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Masterthesis

Study of packaging materials/configurations and the development of a new box

PROMOTOR :

Prof. dr. Rosa PEETERS

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Leen Govers

Scriptie ingediend tot het behalen van de graad van master in de industriële wetenschappen: verpakkingstechnologie

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Foreword

This thesis was written within the framework of my graduation thesis industrial engineer packaging technology. This year the course material could be put into practice and we learned to deal with the practical side of things. During my choice of study, I hesitated for a long time between industrial engineer and something medical. That's why I am glad I met the company Datwyler. As an industrial engineer, I see that I can also help the medical side by ensuring good packaging.

This thesis has taught me that we have only been given a basis by the school that needs to be further expanded. I also learned that many people are ready to teach me something. I would like to thank Datwyler for the opportunities they have given me. Datwyler has taught me a lot this year but has also given me the freedom to discover things for myself.

I would like to thank my internship promoters Thomas Weigert and Marc Philippeth for the good guidance they have given me over the past year. They also brought me into contact with various companies and people, which enabled me to learn a lot. In addition, they also taught me to work more efficiently and independently.
I would also like to thank Peter Dufour, Sara Verjans, Geert Moens and Koen Pagnaer. They trusted me to develop a box for a certain side together with them.

Finally, I would also like to thank my internal promoter Prof. Dr. Peeters for the good guidance she has given me this year. She taught me a lot and was always there for me. Together we managed to accomplish a beautiful academic work.

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Glossary of terms

APQP: Advanced product quality planning
CFU: colony forming units
EMA: European Medicines Agency
EtO: Ethylene Oxide
EVOH: Ethylene vinyl alcohol
FDA: Food and drug administration
Gy: Gray
HDPE: High-density polyethylene
ISO: International Organization for Standardization
LDPE: Low-density polyethylene
RFS: Ready for sterilization
RTP: rapid transfer port
RTU: ready to use
PE: polyethylene
PP: polypropylene
SAL: sterility assurance level

Abstract

The company Datwyler is specialized in making customized sealing solutions worldwide. In Alken, Datwyler has 113 different packaging configurations. This large number of packaging configurations requires many packaging validations, many SAP codes but also many work instructions for the operators. In order to reduce this number of packaging configurations, a survey was sent out to see why customers use these configurations. Due to low response rates, a tool has been developed that salespersons can use to determine a packaging configuration. This tool displays the various existing packaging configurations that meet the customer's requirement from most shipped to least shipped. The purpose of this tool is to choose from the most commonly used packaging configurations and to avoid adding new packaging configurations.

In addition, a box was developed for a particular customer that had to meet the requirements of the customer, the irradiation company and Datwyler itself. Several concepts were developed and concept 4.2 with the following dimensions was chosen: 323.480.215 mm. Concept 4.2 ensures a well-filled pallet, as little transport of air as possible and a sufficient amount of sealing solutions in a bag, while it is also suitable for the irradiation company.

Abstract in Dutch

Het bedrijf Datwyler is gespecialiseerd in het maken *sealing solutions* op maat wereldwijd. Datwyler heeft in Alken alleen al 113 verschillende verpakkingsconfiguraties. Dit groot aantal verpakkingsconfiguraties zorgt veel validatie van verpakkingen, veel SAP codes maar ook veel werkinstructies voor de operatoren. Om dit aantal verpakkingsconfiguraties te reduceren werd er een enquête doorgestuurd om te zien waarom de klanten deze configuraties gebruiken. Door weinig respons is er een tool ontwikkeld dat de mensen van de verkoopafdeling kunnen gebruiken bij het bepalen van een verpakkingsconfiguratie. Deze tool geeft de verschillende bestaande verpakkingsconfiguraties weer die voldoen aan de vereiste van de klant van meest verzonden naar minst verzonden. Het doel van deze tool is dat er geen nieuwe verpakkingsconfiguraties bij komen en dat er gekozen wordt uit bestaande verpakkingsconfiguraties die het meest gebruikt worden.

Daarnaast werd er voor een bepaalde klant een doos ontwikkeld die moet voldoen aan de vereisten van de klant, het bestralingsbedrijf en Datwyler. Hiervoor zijn verschillende concepten ontwikkeld en is er gekozen voor concept 4.2 met de volgende dimensies: 323.480.215 mm. Concept 4.2 zorgt voor een zo goed mogelijke gevulde pallet, zo weinig mogelijk transport van lucht en een voldoende hoeveelheid *sealing solutions* in een zak. Daarnaast is dit nieuwe concept ook geschikt voor het bestralingsbedrijf.

1 Introduction

Adolf Dätwyler was the only man who believed in the wire and rubber factory located in the Swiss Alps. However, this factory was heavily indebted. Thanks to Adolf Dätwyler's determination, the factory became a great success. Nowadays Datwyler is known in different sectors all over the world. They are known as an industrial supplier of sealing solutions, distributor of electronic components and as a manufacturer of specialised cables. The sector technical components is known for an up-to-date and comprehensive range of more than 250,000 electronic components, competent technical advice, high availability and fast delivery create added value for a professional customer base. Datwyler Cabling Solutions offers customers high-quality, future-proof integrated system solutions and services for electrical infrastructures in public and commercial buildings [1].

Figure 1: Datwyler's map (left world, right Europe),[1]

The Sealing Solutions Division of the Datwyler group is a leading supplier of customised sealing solutions to global market segments, such as the automotive, health care, civil engineering and consumer goods industries. With more than 100 years of experience, the segment health care has become a global leader in the industry with the ability to set new standards. There state-of-the-art solutions for drug packaging and medical devices are supplied to leading pharmaceutical and medical companies worldwide. The segment Health Care is situated in Alken (Belgium), Pregnana (Italy), Kesudri (India) and Middletown (USA). Health care provides sealing solutions for injection needles, baxters etc., as shown in the following Figure 2 [2].

Figure 2: Sealing solutions, [1]

This master's thesis is conducted in the segment health care in Alken. Alken is known for First Line with which Datwyler can guarantee the highest levels of quality and safety. In addition Datwyler continues to make investments aimed at meeting the ever-stricter regulatory requirements. First Line has been designed and equipped to meet the very latest good manufacturing practices[1].

[1] GMP is a quality assurance system for the human and veterinary pharmaceutical industry. It is essential that it is precisely defined how and under what conditions a product is made.

This master's thesis can be divided into two parts. For historical reasons Datwyler has a wide range of packaging materials. This results in many active packaging codes in SAP[2], many work instructions for the operators, many packaging validations and many packaging materials that have to be purchased. The aim of the first part of the master's thesis is to reduce the number of packaging configurations. The second part of the master thesis is to develop a box that meets the requirements of a customer. These two challenges are further explained in the research plan.

The thesis is organised as follows: first, the research plan will be discussed. This will be followed by a study of Datwyler and the literature. The fourth point is the first research topic 'reduction of the number of packaging configurations' and the fifth point is the second research topic ' development of a new box for a certain customer'. For each topic, the detailed problem definition can be found and the results are discussed.

[2] SAP is an enterprise resource planning system.

2 Research design

2.1 Research questions

The first part of this master's thesis concerns reducing the number of packaging configurations. To pack their healthcare products Datwyler uses different types of bags and boxes. Each of these bags has its own unique material characteristics that are important for health care products. The different types of boxes and bags are discussed more in detail in section 3.1. Due to the fact that there are many different materials, many combinations can be made. A packaging configuration refers to the combination of different bags with a certain box. In Datwyler Alken there are 113 different packaging configurations. Too many packaging configurations make it more complicated for the operator, salespersons etc. In addition, it is not known whether these packaging configurations are optimal.

The second part of this master's thesis is the design of a new box for a particular customer. As the customer wants to use another packaging configuration problems have been discovered during gamma irradiation. The packaging configuration that is required by the customer is normally transported in a long polypropylene (PP) box ($690.290.150\ mm$) because the packaging configuration is too large to fit in a standard cardboard box ($365.270.212\ mm$). During box sterilisation, the boxes are placed in a tote[3]. The long boxes, however, do not fit in the totes of the irradiation company. A new box will therefore have to be developed that meets the requirements of the customer and the irradiation company.

2.2 Objectives

As the master is divided into two parts, the main objective is also divided into two. These main objectives have sub-objectives.

1. The goal is to reduce the number of packaging configurations so that they are optimal and meet customer requirements.
    a. Analysis of customer requirements
    b. Analysis of possible problems with internal/ external logistics
    c. Reducing the number of packaging configurations

2. The goal is to design a box for a certain customer by April that meets the requirements of the customer, irradiation company and logistics.
    a. Analysis of limiting boundaries of the customer, irradiation company and Datwyler.
    b. Designing a new box.
    c. Testing a new box.
    d. Introducing the new box.

The two objectives are contradictory, because one objective wants fewer packaging configurations and the other objective creates a new packaging configuration. It would be perfect if the two could be combined, for example, to design a box for a certain customer but which could also be used for the other packaging configurations.

[3] A tote is a kind of large cardboard or aluminium box. The products to be irradiated are placed in this tote during irradiation.

2.3 Methodology

The first step of this master's thesis will be to make a study of packaging materials/concepts and packaging processes, at Datwyler. This is intended to take a look at the state of affairs in this area of research. It is essential to look at the materials that Datwyler currently uses, the different sterilization methods that exist and how a box should be developed. After finishing the study, it will be possible to start working on reducing the packaging materials/concepts and developing a new box. The methods for these two parts will be explained more in detail in the following parts 4.2 and 5.2.

3 Study of packaging materials/configurations and packaging processes at Datwyler

This is a preliminary study that gives more information about the different aspects that are discussed during this master's thesis. Firstly, a study was carried out to determine which packaging materials exist within Datwyler and for what reason they are used. Subsequently, a literature study was carried out that shows which the steps are in developing a new box, which types of irradiation methods exist and which irradiation method is used at Datwyler. In addition, the literature study examines the environmental aspect which is an important but often forgotten aspect.

3.1 Packaging materials

Datwyler offers a wide range of different packaging materials for their customers. The sealing solutions can be packed in three different ways: bulk, RFS and RTU. The sealing solutions for bulk packaging are washed, siliconized and packed in different bags. RFS is the abbreviation of ready for sterilisation, the sealing solutions are washed and siliconized. They are then packed in an HDPE/Tyvek bag that is suitable for steam sterilisation. RTU is the abbreviation for ready to use. The sealing solutions are washed and siliconized. The sealing solutions that are packed in this way can be used immediately when they come out of the warehouse. A RTU configuration consists of two PE/EVOH/PE (polyethylene/ethyl vinyl alcohol/polyethylene) bags where vacuum is drawn between them. Then, this packaging is also gamma irradiated otherwise it may not be called RTU. The vacuum technique is used so that the customer can check the sterility. If the packaging is no longer vacuum, this indicates that there is a risk of contamination. The packaging materials can be divided into two parts: the inner packaging and the outer packaging.

3.1.1 The inner packaging

Inner packaging describes all packaging inside the box. For the inner packaging it is important that it meets the standards of the FDA (Food and Drug Administration) and EMA (European Medicines Agency). If the inner packaging does not meet these requirements, it can potentially harm patients.

- HDPE/Tyvek bag

Figure 3: HDPE/Tyvek bag, [1]

Tyvek consists of fixed high-density polyethylene fibres. The material Tyvek is permeable for steam but also for ethylene oxide. These are two ways to sterilise products. In addition, Tyvek is not permeable for microorganisms. This ensures that there is no contamination possible. The HDPE part of the bag is impermeable for both the sterilization methods and the microorganisms [3].

- LDPE bag

  The low-density polyethylene (LDPE) bag is often used as the final bag. This bag protects the configuration from fibres. These fibres can come from the conveyor belt, cardboard boxes etc. In addition, the LDPE bag is also used as packaging material for the bulk packaging. LDPE is characterized by its specific mass of approximately $0,88 - 0,92\ kg/dm^3$. The most significant properties of LDPE are that it is a cheap material with good sealing properties and it also has a high tear resistance [4].

- PE/EVOH/PE bag

The PE/EVOH/PE bag is a multilayer. It consists of two polyethylene (PE) layers that protect the ethylene vinyl alcohol layer (EVOH). EVOH is a good barrier against gases, it can protect the products against contamination. The disadvantage of EVOH is that it is not resistant to water or water vapour and it is a brittle material. If the EVOH absorbs moisture, the oxygen barrier will decrease significantly. Therefore, there are extra PE layers added to protect the EVOH. These PE layers provide a good water barrier [5], [6].

- X/PE/RTU

This is a special bag consisting of a port which is attached to a PE/EVOH/PE bag, this bag is also called the RTP bag. The X indicates the diameter of the port.

Figure 4: X/PE/RTU bag

The first RTP bags were developed in France. The RTP bags are also called DPTE systems. DPTE is the French abbreviation for “Double Porte pour Transfert Etanche” or “Double Door for Leak tight Transfer”. These bags are used because they provide a transfer of sterile sealing solutions with a minimal risk of contamination. As the DPTE name already reveals, two doors are used. An alpha door and a beta door, these will guarantee the sterile transfer. The alpha part is a fixed part and cannot be transported (e.g. often the alpha part is connected to a clean room). There are two types of alpha parts:

- Fixed Mounting: Here is the alpha part fixed. This means that the beta part provide the rotation to connect the two parts to each other (see later).
- Flexible Mounting: In case that the RTP bag is too heavy or too large to rotate it, a flexible alpha port is required. Here, in contrast to fixed mounting, the alpha part will take care of the rotation.

