sheet week and engine types are the data that will be further used. Just paste new raw data in the same format as before.

#### **4.2.3 Volume year-raw– (*raw data document*)**

Planned production volumes based on years for Gent and Torslanda are pasted in this sheet. Even though the production volumes cover more than 6 years, it is only this time period that will be used in the model. This sheet also adds together car models with similar names to make the calculations easier. For example, V40 and V40 CC are added together, because there are only "packaging per car" data for V40.

#### **4.2.4 Packaging per car (blue)**

The sheet called "packaging per car" connects the two different Excel documents with each other. The sheet shows all the existing and planned car models, and the packaging need each car model has of every different packaging type. Data is entered manually from the "VCT-car/VCG-car" sheet and can be found in the other document and depends on where the car model is produced. This process will only be done once. The "packaging per car" sheet also shows engines and its packaging information but these numbers are just estimated and are not based on actual calculations.

#### **4.2.5 Volume week-engine- (*Analysis layer*)**

In the raw data the engine types are divided into LP, MP and HP but this is not significant to the packaging amount. There are three different engine types; VED, VEP and I5P and these are added with the SUMIF formula for every week. Also, in this sheet the packaging amount for engines per week are calculated by multiplying weekly need with “packaging per car” information for engines. The result shows every packaging type included in the model and the engine demand for packaging every week.

#### **4.2.6 Volume week-cars- (*Analysis layer*)**

The rows in “packaging per car” document – car models, does not include cross country (CC)-models, an average of for example V40 and V40CC is calculated and is entered under only packaging per car for V40. Therefore, it is impossible to match Volume week-raw where all models including CC-models exist with the packaging per car. So, in this sheet the volume for V40+V40CC etc. are added together. The formula used is “SUMIF” and this checks a column if there are any cells that contains e.g. “S60”, if that is the case the formula will sum these columns.

#### **4.2.7 Volume+basic- (*Analysis layer*)**

In this sheet the weekly volume and “packaging per car” are added together. The data used to calculate this is “packaging per car” and volume week-cars (amount of produced cars on a weekly basis). The result from this shows how many of every packaging type that is needed every week. “SUMPRODUCT” is the formula used to multiply the “packaging per car” with how many cars that are produced every week.

#### **4.2.8 2016-2021- (*Analysis layer*)**

These sheets are calculating the packaging in circulation for the years 2016-2021. The name of the sheet also describes the new car models for the same year. The sheet collects data from “volume year-raw” and synchronizes with the “presentation yearly” by doing some calculations and there is no need right now to edit this sheet. Currently, all the car models’ “packaging per car” exist in all the years covered in the model. However, in the future an extra step needs to be performed. Then, the existing and planned car models need to be copied from column A in the “packaging per car” sheet and paste them in column A3- and further down. For every packaging type and every car model the model calculates the packaging need based on production volume, SOP/EOP, NWC, “packaging per car” and production days. Normal week capacity (NWC) is used as a volume for car models with SOP during the specific year. These numbers are summed and packaging need for engines and VCCS are added. In the end the different loop times depending on packaging type are added to the calculation. The outcomes from this calculation are “Total number of packaging in circulation. EOP” and “Total number of packaging in circulation. SOP”. These are connected to the “presentation yearly” and in that sheet it is possible to choose time periods to compare to each other. It is important to remember to always check the assumptions before the model is used.

#### **4.2.9 Assumptions – (*assumption layer*)**

In this sheet it is possible to change assumptions at any time. Assumptions included are: produced ratio between VED and VEP engines, loop time for VCCS, pallets, boxes and combitainers, production days per week and year, price per packaging, percentage value to include “not included packaging”, the actual amount of each packaging type from SAP and also

the assumption about how many boxes (840, 780,750) that fits on a L-pallet. If these assumptions change, a new number can be entered in this sheet.

#### **4.2.10 SOP-EOP–** (*assumption layer*)

This sheet is also a kind of assumption. Here is all the information about the car models' start of production (SOP) and end of production (EOP). Also, the car model's normal week capacity (NWC) is also given for cars with a start of production date. These are needed in the yearly calculation.

#### **4.2.11 Presentation weekly–** (*Presentation layer*)

In this sheet the investment sum will show up based on weekly production volumes. The numbers are collected from the analyse sheets and can be checked there too. The user chooses two time periods and the amount of weeks are entered on the top of the sheet. The green cells show the investment sum, both compared to the current number of packaging in SAP and the time periods compared to each other. Before choosing time periods the user needs to check if the weekly volume is normal, otherwise the investment sum will be misleading.

#### **4.2.12 Presentation yearly–** (*Presentation layer*)

This is the second presentation sheet and it is based on yearly production volumes. It is possible to choose time periods to compare to each other or to compare to the current numbers in SAP. The packaging need for all the years are shown to see when the peak volume is.

### 4.3 How is the model calculating

The model calculates packaging in circulation based on the three parameters. The first parameter “packaging per car” can be found in the sheet with the same name. Loop time is the second parameter and it is different for pallets, boxes and combitainers and all of them can be changed in the assumption sheet. Volume is the last parameter and in the raw data the volume is based on a weekly or a yearly demand. To get the calculations correct the volume unit needs to be per/day. So depending on if the volume demand is based on weeks or years the volume has to be divided by production days/week or production days/year and these can be changed in the assumption sheet. However, the cars with a SOP during the analysed year have to use normal week capacity and then divide it by production days/week. For the cars with EOP the volume is divided by the planned production days during that year.

The way the model is calculating is that packaging in circulation (see formula below) for all packaging types and different time periods are calculated in the analysis layers. Then different time periods are compared to each other to see if there is an increased demand of packaging. It is the user’s responsibility to decide the time periods depending on wanted outcome. For example, the time periods can be before a car model has started its production and after, to see how much that is needed to invest in packaging when the new car model has started its production.