The beta part can be transported. In this case it is also linked to the bag in which the sealing solutions are in. Depending on the application, the beta port can consist of different materials for example stainless steel, polyethylene etc. There are flexible or fixed containers and reusable or single use containers. Depending on the application, a certain container is chosen.
The picture below shows how the alpha beta principle works, it consists of different safety locks and seals. The beta port is secured to the alpha port. A rotation of 60 degrees is made after which the doors open [7]–[9].

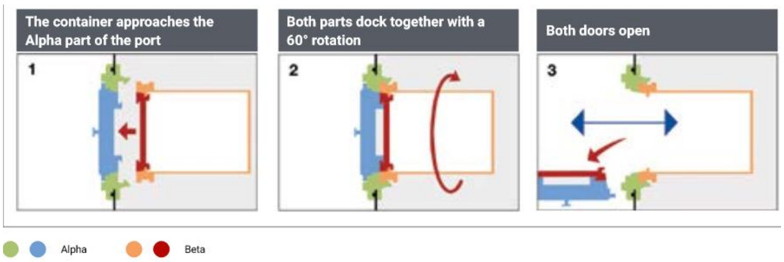


Figure 5: DPTE system, [9]

- X/TYVEK/RFS

  In contrast to the X/PE/RTU bag, the port is attached to a Tyvek bag. RFS is the abbreviation for ready for sterilisation. These bags can be sterilised by the customer.

- Paper Film SPS

3.1.2 The outer packaging

Datwyler uses different materials and dimensions for its outer packaging. Depending on the packaging, a smaller or a larger box will be chosen. The most common box in Alken is the standard box with the following dimensions: $365.270.212\ \mathrm{mm}$. There are plastic and cardboard boxes because cardboard contains fibres. Some customers will choose a plastic box to reduce the risk of contamination. Below are all the boxes used by Datwyler.

- Big box $1160.750.520\ mm$ (3PARTS)
- Hybox $1200.800.750\ mm$
- Long box $690.290.150\ mm$
- Plastic BD LOGO $365.270.212\ mm$
- Plastic First Line logo $372.277.226\ mm$
- Plastic First Line logo $372.277.280\ mm$
- Plastic unprinted $372.277.226\ mm$
- Cardboard printed $365.270.212\ mm$
- Cardboard printed $365.270.280\ mm$
- Cardboard unprinted $365.270.212\ mm$

Figure 6: Left: Long box. Middle: Plastic First Line logo 372.277.226 mm. Right: Cardboard printed 365.270.212 mm (White = product box, coloured = sample box)

3.2 Development of a new box

3.2.1 Advanced product quality planning

Advanced product quality planning (APQP) is a procedure to develop products in the industry. Datwyler also applies this principle when they have a new project with customers, see Figure 7. It is important to look at what the customer wants and what he expects. Then it has to be determined what Datwyler can manage. After that, something will be developed that Datwyler can manage, but that also will keep the customer satisfied. Ultimately, it is important that there is an alignment between the various parties involved.

Figure 7: Advanced product quality planning

3.2.2 The step-by-step plan for developing a box

The development of a box is done in several phases: the analysis phase, the synthesis phase, the stimulation phase and the evaluation phase. These phases will be further explained below.

- Analysis phase: in this phase, it is important that the current situation is described. Also the function and the requirements of the packaging must be defined. In addition, all the wishes of different parties must be described, so that there are no misunderstandings in the end.
- Synthesis phase: this phase involves brainstorming about concepts that could possibly solve the problem. Using sketches and prototypes, a visual overview can be obtained. These prototypes can be discussed in groups, where concepts will be chosen that can be further elaborated.
- Stimulation phase: this phase examines whether the chosen concepts meet the requirements and wishes identified during the analysis phase. This can be done by calculations, visualisations or testing with prototypes. The concepts that pass the chosen tests are then worked out in a very detailed manner.
- Evaluation phase: the final chosen concept is presented to the client. The client will then decide how the project will proceed. [10]

3.2.3 Pallet stack pattern

The design of a box should take into account the stacking method on a pallet. A large number of products are transported via pallets. A poorly stacked pallet can fall or break during transport, which can potentially harm products. This also means that the pallet needs to be restacked. Poor stacking leads to more handling and a higher cost. For this purpose it is crucial to stack a pallet as well as possible [11].

There are different types of stack patterns that can be used. A stack pattern can be columnar or interlocked. The ribs of a box carry 2/3 of the compression strength, this is the strongest part of the box. While the sides of a box carry only 1/3 of the compression strength, this is the weakest part of the box. By stacking the boxes columnar the bottom box maintains its maximum strength. However, there is also a disadvantage to stacking columnar. The pallet becomes less stable and is more likely to fall. By stacking columnar the operators have to make sure that the ribs are on top of each other. With the help of wrapping foil, the pallet can be made more stable. Stacking the boxes interlocked gives a more stable pallet. In contrast to columnar stacking, boxes on the first layer of the pallet can lose up to 50% of their strength. This is due the fact that the weight of the boxes is divided over both the strongest parts and the weakest parts of the box [12], [13]. A pallet can also be stacked so that it is partly columnar and partly interlocked.

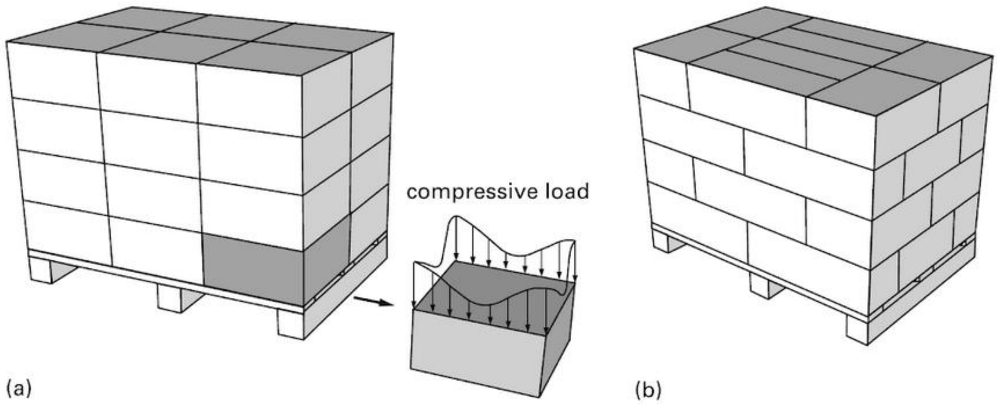


Figure 8: Right: column stacking Left: interlocked stacking, [11]

Sometimes boxes are designed too large for a pallet or that a wrong choice was made in size of pallet. This results in overhang of the boxes. Overhang of the boxes can reduce the strength of the boxes on the first layer of the pallet up to 30%. This percentage depends on how much the box hangs over the pallet. The loss in strength is because there is loss in ribs and sides on which the boxes above can rest [12], [14].

As some boxes are not optimally made to fill the surface of a pallet, a gap is sometimes left between them, see Figure 9. Baker has tested the influence on the strength of the box when the deckboards of a pallet are further apart. He proved that both along the width and length sidewall there is a reduction in strength. It can therefore be concluded that a gap reduces the stability of the boxes. How strong this reduction is depends on the material that is used, where the gap is located and the size of the box. If it is possible, this should be avoided [14].

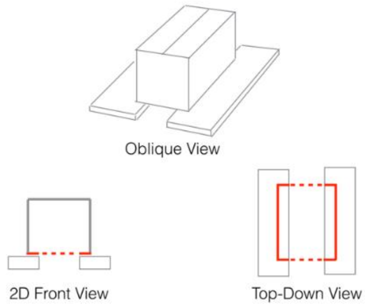


Figure 9: Gap between deckboards,[14] p58

3.3 Sterilization in general

Sterilization refers to the elimination of all forms of live. These forms of live can be bacteria, viruses, spores etc. Sterility is important in the medical world. If a certain product is not sterile, it could harm the health of the patients. Sterilization can be done in different ways such as steam sterilisation, gamma sterilisation, EtO sterilization, X-ray sterilization etc. Each sterilization method has its advantages and disadvantages. Depending on the product, it is necessary to determine what is the best sterilization method for that particular product.

3.3.1 Sterility assurance level

Sterility means that there are no viable microorganisms present anymore [15]. The sterility of a product is defined as the probability that living microorganisms would be present after sterilization of the product. The sterility assurance level (SAL) represents this probability [16]. SAL is expressed as 10^{-n}, the most common values are 10^{-3} and 10^{-6}. A 10^{-6} SAL provides a better sterility assurance then 10^{-3}. 10^{-6} SAL means that there is only 1 nonsterile product out of 1 000 000 products whereas 10^{-3} means that there is 1 nonsterile product out of 1 000 products [17]. For medical products a 10^{-6} SAL is often required, however, this depends on the application of the medical product. It will never be possible to reduce the probability of living microorganisms on a product after sterilization to zero, there will be always a small probability of a nonsterile product [18].

3.3.2 Bioburden

Bioburden indicates the amount of microbiological contamination of a product before sterilization. It is important to know the bioburden before sterilization so that it can be determined whether this sterilization is effective. [19] Bioburden is the sum of several sources that sum up to the microbial contamination. These sources are raw materials, clean rooms, packaging etc [20]. It is usually expressed in colony forming unit (CFU) per gram [21]. There are two different methods from which CFU can be calculated: the plate count methods and membrane filtration method.

The plate count method can be divided into two different methods. As first there is the pour plate method. Here the sample (or a dilution of the sample) is mixed in a Petri dish with heated agar nutrient. After the agar has hardened, the sample is incubated. Incubation is the growth of microorganisms in a thermostat. After the incubation, the colony forming units can be counted. The second method is the spread plate method, where a glass drigalski spatula is used. With the help of the spatula, the sample (or a dilution of the sample) is spread out on solid agar [22].

Figure 10: Glass drigalski spatula, [23]

The membrane filtration method filters the sample. The microorganisms that may be present in the sample are stopped on the filter paper. After the filtration, the filter paper is placed in a Petri dish and the colonies can be formed. Then, the number of colony forming units can be counted.

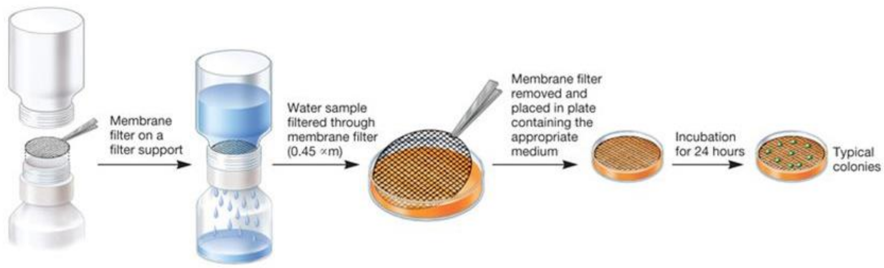


Figure 11: Membrane filtration, [24]

3.3.3 Gamma irradiation

Gamma sterilization is obtained by the use of electromagnetic waves. There are two sources which are used for gamma irradiation; ^{60}Cobalt and ^{137}Cesium. ^{60}Cobalt is a radioactive nuclide that decays via a beta-decay into the stable nuclide ^{60}Nikkel.

$$^{60}_{27}\mathrm{Co} \rightarrow {}^{60}_{28}\mathrm{Ni} + \mathrm{e}^{-} + \gamma$$

It has a half-life of 5.27 years. The half-life refers to the time when exactly half of the original amount of the sample remains. If ^{60}Cobalt is used, the gamma radiation produces photons with two frequencies. These frequencies have corresponding energies of 1.17 MeV and 1.33MeV. ^{137}Cesium is as ^{60}Cobalt a radioactive unstable isotope that decays via a beta-decay, ^{137}Cesium decays to ^{137}Barium.

$$^{137}_{55}\mathrm{Cs} \rightarrow {}^{137}_{56}\mathrm{Ba} + \mathrm{e}^{-} + \overline{\nu_{\mathrm{e}}}$$

^{137}Cesium has a half-life of 30.2 years and the energy of the gamma radiation is 0.66 MeV. The energy difference between ^{60}Cobalt and ^{137}Cesium is immediately noticeable. This difference is crucial when determining which source should be used for a certain product. Sealing solutions have a relatively high density, so ^{60}Cobalt would be a better option here. Due the fact of the higher energy it is more likely to penetrate through products/materials with higher density [25].

Gamma irradiation has a major impact on microorganisms. During gamma irradiation, the nucleic acids of microorganism are ionised. This means that the DNA, which consist of deoxyribonucleic acid, will be broken down. Eventually this will lead to the death of the microorganism.

3.3.4 Steam sterilization

Steam sterilization is in most cases done by an autoclave. This autoclave is filled with a small amount of water and sealed airtight. Saturated steam is produced that will create an overpressure. This increases the boiling point of water, which means that temperatures can be obtained above 100°C. Depending on the temperature (121 °C to 134 °C), the products are exposed to the steam for 3 to 15 minutes. Using this method enzymes will be denatured but also other essential cell components will be destroyed. By using steam sterilization, spores can also be killed [26].

However, the total process of steam sterilization takes more than 15 minutes. In order to sterilize products by steam, they have to undergo several steps, see Figure 12:

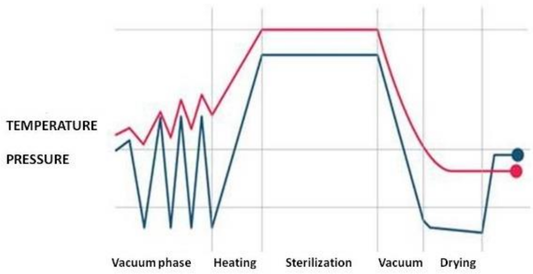


Figure 12: Steam sterilization cycle

-Air removal (30 min): the air in the autoclave is removed as much as possible by vacuuming the autoclave. This is an essential condition for a successful sterilization. If the air is not removed completely, the autoclave may display a wrong value of thermodynamic equilibrium of temperature/saturated steam pressure, which would make it unreliable.

-Stabilization period: this phase ensures that a balance is achieved between the temperature and the pressure.

-Sterilizing the products (3-15 min)

-Drying (30 min): The moist material must be dried, this is done by vacuuming the autoclave. This is a very crucial phase because moist places are good sources for microorganisms to grow.

- Venting: the autoclave is brought back to the correct pressure [27]–[29].

The time required for the different phases depends on the load inside the autoclave.

3.3.5 X-ray sterilization

X-ray is like gamma radiation a ionising radiation. It is also called the *bremsstrahlung*. This is a charged particle that undergoes an acceleration, it then emits electromagnetic radiation. A major advantage of X-ray is that the source can be switched on and off, this is not possible with gamma irradiation [30].

3.3.6 Electron beam

Electron beam is also called cathode radiation. A vacuum tube is being used, it has a positive and a negative electrode over which a positive voltage is applied. Electrons will be transferred from the positive electrode to the negative electrode as a result of this positive voltage. The electrons are accelerated at a speed higher than the speed of light. However, electron beam has a limited penetration in the product. This is due to the fact that an electron beam contains charged particles in contrast to gamma irradiation. The electrons have an energy range from 3 to 10 MeV that they produce. The most common use is 10 MeV because it ensures the best penetrations.

Figure 13: Electron beam radiation

As shown in Figure 13, electron beam uses box sterilisation. The boxes are removed from the pallet and placed on a conveyor belt or in containers. The boxes will then move along the electron beam [26], [30].

3.3.7 EtO

In contrast to the previous sterilization, ethylene oxide sterilization uses a gas and not irradiation. This sterilization method requires special attention. Ethylene oxide is volatile, carcinogenic and explosive. This method is mainly used for products that cannot be sterilized by irradiation or steam [31].

3.3.8 Sterilization method used at Datwyler

Datwyler does not sterilise the sealing solutions itself. As mentioned before, they offer different kinds of packaging materials. These can be suitable for different types of sterilisation, such as the Tyvek bag that can be used for steam or EtO sterilisation. The sterilization of the sealing solutions can be carried out by the customers themselves. However, there is a sterilization method that Datwyler offers to their customers, known as gamma sterilisation (Figure 14). The gamma sterilization is performed by an external company. The sterilization can be achieved by two methods, either $\mathrm{VD_{max}}$ 25 kGy or Method1.

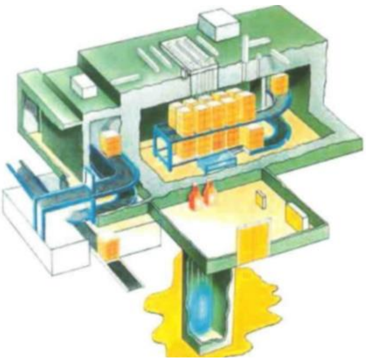


Figure 14: Gamma irradiation process

The $\mathrm{VD_{max25}}$ is a referenced dose that guarantees a SAL of 10^{-6}. For the $\mathrm{VD_{max25}}$ method, sealing solutions are irradiated with a minimum dose of 25 kGy and a maximum dose of 40 kGy. This method is achieved by the use of tote sterilization because the $\mathrm{VD_{max}}$ 25 kGy is not guaranteed for pallet sterilization. These boxes are placed in a tote, which consists of cardboard and polystyrene foam or aluminium. The tote will then will go around the cobalt source.
The gamma irradiation has an influence on the rubber, if the irradiation is above 40 kGy, these influences will become significant. Gamma irradiation causes radicals which can break elastomer chains, but the radicals also cause extra cross-links. For some compounds the chain breakdown will dominate, for other compounds extra cross-links will be formed. Some rubbers will be formed. Some rubbers will become harder, others will become softer. This will also have an effect on physical, functional and chemical properties. The effect of gamma irradiation on rubber above 40 kGy is therefore strongly dependent on the rubber.

Method 1 is like the VD_{max} method a method of ISO 11137. In Method 1 will look at the average bioburden. If the average bioburden is known, the minimum amount of kGy can be determined depending on the desired SAL value, see Figure 15. At Datwyler they have a maximum bioburden of 0.5 X, if this is higher the sealing solutions will be washed again. To irradiate, they need a minimum of 13.5 kGy to reach a SAL of 10^{-6}. For safety reasons, they do an overkill and the sealing solutions will be irradiated at a minimum dose of 13.5 kGy and a maximum dose of 40 kGy. Method 1 can be used for both pallet sterilization and box sterilisation.

Table 6 — Radiation dose (kGy) required to achieve a given SAL for an average bioburden in the range of 0,1 to 0,9 having the standard distribution of resistances (SDR)

Average bioburden	Sterility assurance level SAL						Average bioburden	Sterility assurance level SAL				
	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}			10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
0,10	1,3	3,0	5,2	8,0	11,0		0,45	2,3	4,4	7,0	9,9	13,1
0,15	1,5	3,3	5,7	8,5	11,5		0,50	2,4	4,5	7,1	10,0	13,2
0,20	1,7	3,6	6,0	8,8	11,9		0,60	2,5	4,7	7,3	10,3	13,5
0,25	1,9	3,8	6,3	9,1	12,2		0,70	2,7	4,8	7,5	10,5	13,7
0,30	2,0	4,0	6,5	9,4	12,5		0,80	2,8	5,0	7,7	10,7	13,9
0,35	2,1	4,1	6,7	9,6	12,7		0,90	2,9	5,1	7,8	10,8	14,1
0,40	2,2	4,3	6,8	9,7	12,9							
NOTE For an average bioburden within the range >0,9 and <1,0, enter Table 5 at an average bioburden of 1,0.												

Figure 15: Radiation dose required to achieve a given SAL

The difference between tote and pallet sterilization is that a larger range in dose is required for pallet sterilization. A pallet or a tote are always irradiated on two sides. Figure 16 depicts the difference in dose. The blue curve is when the pallet/ tote passes the source with its front side the closest to the source. This means that the front box gets the highest dose but the point that is the furthest from the source gets a smaller dose. The orange curve is when the pallet/tote passes the source with its back side the closest to the source. To calculate the total dose, the sum of the blue and orange curve is taken.

With pallet sterilization there is a significant difference between the points that have been close to the source and the points that have been far away from the source. Some points will have a high dose while others contain a relatively low dose. Pallet sterilization always requires a large range to ensure that he centre point meets the minimum dose requirement.

During pallet and tote sterilization it is important that the boxes are fully filled. If the box is half full, the result can be strongly influenced. Irradiation companies place as many different products as possible from different customers with the same density in the same cycle. If the box is only half full, this can also affect the results of the surrounding products.

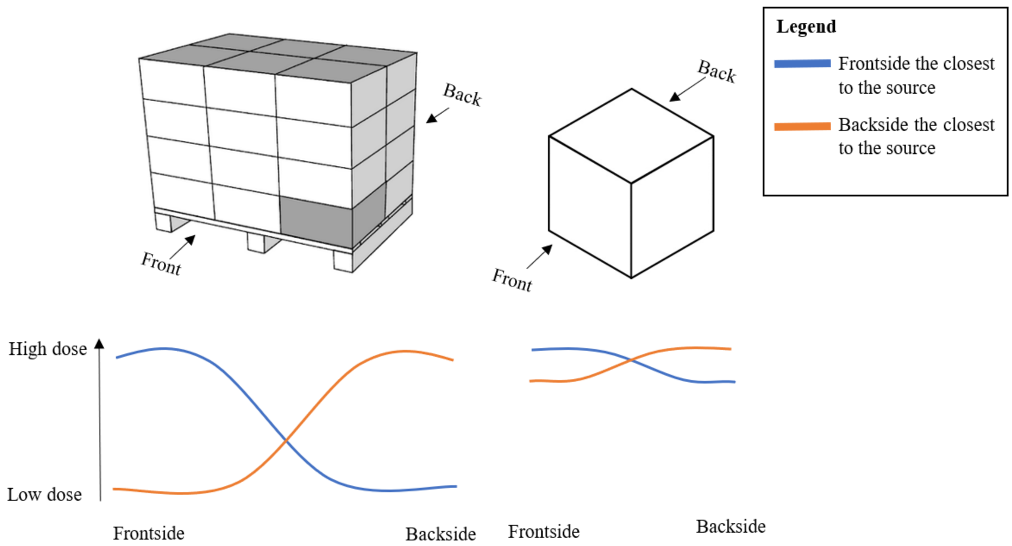


Figure 16: Left: pallet sterilization. Right: tote sterilization.

3.4 Environment

3.4.1 *Designing a packaging*

The role of packaging is to protect and prolong the shelf life of products. Packaging makes products less likely to be thrown away. But packaging can have an impact on the environment in various ways. The most polluting form everyone thinks of is illegal dumping of waste. However, with packaging there is much more to it than dumping of waste, such as air, water and soil emissions, but also energy consumption. Figure 17 depicts the life cycle of a packaging. During the design of a packaging, the environmental aspect can be taken into account on several levels.

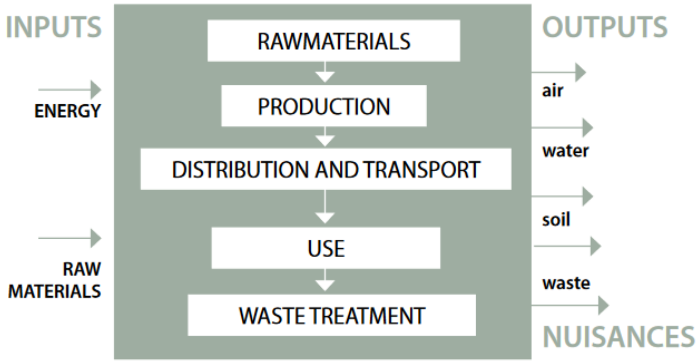


Figure 17: Life cycle of a product or packaging

First and foremost, there are the packaging materials. The production process of the material can be very polluting. Depending on which material is used, this production process has a smaller or a bigger environment impact. If paper and plastic are compared, it can be concluded that 1 kilo of paper causes less greenhouse gases than 1 kilo of plastic. Greenhouse gases are gases in the atmosphere that absorb and immediately emit thermal radiation. They contribute to the global warming. The best-known greenhouse gases in the atmosphere are water vapour, carbon dioxide, methane, nitrous oxide and ozone. The properties of a material are also essential. Cardboard is not as strong as plastic, so to achieve the same strength more material will have to be used.

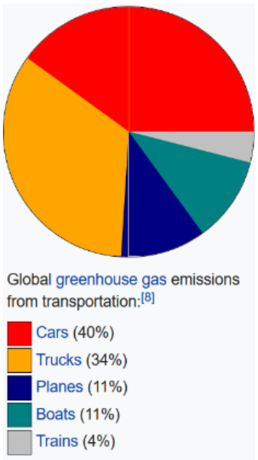


Figure 18: Global greenhouse gas emissions

A second aspect that can have an impact on the environment is transportation of packaging. Today, a large amount of goods are transported all over the world. However, this transport has a major impact on the environment. There are several ways in which products can be transported: truck, train, plane and ship. The following Figure 18 gives a global view of which transport emits the most greenhouse gases. It can be established that trucks provide a major part of the greenhouse gases.

If a package is badly designed, it may be that great quantity of air is transported. Transport of air should be avoided as much as possible. The more transport of air, the more unnecessary greenhouse gases are emitted. An incorrect choice of material can result in a reduction in the number of boxes that can be stacked high during transport. This means that more transport vehicles have to be used than necessary [32], [33].

3.4.2 *Waste hierarchy*

The packaging used will eventually become waste. In order not to harm the environment, waste management is important. The waste hierarchy, see Figure 19, is aimed at giving priority to the most environmentally friendly processing method. In the following part the waste hierarchy is explained. In reality it there will be looked at whether a certain step can be realised. If this cannot be realised, a lower step will be considered [4], [34].