The formula for calculating packaging in circulation is:

$$\text{Volume} \times \text{Packaging per car} \times \text{Looptime} = \text{Packaging in circulation}$$

In the yearly calculation there is an assumption about the engine volume, and this can be changed at any time in the assumption sheet.

VCCS uses packaging and right now in the assumption sheet VCCS’s demand is 20% of the total volume. So, the sum of packaging in circulation includes packaging for car models, engines and VCCS.

## **4.5 How to calculate the investment sum**

When using this document there are options of how to use it. There is calculation based on both weekly and yearly volume programs. Therefore the outcome of the investment sum can be different in these two sheets depending on which weeks that the user chooses and year etc. The weekly calculation is always recommended to use first, because the planned production volume is more precise than the yearly production volume

A description of how to use the document will now follow, first the weekly and secondly a description of the yearly model.

## 4.5.1 How to use the document, weekly

1. Start of with update the raw-data. And the raw-data that are used in this calculation are the volume program weekly for both cars and engine. The new updated data can be pasted in the sheet called “Volume week-raw” and “Volume week-engine-raw” depending on if the data is for cars or for engines. It is important that the raw data is pasted in the same way as before and no changes in the raw-data are made before pasting.
2. It is important to look over the assumption before inspecting the investment sum. The assumptions make a huge difference in the calculations’ outcome, and if there are any changes in these, this needs to be changed in the sheet “assumptions”.
3. To see the investment sum for the weekly perspective, go to the sheet called “presentation-weekly”.
4. There is an option to choose how many weeks that the model will calculate for. If the user only wants to compare two weeks with each other it can be done, and the maximum time period is 8 weeks. A description of how to write the weeks will now follow:
  - a. Start with looking up which weeks that are “good” weeks. A good week means weeks with full production and no break in production or a week when a car start or end its production.
  - b. The weeks are written out in a specific way for the model to understand, for example w1630. The w stands for week and the first two numbers stand for the year, in this example 2016. And the two last numbers stands for the week number, in this example week 30. So if the chosen week is week 20 in year 2018 it is written out as w1820.
  - c. Write the first week of the first time-period in column C and row 4 (see number 1 in picture below). Continue to fill the same row to the right, with the following weeks. Then do the same with the second time period, the first week of the time period in column C and row 5 and then the following week in the same row after the first week.
  - d. If there have been chosen less then 8 week, the empty cells at the ends always needs to be filled with a hyphen(-). (See number 2 in picture below)
5. The total needed investment sum when comparing the two time periods can now be seen in the green cell in column C row 22 (see number 3 in picture below).
6. The total needed investment sum when comparing the last time period with the current packaging is shown in the green cell in column C and row 27 (see number 4 in picture below).

The screenshot shows a spreadsheet with a table of weekly data. The table has columns for years (2016, 2017, 2018) and rows for different weeks. The data is organized into a grid. Four red circles with numbers 1, 2, 3, and 4 are overlaid on the spreadsheet to indicate specific cells of interest. Circle 1 is at the top left of the data grid. Circle 2 is at the top right. Circle 3 is at the bottom left, pointing to a green cell. Circle 4 is at the bottom left, pointing to another green cell. The spreadsheet also shows some summary rows at the bottom, including a green cell in column C row 22 and another green cell in column C row 27.

## 4.5.2 How to use the document, yearly

1. Start of with update the raw-data. And the raw-data that are used in this calculation are the volume program yearly. The new updated data can be pasted in the sheet called “Volume year-raw”. It is important that the raw data is pasted in the same way as before and no changes in the raw-data are made before pasting. Also, it is important to check if name of the car changes, then it also needs to be update manually in basic data.
2. It is important to look over the assumptions before inspecting the investment sum. The assumptions make huge difference in the calculations’ outcome, and if there are any changes in these, this needs to be changed in the sheet “ assumptions”. Remember to update the current number of packaging from SAP.
3. Look over the SOP and EOP and change week for SOP/EOP if this is needed. Also, check NWC if the numbers are correct.
4. To see the investment sum for the yearly perspective, go to the sheet called “presentation-yearly”.
5. Start with choosing the first time period in the drop-down list in column B and row 4, and the second time period in column B and row 5. If the year has EOP written out after the year, it means that the cars that end their production the same year is included in the calculation. If the year has SOP written out after the year, it means that the cars that start the production are included in the calculation, and that the cars that ended their production the same year are not included. Current packaging in circulation can also be chosen to compared with, then choose “current” in the drop-down list. (See number 1 and 2 in picture below).
6. The total needed investment demand is shown in the green cell in column C, row 7 (see number 3 in the picture below)

Year	Year	Year	Year	Year	Year
2010	2010	2010	2010	2010	2010
2011	2011	2011	2011	2011	2011
2012	2012	2012	2012	2012	2012
2013	2013	2013	2013	2013	2013
2014	2014	2014	2014	2014	2014
2015	2015	2015	2015	2015	2015
2016	2016	2016	2016	2016	2016
2017	2017	2017	2017	2017	2017
2018	2018	2018	2018	2018	2018
2019	2019	2019	2019	2019	2019
2020	2020	2020	2020	2020	2020
2021	2021	2021	2021	2021	2021
2022	2022	2022	2022	2022	2022
2023	2023	2023	2023	2023	2023
2024	2024	2024	2024	2024	2024
2025	2025	2025	2025	2025	2025
2026	2026	2026	2026	2026	2026
2027	2027	2027	2027	2027	2027
2028	2028	2028	2028	2028	2028
2029	2029	2029	2029	2029	2029
2030	2030	2030	2030	2030	2030