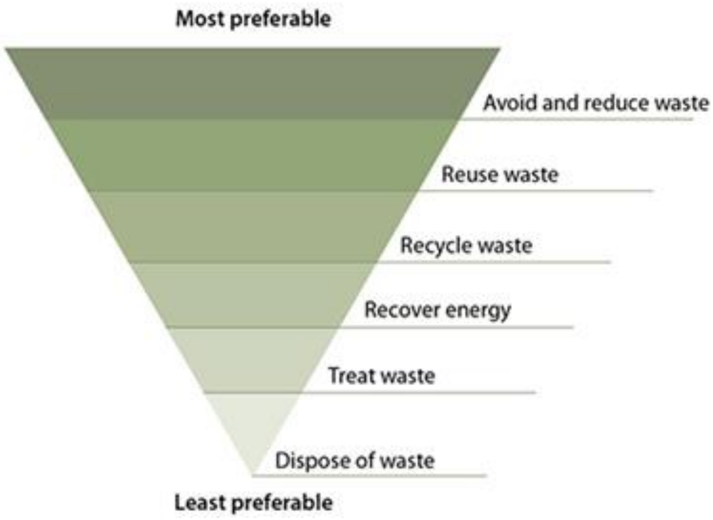


Figure 19: Waste hierarchy

Prevention: is to prevent unnecessary waste. It is important that packaging is used only where necessary.

Reuse: is to reuse a product without applying an additional processing step or treatment step. For example, beer bins are simply reused, the material is not re-melted to make a new beer bin.

Recycling: is making a product of waste material with the help of treatment steps.

Energy recovery: The waste will be incinerated, which will release heat and electricity that can then be used again.

Incineration: The waste that could not be generated in the above steps will be incinerated if possible.

Disposal: If there is no other option, the waste will be sent to a dumping site.

4 Research topic 1 : Reduction of the number of packaging configurations

4.1 Detailed problem definition

To pack their healthcare products Datwyler uses different types of bags and boxes. Two types of boxes are used: plastic boxes and cardboard boxes. The different types of bags, which can be found in different sizes, are Tyvek/HDPE, EVOH bag, RTP bag etc. There are many different packaging configurations, for example four single bags in one single bag or two single bags in one double bag (Figure 20). A packaging configuration does not only refer to the different combinations of inner packaging (all packaging in the box) but refers to the different combinations of inner and outer packaging (the box).
As mentioned earlier, approximately 170 different packaging configurations are used for the customers. Too many packaging configurations make it more complicated for the operator, salespersons etc. In addition, it is not known whether these packaging configurations are optimal.

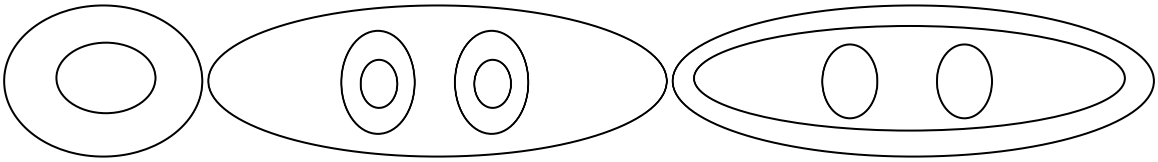


Figure 20: Left: 2 double bags. Middle: 2 double bags in 1 single bag. Right: 2 single bags in 1 double bag.

4.2 Materials and methods

To reduce the number of packaging configurations, it is interesting to know why customers use a particular packaging configuration. In order to find out, a survey was conducted. The first step was to find out which customers needed to be addressed in order to send out this survey in the most targeted way possible. This was done by using the Pareto principle and a matrix. From the matrix, the customers to whom a survey had to be sent could be identified. The data obtained from the surveys were analysed. In addition, with the help of Excel, a document could be created that shows the various packaging configurations for a particular stopper.

4.3 Results and discussion

In total there are 113 different packaging configuration in Alken. The first step was to find out why customers use certain unique packaging configurations. In order to find out what the unique packaging configurations are, a matrix had to be created. This matrix could be created by using the Pareto principle. The Pareto principle was applied to what had been shipped in Alken in the past six months (March - August). By using the Pareto principle, a distinction could be made between the packaging materials/configurations that generated the most turnover and the packaging materials/configurations that generated the lowest turnover.
Figure 21 depicts the Pareto principle for the different packaging configurations. All packaging configurations are numbered in advance, Appendix B lists all packaging configurations. The packaging configurations in the green box are the 20% that gives the highest turnover. The packaging configurations in the red box are the 20% that gives the lowest turnover. Based on this, each packaging configuration has been assigned a number, one, two or three. An 1 was assigned to all packaging configurations in the red box, a 2 was assigned to all

packaging configurations in the orange box and a 3 was assigned to all packaging configurations in the green box.

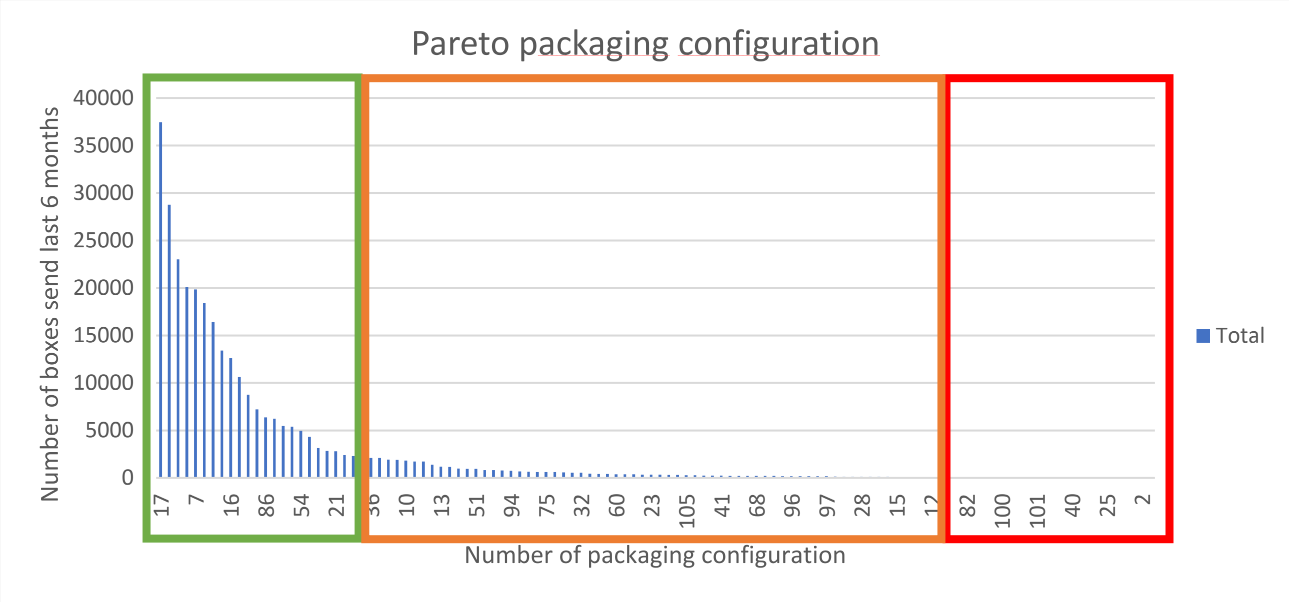


Figure 21: Pareto packaging configuration

The same principle as above was applied to the packaging materials, the Pareto of which is shown in Figure 22. All packaging materials were numbered in advance, Appendix C lists all packaging materials. Because the boxes are standardized the number of different boxes cannot be reduced, the Pareto of the packaging materials only includes the inner packaging materials.

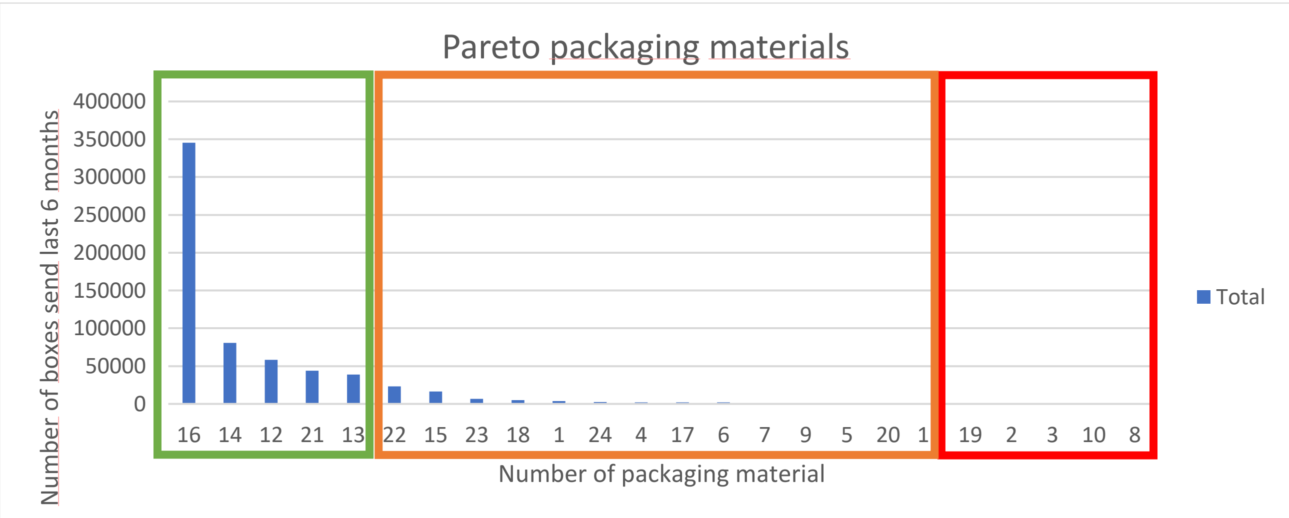


Figure 22: Pareto packaging materials

By combining the two Pareto principles, the matrix could be created. Figure 23 depicts the matrix.

Packaging configuration			
3		5	18
2	3	28	36
1	2	9	12
	1	2	3
	Packaging material		

Figure 23: Matrix

The matrix can be divided into three different colours. Green colour means that it is a frequently used packaging configurations with frequently used packaging material. Orange/yellow colour means that it is a less frequently used packaging configuration with a less frequently used packaging material. Red means that it is a very unique packaging configuration with sometimes even packaging materials.
For example, when looking at number five in the matrix, it can be determined that the packaging configuration belongs to the green Pareto zone, see Figure 21 (so is assigned value three). The packaging material belongs to the orange Pareto zone, see Figure 22 (so is assigned value two). Now the product is made of 3 and 2, this is 6 and is smaller than 9, so it is located in the orange zone. If the product were smaller than four it would be in the red zone of the matrix. As a result, the number 5 means that there are 5 packaging configurations that are often used, but these packaging configurations use packaging materials that are slightly less common.

Based on this matrix, surveys could be targeted at customers who use very unique packaging configurations or materials. A survey was sent out to all customers using packaging configurations from the red part of the matrix. The survey that was sent to these customers can be found in appendix A.
There are several reasons why customers want a certain packaging configuration:

- Because the customer has to pass through a certain number of airlocks. The easiest way for the customer is that the number of bags around the sealing solutions is equal to the number of locks. This allows the customer to remove a bag at each airlock and avoids the need to clean/sterilize these bags.
- Because a customer has a run of a certain amount of sealing solutions: it is then ensured that the amount of sealing solutions in a bag corresponds to this run. In other words, it will be determined how many bags the customer needs per hour to ensure that the production line runs smoothly.
- For the convenience of the operators.

Due to the low response rate to the survey, another solution was sought to reduce the number of packaging configurations. The number of packaging configurations can be reduced by preventing that new packaging configurations are created. In other words, promote the sending of as many packaging configurations as possible that are in the green zone of the matrix.

For this purpose, a Excel-document has been drawn up that salespersons can use to link a good packaging configuration to the sealing solutions that have been sold. Figure 24 depicts what this document looks like. The salesperson can choose from different elements that are interesting for them to have in the packaging configuration. These elements are:

- **Production plant** → 2000 (Belgium), 3000 (Italy), 4000 (USA) and 6000 (INIA).
- **Production drawing** → The sealing solution chosen by the customer, this does not take into account the type of siliconization.
- **Number of sealing solutions in a box**.
- **Type of first bag.**

- **Number of locks** → Some customers want a certain number of bags around their sealing solutions because they have to go through a certain number of airlocks. The easiest thing for the customer is if they can remove one bag per airlock. If this is not possible, the customer will have to disinfect the bags.
- **RFS, bulk or RTU configuration**.
- **Show different 11codes?** Different 11 codes may contain the same packaging configuration. When this is turned off, a better visual picture can be given of the packaging configurations that are the most and least sent.

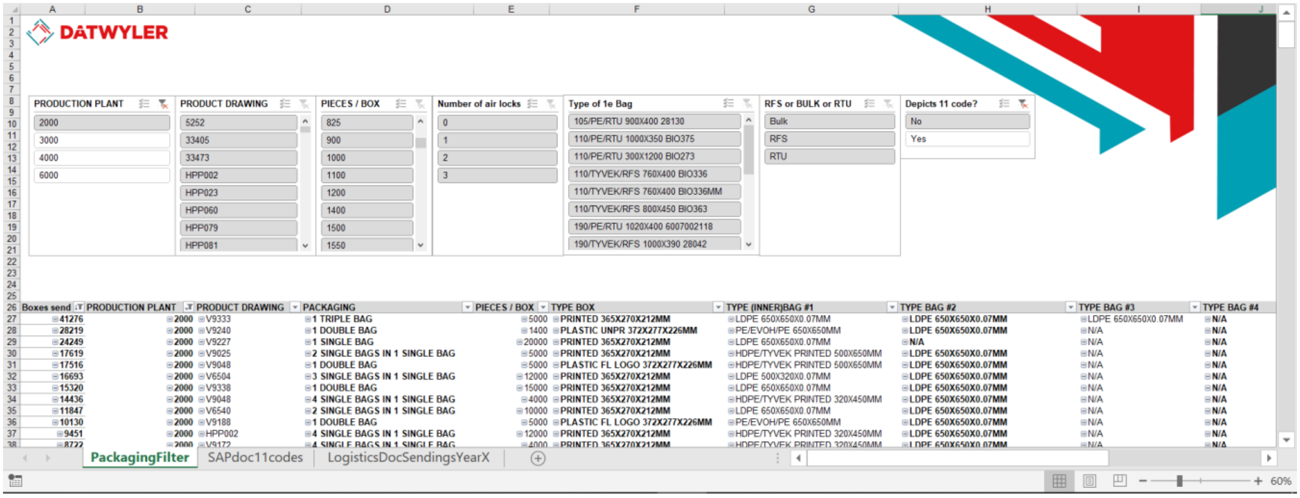


Figure 24: Tool for salespeople

Depending on what is clicked on by the salesperson, the Excel-document will automatically show which packaging configurations meet the clicked requirements. These packaging configurations are then sorted form most to least shipped boxes in 2017.

Throughout the years, packaging configurations will change or new configurations will be sent more than old ones. Therefore it is important to update this Excel-document regularly with the new 11 codes. The manual to update the Excel-document can be found in the appendix D.

This tool does not display the preferred configurations for Datwyler. However, these preferred configurations are not yet fixed. The Excel tool can be a first step in finding out what the preferred packaging configurations are of both the customer and Datwyler. The next phase in the future would be to make a list of the preferred packaging configurations in order to be able to standardise with new customers.

5 Research topic 2 : Development of a new box for a certain customer

5.1 Detailed problem definition

The second part of this master's thesis is the design of a new box for a particular customer. As the customer wants to use RTU RTP bags irradiated in a range of 25-40 kGy, problems have been discovered during gamma irradiation. RTU RTP bag is used to extract material into or out of a sealed barrier without affecting their environmental characteristics.

The RTU RTP bags are normally transported in a long polypropylene (PP) box ($690.290.150\ mm$) because the ports of the RTP bags are too large to transport in a standard cardboard box ($365.270.212\ mm$). There are two different methods of gamma irradiation: pallet sterilization and tote sterilization. Pallet sterilization has an irradiation range of 13,5-40 kGy and tote sterilization has a range of 25-40 kGy. Pallet sterilization is not possible in this case due to the fact that the pallet sterilization does not meet the requirements of the customer. During box sterilisation, the boxes are placed in a tote during the sterilization process. The long boxes, however, do not fit in the totes of the irradiation company. A new box will therefore have to be developed that meets the requirements of the customer and the irradiation company.

5.2 Materials and methods

Designing a box consist of several steps. The first designs will never be perfect, so some steps will have to be done several times.

Step 1: The first step analyses the problem and also looks at the customer's requirements.

Step 2: Secondly, the requirements must be analysed for the development of this particular box. For this purpose, it is essential to look at different parties involved: customer, irradiation company and Datwyler itself. These involved parties are visited or contacted to find out all the necessary information. Each party involved has its own specific requirements to which the design must comply. All the requirements will be taken into account when designing this box.

Step 3: If step two is completed, all limiting properties are known and now the design of the box can start. It is essential to work out different designs. These designs are first sketched, but then also drawn with Inventor to get a better visual image. Manual prototypes will be made from the different concepts. These prototypes will give a better representation of the advantages and disadvantages of each concept. All designs will then be discussed with the various parties involved, but also with cardboard/plastic box suppliers. Cardboard/plastic suppliers can make quotations and can tell which designs are realistic or unrealistic. The customer's feedback can be found in appendix G.

Step 4: Once a design has been chosen, a prototype of the box can be made. This prototype will then be tested for strength, gamma sterilization, deformation of sealing solution, etc. The test of gamma irradiation will be done because a certain degree of gamma irradiation must be achieved.

Step 5: Finally, the design of the box can be optimised if the box has not passed all the tests.

Since this is a project with a customer, deadlines have been set, which can be found in appendix E. As a result of these deadlines, the concept has not yet been fully implemented.

5.3 Results and discussion

In the first section the requirements of the customer, irradiation company and Datwyler will be discussed. This was a first important step in the development of a new box. Secondly, the different concepts will be discussed. The prototypes of different suppliers of the chosen concept will be compared and discussed in point three. It was crucial that the packaging configuration was properly tested, these tests are discussed in the fourth point. In the fifth point it will discussed what the operators can use as a possible attachment or how to pack the packaging configuration. The last point describes the pallet configurations that can be used.

5.3.1 The requirements / handling processes of the customer, irradiation company and Datwyler

For the requirements and handling processes, various parties involved were visited. First the customer was visited to know clearly what was expected and when. Two irradiation companies were also visited to see how the irradiation works. When developing a box, it is important that the requirement of the parties involved are taken into account.

Table 1 shows the customer requirements. The customer would like to change from cardboard boxes to plastic boxes. This change is due to the fact that cardboard boxes can contain fibres. In the pharmaceutical world, people always want as few fibres as possible so that the risk of contamination remains minimal. Plastic boxes are the perfect solution for these fibres.

Table 1: Requirements of the customer

General	
Type of irradiation	20-40 kGy
Number of stoppers per hour	24000
Maximum lift weight (kg)	9.2
Pallet	
Type	Heat treated wood
Length (mm)	1000
Width (mm)	1200
Maximum Height (mm)	1500
Box	
Type	Plastic

Table 2 shows the requirements for the irradiation company. For the gamma irradiation, three different irradiation companies must be taken into account. If there are any problems with the main irradiation company assigned to this customer, the boxes must also be able to be sterilised in another irradiation company without any problems. The irradiation companies prefer a layer of PS foam in the tote to improve the irradiation. The height will be lower than given in Table 2.

Table 2: Requirements of the irradiation companies

	Length (mm)	Width (mm)	Height (mm)
Company 1	450	600	900
Company 2	525	420	870
Company 3	1060	450	680

For Datwyler it is essential to take into account that the boxes will not be packed here in Alken (Belgium) but in Pregnana (Italy). This means in first instance that everything that is developed here must also be clearly transferred to Italy such as working instructions and why this packaging was chosen. In Italy they use an automated packaging line, see Figure 25, while in Belgium everything is done manually. The automated packaging line works as follows:

1. The robot arm picks up the box that is needed for the required packaging configuration.
2. The box is folded by the robot arm.
3. The inner packaging is slightly pressed into a square so that they easily fit into a box.
4. The box is taped.
5. The boxes are stacked on a $800.1200\ mm$ pallet.

The problems that will occur with the new concept are that it is currently not possible yet to stack on $1000.1200\ mm$ pallets and that no RTP bags are packed with the automatic line. Because RTP bags are special bags, tests will be necessary to see if the packaging configuration is not damaged by the automatic packaging line. However, as it is also not possible to stack on a $1000.1200\ mm$ pallet, the pallets for this customer will be set up manually.

Figure 25: Top left: The robot arm grabs a box. Top right and bottom left: the box is folded and prepared to insert the sealing solutions. Bottom right: using this robot arm, the boxes are placed on a pallet.

The requirements are not the only essential factor to take into account when developing the box. The handling must also be taken into account. During the development of the box, it must therefore be ensured that this box is also practically manageable. In addition, RTU RTP bags are fragile bags. If this RTU RTP bag would break

during handling, it will bring a large cost. There are three places where a large amount of the handling takes place: at Datwyler itself, at the irradiation company and the customer.
At Datwyler, most of the handling steps take place. Firstly, the sealing solutions are inserted in the cleanroom in the required packaging configuration. Subsequently, the sealing solutions are transported to the warehouse, via a conveyor belt, and the operator can put the sealing solutions in a box. It must be ensured that the operator gets the packaging configuration smoothly into the box without having to apply extra pressure to the configuration. The final handling step at Datwyler is column stacking the boxes on the pallets. A good packaging configuration, made by the first operator in the cleanroom, ensures that the next handling steps are easier for other operators. For this purpose it is essential to have a good packaging instruction.

Once the pallets have been completely finished, they go to the irradiation company. Because of the use of tote irradiation, the boxes must be removed individually of the pallet and inserted into the tote. After irradiation the boxes are removed from the tote and then restacked on the pallet. Depending on which irradiation company the sealing solutions go to, the handling is done in a slightly different way. Irradiation company 1 sets the tote at 45°, as shown in Figure 26. The boxes are then individually placed in the tote, as discussed above. The irradiation company 2 works with totes that contain a movable base. This bottom rises when the operator wants to insert the boxes into the tote. For both irradiation companies it is important that the boxes are not turned upside down during this handling. This could potentially damage the port of the RTU RTP bag. Therefore, it is relevant that the top and bottom of the box are made visually clear.

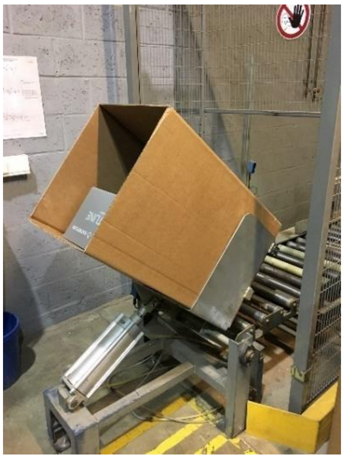


Figure 26: Irradiation tote

The final steps of handling are carried out at the customers location. Here the sealing solutions are taken out of the box and put in a chart. During opening of the box it must be observed that the inner bag is not cut. Datwyler already has a solution for this. The inner flaps of the box have been lengthened. If the box is cut up now, the inner flap is cut and not the inner bag. Then, the cart is driven to the cleanroom, where one bag of the packaging configuration is removed per lock.

From the above it can be concluded that the boxes have to undergo a large number of handling steps. In addition, the boxes have to go through a long journey of transport. For sealing solutions that need to be irradiated, the route is as follows: They leave at a Datwyler plant and are sent to the irradiation company. Then they go from the irradiation company back to a Datwyler plant. Finally, they go from the Datwyler plant to the customer. For this purpose, it is important that the box that is being developed is strong enough, that it is not convex due to too much product and that it can provide a stable and solid pallet.

5.3.2 Concepts

Different concepts were devised to meet the different requirements of the parties involved. These concepts were immediately tested with simple prototypes to give a visual representation of the pros and cons. For these self-made prototypes the following elements were used:

- 1 RTP RTU bag;
- 10 000pcs of the sealing solution V9250 (Figure 27);
- 10 000pcs of the sealing solution V9172 (Figure 27);
- Cardboard to make a box out of.

In order to test as realistic as possible, the requested sealing solutions were tested, but because the V9334 was not present in Alken, V9172 was used. The V9172 was the most similar to the V9334 in terms of dimensions and weight.

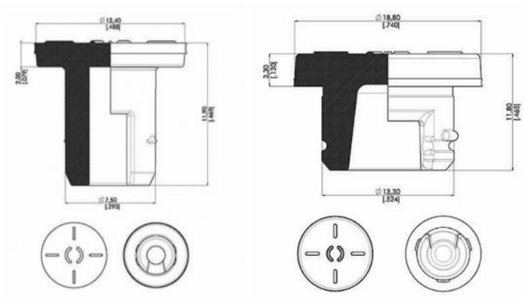


Figure 27: Left: V9250 (13 mm). Right: V9172 (20 mm)

5.3.2.1 Concept 1: 380.480.215 mm

The first concept was developed with the idea of creating a box as large as possible that fits all the totes, with which the pallet is optimally filled and that meets all the requirements. Figure 28 represents concept 1 with has the following dimensions 380.480.215 mm. It can be concluded from the pictures below that the pallet is nicely filled, that the RTU RTP bag fits tidily in the box and that with these dimensions two boxes would fit into one tote. The disadvantage is that there is a large amount of air transport and that only six boxes fit on one layer of the pallet.

The port of the RTU RTP bag can be placed in the box in different ways. Either it can be placed on the sealing solutions (see Figure 28 right) or it can be placed along the bag (see Figure 28 left and middle). If the second option would be chosen, the box must be made higher. The diameter of the port is larger than 215mm. However, this provides more transport of air, because the box should be made higher and the bag will contain the same number of sealing solutions. As mentioned earlier in , transport of air must be avoided. This is why it was decided to develop a box where the port lies on the sealing solutions.

Figure 28: Concept 1

5.3.2.2 Concept 2: 290.480.215 *mm*

The second concept has been developed in such a way that there is less transport of air than concept one but the pallet is still filled as optimally as possible. Figure 29 shows concept 2, which has the following dimensions 290.480.215 mm. With these dimensions there could be eight boxes per layer on a pallet. The disadvantage is that these dimensions are too narrow for a RTP RTU bag filled with 10 000 V9250 sealing solutions. It must be taken into account that in reality, which is not yet shown in Figure 29, there will still be three bags around this tested RTU RTP bag. The sealing solutions are too compact in this box which causes them to press against the side walls of the box. The boxes will become bulged as a result. Bulging boxes lose their strength.

Figure 29: Concept 2: 290.480.215 mm

5.3.2.3 Concept 3: 330.480.215 *mm*

Concept 3 combines the advantages of concept 1 and 2 and tried to eliminate the disadvantages. Concept 3 is shown in Figure 30and has the following dimensions 330.480.215 mm. By using concept 3, seven boxes per layer can be placed on a pallet, see Figure 30 right. In addition, concept 3 also has a larger volume than concept 2, which gives the RTU RTP bags more space. One of the disadvantages of concept 3 is the stacking pattern. Figure 30 shows that the boxes do not fit together perfectly. Interlocked stacking would not be possible here because the layers would not be supported 100% by each other. This would result in overhang of the boxes, which means that the boxes would lose strength. Another disadvantage of this concept is that the operators will have to stack very precisely. The space that is available in the length is 6 cm and in the width only 1 cm. This problem could be solved by using an angled corner. The purpose of this corner is further explained in 5.3.5.

Figure 30: Concept 3 (Left: packaging configuration. Right: pallet configuration)

5.3.2.4 Concept 4

Concept 4 consists out of sub options.

Concept 4.0

During the development of concept 4.0, the disadvantage of concept 3 that no interlocked stacking is possible was taken into account. Concept 4.0 has the following dimensions: 330.495.215 mm. The advantage is that the RTU RTP bag has sufficient space and that interlocked stacking could be applied if necessary. The disadvantage is that the operator still has to stack very precisely to avoid overhang of the boxes.

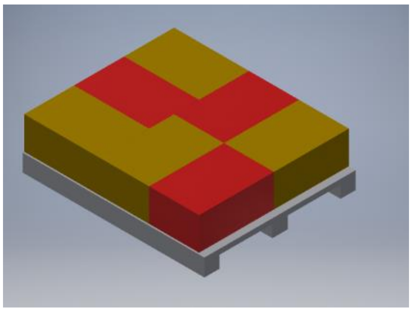


Figure 31: Concept 4 pallet configuration

To ensure that operators should not stack so precisely, concepts 4.1 and 4.2 have been developed.

Concept 4.1

Concept 4.1 has the following dimensions 320.480.215 mm .The boxes are smaller, so operators need to stack less precisely. However, there is one disadvantage to this. The pallets are no longer optimally filled. Figure X shows that here is 4 cm space left in the length and 2 cm in the width of the pallet. During transportation, pallets sometimes rest against each other. Figure 32 how 1000.1200 mm pallets are transported in a truck. This means that there is 8 cm space between two pallets and their boxes. The more space between two pallets the less stable these pallets are, therefore this space should be as small as possible. Based on concept 4.1 concept 4.2 has been developed.

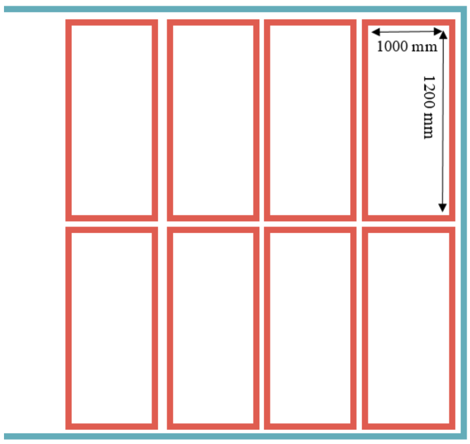


Figure 32: Arrangement of 1000.1200 mm pallets in a truck

Concept 4.2

Concept 4.2 has the following dimensions: 323.480.215 mm. This concept would fill a pallet more optimally than concept 1. There is still a little space left on the pallet, but that makes it easier for the

operators to stack the pallet. There is 3.5 cm space left in the length and 1.5 cm in the width of the pallet.
Concept 4.2 is the most developed design of concept 4. Here it is taken into account that interlocked stacking could be applied if necessary and that the operators do not have to stack very precisely.

5.3.2.5 Concept 5: 350.495.330 *mm*

Concept 5 has been developed to use the optimal space of a box entirely and to avoid transport of air. Concept 5 would have the following dimensions:350.495.330 mm. The concept would contain two bags in one box. To realise this concept, an intermediate piece is used. The excess air would be compensated by putting one bag upside down in the box. However, this concept is not optimal and there are several disadvantages.
The first disadvantage is that, as shown in Table 3, fewer sealing solutions can be transported on a pallet compared to concept 4.2, which will increase the cost of transporting the same amount of stoppers. Another disadvantage is that these boxes need more handling and are heavier to lift. This also means that the concept 5 do not meet the customer's requirement to handle a maximum lift weight of 9.2 kg. In addition, it is very difficult to lay the bags in this way once that there is vacuum drawn between the two EVOH bags.

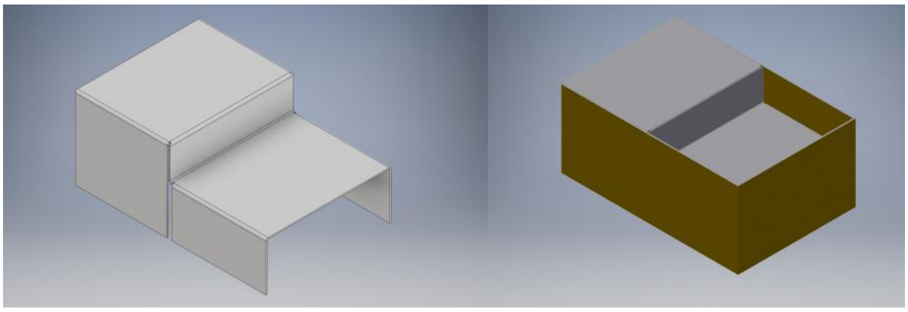


Figure 33: Concept 5: intermediate piece

Table 3: The financial difference between concept 4 and 5

	Concept 4	**Concept 5**
Number of stoppers per bag (V9250)	10000	8000
Boxes per layer	7	6
Number of boxes on top of each other	6	4
Number of bags per pallet	42	48
Number of stoppers per pallet	420000	384000

The table below summarises all the advantages and disadvantages of all concepts. From this it can be concluded that concept 4.2 is the best concept. This concept has the most advantages and the least disadvantages. In the following sections there will be further worked with concept 4.2.

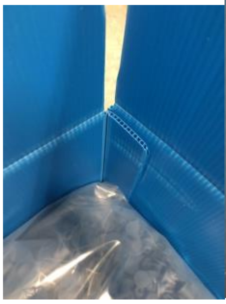
Table 4: Summary of the different concepts

	Concept 1: 380.480.215 *mm*	Concept 2: 290.480.215 *mm*	Concept 3: 330.480.215 *mm*	**Concept 4.2:** 323.480.215mm	Concept 5: 350.495.330*mm*
Does the packaging configuration fit into the box?	+	-	+	+	+
Number of boxes on 1 layer of the pallet?	6	8	7	7	6
Transport of air?	++	+	+	+	-
Columnar stacking possible?	+	+	+	+	+
Interlocked stacking possible?	-	-	-	+	-

5.3.3 *Prototypes*

In order to see if the sealing solutions in their current packaging configuration fit into the concept 4.2 box, prototypes were requested from two different suppliers. Table 5 shows the different prototypes that were received. Depending on the supplier, the polypropylene box has different properties and a different price.

Table 5: Different prototypes of concept 4.2

	Prototype 1 (supplier 1)	Prototype 2 (supplier 2)	Prototype 3 (supplier 2)
Type of box	700 gr PP box	800gr PP box → Welding with flap	800gr PP box → Mirror welding
Picture		 	

The three prototypes all have a different way of sealing their box.

- Prototype 1 has a nicely sealed corner that does not cause any problems when stacking pallets.
- Prototype 2 has like cardboard boxes a piece of plastic on the inside of the box that is sealed, as shown in Table 5. However, this piece of plastic has sharp edges which can damage the bags. On the outside of the box a small print on the place where the box is sealed could be noticed. This small print makes prototype 2 visually less attractive than prototype 1.
- For prototype 3 the same principle was used as for prototype 1, but the sealed corner is a little bit longer. This extension could cause problems when stacking pallets because the extension prevents other boxes from being placed against them.

One of the most important properties of a box is its strength, which is represented by the BCT value. The BCT value can theoretically be calculated according to the ASTM D-4169 standard, see Equation 1. The safety factor depends on the filing of the box and the conditions under which it can be used. In this case, the box must carry everything, otherwise it could damage the RTP bag or the sealing solutions. In addition, it can be established that an ordinary road is used (level 2), which means that the safety factor according to the ASTMD 4169 standard will be 7. The packaging configurations for the V9334 weighs approximately 9.118 kg for 3500 sealing solutions and the V9250 weighs approximately 8.743 kg for 9500 sealing solutions. The theoretically calculated BCT value for 10 kg in a box with a safety factor of 7 is 3434 N.

Equation 1: BCT value

$$\text{BCT value} = (\text{no. of boxes on first layer} \cdot \text{weight in a box (kg)}) \cdot 9.81\text{N} \cdot \text{safety factor}$$

The table below shows the BCT value for the different boxes of the different suppliers.

Table 6: BCT values for the different suppliers/ different type of boxes

	BCT value
Supplier 1: 650gr PP box	245 kg → 2403 N
Supplier 1: 700gr PP box	255 kg → 2502 N
Supplier 2: 800gr PP box	236 kg → 2315 N

From Table 6 it can be determined for supplier 1 that the boxes, both 650gr and 700gr, are not strong enough for the transportation. The box should have a BCT value of approximately 3434N to be capable of stacking 6 boxes high. In case six boxes would be stacked high with these boxes, there is a considerable chance that the lower boxes will be bulging or even collapse. This can cause damage to the bag and the sealing solutions which should be avoided.
In addition, it is also possible to calculate how many boxes can be stacked on top of each other, for example for a BCT value of 2502 N. From this calculation it can be concluded that only four boxes can be stacked on top of each other during transportation. In this case, pallets cannot be stacked double and this has a major logistical disadvantage because there is an adequate amount of transport of air in the truck. In addition, more trucks will be needed to send the same number of sealing solutions.
From Table 6 it can also be concluded that the quality of the boxes of supplier 2 is lower than supplier 1. The BCT value for an 800gr box is only 2315 N and this is lower than the BCT value for a 650gr box for supplier 1.

The plastic boxes mentioned above could not be stacked six boxes high. If only four boxes can be stacked high, it means higher transport cost, larger environmental impact but there is also more storage space needed in the warehouse to store the same amount of sealing solutions. For this reason, a quotation has also been requested from a cardboard supplier. These boxes would have a BCT value of at least 400kg. There is also a remarkable price difference, see Table 7.

Table 7: Price per supplier per type of material

	Cardboard	Supplier 1: 650 gr	Supplier 1: 700 gr	Supplier 2: 800 gr
Price	X	$X \cdot 426\%$	$X \cdot 460\%$	$X \cdot 526\%$

It would be possible to ask the plastic boxes supplier for a stronger box. A stronger box will undoubtedly have even a higher price. A cardboard box would therefore be technically better. However, this choice will depend on the customer's preferences.

5.3.4 Tests

Several tests were conducted to see if the packaging configuration would fit into the box. As mentioned earlier in X, the packaging configuration consists of:

- 1st bag: RTP bag, sealed;
- 2nd bag: EVOH bag, sealed;
- 3rd bag: EVOH bag, sealed;
- 4th bag: LDPE bag, stripped.

Between the 2nd and the 3rd bag there will be vacuum sealed.

5.3.4.1 Test 1

For the first test that was carried out, 10 000 V9250 sealing solutions were used. The packaging configuration was made in the lab. Here, it was impossible to vacuum seal, which meant that this test could not yet represent reality. The packaging configuration just went into the box without bulging. Because the space in the box was quite narrow, it was decided that the number of stoppers will be reduced to 9500.

During testing it could also be established that the normally used EVOH bags 400.1200 mm do not go around the packaging configuration. These bags are too narrow and too long, which would be a waste of material. Besides the 400.1200 mm EVOH, Datwyler has other bags in its range:

- RTU PE/EVOH/PE $270.400\ mm$
- RTU PE/EVOH/PE $400.500\ mm$
- RTU PE/EVOH/PE $650.650\ mm$

The first two bags are too small for this packaging configuration, but the RTU PE/EVOH/PE 650.650mm bag fits around the port bag. The only disadvantage of this bag is that it is not the best bag for handling. In addition, there has also been tested to see what the perfect size of the EVOH bag would be and that would be a bag of 475.780 mm. Due to a too large number of bags that would have to be ordered from the supplier, the formatted bag is not realized.

5.3.4.2 Test 2

The second test was performed in the cleanroom, where 9500 V9250 sealing solutions were used. The EVOH bag used in this test has the following dimensions:650.650 mm. It is crucial these sealing solutions can still move a bit when they are in their packaging configuration. If this is not the case, the sealing solutions may stick together after gamma irradiation. Between the RTP and the first EVOH bag, there was no vacuum drawn so these the sealing solutions would sit freely. However, there was vacuum drawn between the two EVOH bags. This configuration did not fit so well in the box. Since there was not vacuum drawn between the RTP and the first EVOH bag, these bags behaved like a balloon.

Figure 34: Packaging configuration test 2

The LDPE bag, the last bag around the configuration, had the following dimensions: 1200.400m. The packaging configuration fitted well into the LDPE bag but there was a large amount of bag on spare. This would be a waste of material and is not good for the environment.

During the vacuum drawing it could be concluded that it is important that the bags are already vacuumed in the right shape. This means that it is recommended putting the bags in sort of aluminium box, with slightly smaller dimensions than concept 4.2, during the vacuum process.

5.3.4.3 Test 3

The third test was also performed in the cleanroom, 9500 V9250 sealing solutions were used. Due to the fact that in test two too much air was present in the packaging configuration, a slight vacuum was drawn between the RTP and the first EVOH bag during the 3rd test. Then, the packaging configuration was completed with a vacuum seal on the second EVOH bag and an LDPE bag. The LDPE bag had the following dimensions: 650.650 mm. This LDPE bag fitted perfectly around the packaging configuration and has no longer too much material left over.

Figure 35: Packaging configuration test 3

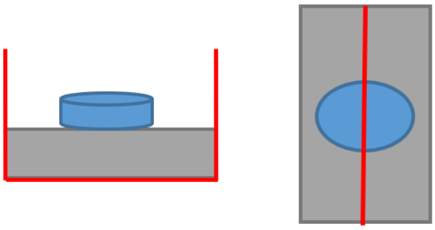
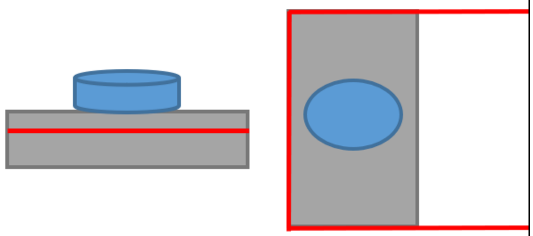
With this packaging configuration, the box barely closed. However, there was still space available in the box, see Figure 35. The packaging configuration was made a too compact. Through this available space in the box the sealing solutions can be spread a bit more and then the box will close easily. The stoppers were movable in the packaging configuration, which reduces the chance of sticky stoppers during gamma irradiation.

5.3.4.4 Test 4

During the fourth test, a packaging configuration was developed that fits better in the box but is also easy for the operator to handle. The packaging configuration of test 4 will look slightly different from test 3. Table 8 (left) illustrates how the RTP bag was packed in the EVOH bag according to test 3. The red lines represent the sealing seams of the EVOH bag. The lower seam runs in the middle of the RTP bag as a consequence the bag could not expand properly and the corners of the box were not completely filled.

Table 8 (right) show the new packaging configuration. The RTP bag is inserted into the EVOH bag from its side. By using this packaging configuration, the corners of the box can be filled better. In addition, the last LDPE bag will be sealed instead of being stripped. The sealing will prevent that there is a thick knot on the RTP port. The danger that this entails is that there is not enough air being squeezed out of the LDPE bag so that it will behave like a balloon. The operator who has to fill the boxes will have trouble with packing the configuration if there is too much air in the LDPE bag. A solution would be to vacuum the LDPE bag. The LDPE bag will never remain in vacuum but will no longer behave like a balloon. This new packaging configuration ensures that the box is filled more optimally and that the box closes well.

Table 8: The different ways to put a RTP bag in a PE/EVOH/PE bag

	RTP & PE/EVOH/PE configurations: test 3	RTP & PE/EVOH/PE configurations: test 4
Schematic representation. (Red line = seal of EVOH bag)		
Configuration in reality		

5.3.5 *Handling operators*

During the development of the box, it is also important that the operator's handling is taken into account. The better the work instructions or the better the tools for the operator, the easier it is for the operator to correctly pack the sealing solutions. The work instructions will be explained in appendix F. The tools can be used to make it easier for the operator, they are not necessary. There are attachments for both the cleanroom operators and the operators in the warehouse to pack the packaging configurations.

Figure 36 depicts a tool that can be used by operators in the clean room. This is a kind of basin where the first bag of sealing solutions can be put in. Now it is much easier to pull the second bag around the first bag without the first bag being creased in the second bag. However, this principle is already applied in First Line. For concept 4.2 it would be easy if the basin was used for both pulling bags over the first bag and as a preform for vacuum sealing. The preform ensures that the bags are vacuumed in the same form as the box. This makes it easier for the operators in the warehouse to insert the packaging configurations into the boxes without having to apply any pressure. The step-by-step plan for the use of this tool would be as follows:

1. Fill the RTP bag with sealing solutions
2. Place the filled RTP bag in the basin
3. Pull an EVOH bag over the RTP bag with the help of the basin
4. Place the spacer in the basin so that the basin has a part in the shape of the box → put the packing configuration in the preform

5. Seal the EVOH bag lightly vacuum
6. Pull a second EVOH bag over the packaging configuration
7. Put this configuration back in the preformed part of the basin
8. Seal the bag vacuum
9. Pull an LDPE bag around the packaging configuration
10. Seal the LDPE bag

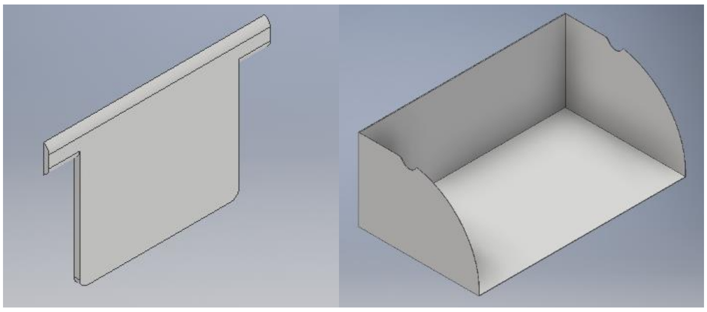


Figure 36: Left: spacer. Right: basin.

Figure 37 depicts what the operator in the warehouse can use as a tool for stacking the boxes. This is a corner at which the pallet is placed. Next, boxes are stacked against this corner, this ensures that the boxes are at a perfect distance from the edge of the pallet. If the free space on a pallet is limited, this tool would ensure that operators put the boxes on the pallet and that there is certainly no overhang of boxes.

Figure 37: Corner tool

5.3.6 Pallet configurations

Concept 4.2 has been developed to handle different pallet configurations. The customer has a requirement regarding the pallet configurations, which is that the maximum height for stacking is 1.5m including the pallet. This is due to the shelves in the customers warehouse. This means that with concept 4.2 a maximum of 6 boxes can be stacked on top of each other. The height of 1,431 m is then obtained. There are 3 different pallet configurations that can be applied.

The first pallet configuration is simply column stacking, as shown in Figure 38 (left). the column stacking ensures that the bottom box can retain its maximum strength, as mentioned in the literature study.

Secondly, it is also possible to stack interlocked, as shown in Figure 38 (middle). As mentioned earlier in the literatures study, the lower box loses up to 50% percent of its strength with this pallet configuration. These pallet configurations do give more stability than column stacking.
Finally, the previous pallet configurations can be combined. Figure 38 (right) shows this combination. In this case there can be chosen 3 layers column and 3 layers interlocked or 4 layers column and 2 layers interlocked. The combination of the previous pallet configurations ensures a solid but also a stable pallet configuration. The bottom box will not lose its strength in this configuration.

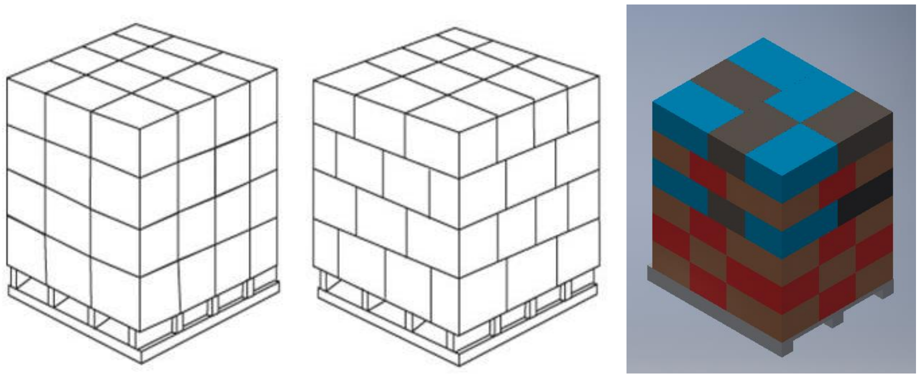


Figure 38: Left: columnar stacking. Middle: interlocked stacking. Right: combination of an interlocked of a columnar pallet configuration

6 Conclusion

During this study, two research topics were investigated: how to reduce the number of packaging configurations and how to develop a box for a particular customer.

For topic 1, it can be concluded that there are several reasons why customers choose a specific packaging configuration. It is therefore not easy to remove these specific packaging configurations, but it is possible to avoid creating new packaging configurations. Using an Excel tool, salespersons can see which packaging configurations exist for the customer requirements. The tool displays the different options for packaging configuration in order from most shipped to least shipped.

The tool does not reflect Datwyler preferred packaging configurations. This is something that can be worked on in the future. A list can be made of all the preferred packaging configurations which can then be implemented in the tool.

For topic 2, the different requirements and handling steps of the customer, the irradiation company and Datwyler itself were first thoroughly analysed. Subsequently, various concepts could be developed. Concept 4.2 was chosen as it had many advantages such as:

- Seven boxes per layer on a pallet.
- Well-filled pallet.
- Sealing solutions have enough space.
- Only a small amount of transport of air.

Prototypes from different suppliers were requested to test whether the internal packaging configuration would fit. The different prototypes were varying in grammage or type of material: plastic box 650gr, plastic box 700 gr, plastic box 800gr and a cardboard box. It could be established that the cardboard box has a better BCT value than the plastic boxes and a better price. Due to the low BCT value of plastic boxes only four boxes could be stacked high. This ensures a high logistic cost and a high environmental impact.

For the correct internal packaging of the sealing solutions, it could be established that the vacuum process was preferably done in an aluminium container, in the shape of the box, so that the internal packaging configuration would fit well in the box afterwards.

After approval of the customer and several other validation processes, concept 4.2 can be implemented at Datwyler.

7 Future

Recently, there have been a few complaints about plastic boxes that are bulging. This problem is seen by the customer and Datwyler itself. At the moment it is not known yet whether bulging boxes cause complaints of bags that are broken. If there is a complaint about a broken bag, it will not be linked to a bulging box by the customer. The problem of these convex boxes is currently being analysed by Datwyler in order to prevent the sealing solutions from being damaged.

First of all, the warehouse can be checked to see if there are any bulging boxes. These bulging boxes can be linked to their packaging configuration, weight per box and stack height. Next, a reason can be searched that can explain the bulging boxes.

Secondly, it could be concluded that the minimum required BCT value was not met by the supplier. Using the ASTM-D4169 standard, it was possible to calculate how high boxes can be stacked during transportation and during storage.

- Boxes with a BCT value of 295 kg (minimum required value): five boxes can be stacked high during transportation and seven boxes can be stacked high in a tote during sterilization.
- Boxes with a BCT value of 261 kg (value as tested by the supplier himself): four boxes can be stacked high during transportation and six boxes can be stacked high in a tote during sterilization.

From the above calculation it can be concluded that if the minimum BCT is not met, this will have a major impact on the stacking pattern. Not complying with the minimum BCT value will also be one of the reasons why the plastic boxes become bulging. For the future it is important to find out why the boxes do not meet the minimum BCT value in order to avoid bulging boxes.

Finally, it is known that boxes, both plastic and cardboard boxes, lose their strength during irradiation. However, it is not known how much their strength is decreasing after irradiation. After irradiation the boxes still have a long way to go. From the irradiation company the boxes first go back to a Datwyler plant and then they are sent to the customer. If the strength of a box decreases too much during the irradiaton of the sealing solutions, the box may collapse before it reaches the customer.
From experience, the irradiation company has already established that a plastic PP box can only be irradiated twice in the range of 25-40 kGy. Then the PP box will fall apart completely. The irradiation company uses cardboard totes that can be used up to eight times, depending on the irradiation range they have to pass through.

In order to determine how much strength a box, both cardboard and plastic, loses during irradiation, Datwyler can carry out the following test in the future. In order to be able to create a graph with loss of strength of a box in function with the number of cycles through an irradiator, the following information is required:

- Three plastic boxes that go one cycle around the cobalt source
- Three plastic boxes that go two cycles around the cobalt source
- Three cardboard boxes that go one cycle around the cobalt source
- Three cardboard boxes that go two cycles around the cobalt source
- Three cardboard boxes that go three cycles around the cobalt source

Because it is known that plastic is less resistant to gamma irradiation, a maximum of two cycles is sufficient. Irradiation companies must make the best possible use of their capacity. In order to use as little totes as possible, the following scheme (table 9) can be applied.

Table 9: Irradiation test

	Tote 1	Tote 2	Tote 3
Round 1	Cardboard - Cardboard – Cardboard – Cardboard	Cardboard - Cardboard - Plastic - Plastic	Plastic - Plastic - Plastic - Plastic
Round 2	Cardboard – Cardboard – Cardboard – Cardboard	Cardboard – Cardboard - Plastic - Plastic	Plastic - Cardboard – Cardboard – Cardboard
Round 3	Cardboard – Cardboard – Cardboard		

The first and second round 3 totes are filled, only in the second round 3 plastic boxes are replaced by 3 cardboard boxes. The third round only one tote will be filled with three cardboard boxes. In this way, the necessary data will be obtained.

The next step is to measure the BCT values of the irradiated boxes. These values can be compared with the unirradiated BCT values of the boxes, from which it can be concluded how much strength a box loses due to gamma irradiation. Finally, a curve can be created with the strength of the box in function with the number of cycles through an irradiator.

If Datwyler wants to calculate how many boxes can be stacked on the first box during transport after the irradiation, the following formula can be used according to the ASTM D-4169 standard, see Equation 2. The measured BCT value, average number of kilogrammes in a box and a safety factor of seven can be filled in the formula.

Equation 2: Number of boxes on the first layer

$$no. of\ boxes\ on\ first\ layer = \frac{weight\ in\ a\ box\ (kg) \cdot 9.81N \cdot safety\ factor}{BCT\ value}$$

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Appendix

Appendix A: Customer survey

Q29
Dear customer
I am Leen Govers, student packaging engineering. My master's thesis is being conducted at Datwyler. The aim of the master's thesis is to design a new packaging concept. With the help of this survey, it is possible for me to clarify the wishes of the customers so that a new packaging concept can be worked out. Thank you for your participation.

DATWYLER

Q22 Name of your company:

____

Q31
To check everything thoroughly, a difference is made between the inner and outer packaging. The following questions will only concern the inner packaging. With the inner packaging is meant everything that is inside the cardboard/ plastic box. In your mail you will find the different packaging configurations your company uses. The following questions are about the packaging configuration that is indicated in colour.

Q19 Why / for what reason does your company use the current packaging configuration?

- ▢ Technical reason (1) ____
- ▢ Economic reasons (2) ____
- ▢ Quantity in the bag (3) ____
- ▢ Other reasons (4) ____

Q38 To what extent is your company satisfied with the current packaging configuration?

- ○ 0 (0)
- ○ 1 (1)
- ○ 2 (2)
- ○ 3 (3)
- ○ 4 (4)
- ○ 5 (5)
- ○ 6 (6)
- ○ 7 (7)
- ○ 8 (8)
- ○ 9 (9)
- ○ 10 (10)

Q23 Are there any problems your company experiences with the current packaging configuration?

- ○ No problems with the current packaging configuration. (4)
- ○ Yes. In that case, please describe them briefly. (5)
____

Q25 What are the most critical aspects of the packaging configuration that your company has today?

____

Q24 Are there any aspects irrelevant to the packaging configuration that your company has today?

____

Q40 Are there any aspects of your packaging configuration that your company does not have today but would like to have?

____

Q32
The following questions will only concern the outer packaging. With outer packaging is meant the cardboard/plastic boxes, stacking mode of these boxes, wrapping of the pallet ect.

Q41 What kind of box does your company use?

- ○ Plastic (1)
- ○ Cardboard (2)

Q34 Is your company experiencing problems with the cardboard/plastic boxes?

- ☐ Too weak (1)
- ☐ Too big (2)
- ☐ Too small (3)
- ☐ Other (4) ____
- ☐ No problems regarding the box. (6)

Q33 Is your company experiencing problems with the stacking method of the cardboard/plastic boxes?

- ○ No. (1)
- ○ Yes. In that case, please describe them briefly. (2) ____

Q35 Is your company experiencing problems with the wrapping method of the pallets?

- ○ No. (1)
- ○ Yes. In that case, please describe them briefly. (2) ____

Q36 What are your expectations for the future regarding outer packaging?

____

Appendix B: Packaging configurations

Inner packaging Configuration	Box type	1st Bag	2nd Bag	3e Bag	4e Bag	nr
(4X(4 DOUBLE BAGS IN 1)) IN 1	PRINTED 365X270X212MM	PAPER FILM SPS 280X160MM	PAPER FILM SPS 280X160MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	1
1 DOUBLE BAG	LONG BOX 690X290X150MM	110/TYVEK/RFS 800X450 BIO363	LDPE 1200X500X0.07MM	N/A	N/A	2
1 DOUBLE BAG	LONG BOX 690X290X150MM	190/TYVEK/RFS 1000X390 28862	LDPE 1200X500X0.07MM	N/A	N/A	3
1 DOUBLE BAG	PLASTIC BD LOGO 365X270X212MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	4
1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	110/TYVEK/RFS 760X400 BIO336	LDPE 650X650X0.07MM	N/A	N/A	5
1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	6
1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	N/A	N/A	7
1 DOUBLE BAG	PLASTIC FL LOGO 372X277X280MM	190/TY/RFS1200X470MM6 007013965	LDPE 650X650X0.07MM	N/A	N/A	8
1 DOUBLE BAG	PLASTIC FL LOGO 372X277X280MM	190/TYVEK/RFS 1240X510 26871C	LDPE 650X650X0.07MM	N/A	N/A	9
1 DOUBLE BAG	PLASTIC UNPR 372X277X226MM	110/TYVEK/RFS 800X450 BIO363	LDPE 650X650X0.07MM	N/A	N/A	10
1 DOUBLE BAG	PLASTIC UNPR 372X277X226MM	190/TYVEK/RFS 1000X390 28862	LDPE 650X650X0.07MM	N/A	N/A	11
1 DOUBLE BAG	PLASTIC UNPR 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	12
1 DOUBLE BAG	PLASTIC UNPR 372X277X226MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	13
1 DOUBLE BAG	PLASTIC UNPR 372X277X226MM	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	N/A	N/A	14
1 DOUBLE BAG	PRINTED 365X270X212MM	110/TYVEK/RFS 760X400 BIO336	LDPE 650X650X0.07MM	N/A	N/A	15
1 DOUBLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	16
1 DOUBLE BAG	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	17
1 DOUBLE BAG	PRINTED 365X270X212MM	LDPE 650X650X0.07MM EASY TEAR	LDPE 650X650X0.07MM	N/A	N/A	18
1 DOUBLE BAG	PRINTED 365X270X280MM	190/TYVEK/RFS 1000X390 28862	LDPE 650X650X0.07MM	N/A	N/A	19

1 DOUBLE BAG	PRINTED 365X270X280MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	20
1 QUADRUPLE BAG	LONG BOX 690X290X150MM	105/PE/RTU 900X400 28130	PE/EVOH/PE 1200X400MM	PE/EVOH/PE 1200X400MM	LDPE 1200X500X0.07M M	21
1 QUADRUPLE BAG	LONG BOX 690X290X150MM	110/PE/RTU 1000X350 BIO375	PE/EVOH/PE 1200X400MM	PE/EVOH/PE 1200X400MM	LDPE 1200X500X0.07M M	22
1 QUADRUPLE BAG	LONG BOX 690X290X150MM	190/PE/RTU 1020X400 6007002118	PE/EVOH/PE 1200X400MM	PE/EVOH/PE 1200X400MM	LDPE 1200X500X0.07M M	23
1 QUADRUPLE BAG	PLASTIC UNPR 372X277X226MM	105/PE/RTU 900X400 28130	PE/EVOH/PE 650X650MM	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	24
1 QUADRUPLE BAG	PRINTED 365X270X212MM	190/PE/RTU 1020X400 6007002118	PE/EVOH/PE 650X650MM	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	25
1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	N/A	N/A	N/A	26
1 SINGLE BAG	UNPRINTED 365X270X212MM	LDPE 650X650X0.07MM	N/A	N/A	N/A	27
1 TRIPLE BAG	LONG BOX 690X290X150MM	110/TYVEK/RFS 760X400 BIO336	LDPE 1200X500X0.07MM	LDPE 1200X500X0.07M M	N/A	28
1 TRIPLE BAG	LONG BOX 690X290X150MM	110/TYVEK/RFS 760X400 BIO336MM	LDPE 1200X500X0.07MM	LDPE 1200X500X0.07M M	N/A	29
1 TRIPLE BAG	LONG BOX 690X290X150MM	110/TYVEK/RFS 800X450 BIO363	LDPE 1200X500X0.07MM	LDPE 1200X500X0.07M M	N/A	30
1 TRIPLE BAG	PLASTIC FL LOGO 372X277X226MM	105/PE/RTU 900X400 28130	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	31
1 TRIPLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	32
1 TRIPLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	33
1 TRIPLE BAG	PLASTIC FL LOGO 372X277X226MM	RTP105 900X400MM 28130 S.COVER	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	N/A	34
1 TRIPLE BAG	PLASTIC UNPR 372X277X226MM	105/PE/RTU 900X400 28130	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	35
1 TRIPLE BAG	PLASTIC UNPR 372X277X226MM	RTP105 900X400MM 28130 S.COVER	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	N/A	36

1 TRIPLE BAG	PRINTED 365X270X212MM	190/PE/RTU 1020X400 6007002118	PE/EVOH/PE 650X650MM	LDPE 650X650X0.07MM	N/A	37
1 TRIPLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 500X650MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	38
1 TRIPLE BAG	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	39
10 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	40
10 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 200X300MM	LDPE 650X650X0.07MM	N/A	N/A	41
2 DOUBLE BAGS	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	HDPE/TYVEK PRINTED 500X650MM	N/A	N/A	42
2 DOUBLE BAGS	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	43
2 DOUBLE BAGS	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	44
2 DOUBLE BAGS	PLASTIC UNPR 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	45
2 DOUBLE BAGS	PLASTIC UNPR 372X277X226MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	46
2 DOUBLE BAGS	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	47
2 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	48
2 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	49
2 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 400X500MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	50
2 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	51
2 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	PE/EVOH/PE 400X500MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	52
2 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	110/PE/RTU 300X1200 BIO273	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	53
2 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	54
2 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 500X650MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	55
2 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	56

2 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	PE/EVOH/PE 400X500MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	57
2 SINGLE BAGS	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	N/A	N/A	N/A	58
2 SINGLE BAGS IN 1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	59
2 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	60
2 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	61
2 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	62
2 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	63
2 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	N/A	64
2 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	65
3 DOUBLE BAGS IN 1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	66
3 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	67
3 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	68
3 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	69
3 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	70
3 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	71
3 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	72
3 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 400X500MM	HDPE/TYVEK PRINTED 500X650MM	LDPE 650X650X0.07MM	N/A	73
3 SINGLE BAGS IN 1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	74
3 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC BD LOGO 365X270X212MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	75
3 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	76

3 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	77
3 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	78
3 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	79
4 DOUBLE BAGS	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	N/A	N/A	80
4 DOUBLE BAGS IN 1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	81
4 DOUBLE BAGS IN 1 DOUBLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	82
4 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	83
4 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 270X400MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	84
4 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 400X500MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	85
4 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	86
4 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	87
4 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	PE/EVOH/PE 400X500MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	88
4 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X280MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	89
4 SINGLE BAGS IN 1 DOUBLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	LDPE 650X650X0.07MM	N/A	90
4 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	91
4 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	92
4 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	93
4 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	94
4 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	95
4 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X280MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	96

5 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	PE/EVOH/PE 270X400MM	PE/EVOH/PE 270X400MM	LDPE 650X650X0.07MM	N/A	97
5 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	98
5 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	99
5 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	100
5 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	101
6 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	102
6 DOUBLE BAGS IN 1 SINGLE BAG	PLASTIC UNPR 372X277X226MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	103
6 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	HDPE/TYVEK PRINTED 400X500MM	LDPE 650X650X0.07MM	N/A	104
6 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	105
6 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	PE/EVOH/PE 400X500MM	LDPE 650X650X0.07MM	N/A	N/A	106
6 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	107
7 DOUBLE BAGS	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	N/A	N/A	108
7 SINGLE BAGS IN 1 SINGLE BAG	PLASTIC FL LOGO 372X277X226MM	HDPE/TYVEK PRINTED 320X450MM	LDPE 650X650X0.07MM	N/A	N/A	109
8 DOUBLE BAGS	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	N/A	N/A	110
8 DOUBLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	111
8 SINGLE BAGS IN 1 SINGLE BAG	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 650X650X0.07MM	N/A	N/A	112
9 DOUBLE BAGS	PRINTED 365X270X212MM	LDPE 500X320X0.07MM	LDPE 500X320X0.07MM	N/A	N/A	113

Appendix C: Packaging materials

Packaging materials	Nr
N/A	0
105/PE/RTU 900X400 28130	1
110/PE/RTU 1000X350 BIO375	2
110/PE/RTU 300X1200 BIO273	3
110/TYVEK/RFS 760X400 BIO336	4
110/TYVEK/RFS 760X400 BIO336MM	5
110/TYVEK/RFS 800X450 BIO363	6
190/PE/RTU 1020X400 6007002118	7
190/TY/RFS1200X470MM6007013965	8
190/TYVEK/RFS 1000X390 28862	9
190/TYVEK/RFS 1240X510 26871C	10
HDPE/TYVEK PRINTED 200X300MM	11
HDPE/TYVEK PRINTED 320X450MM	12
HDPE/TYVEK PRINTED 400X500MM	13
HDPE/TYVEK PRINTED 500X650MM	14
LDPE 500X320X0.07MM	15
LDPE 650X650X0.07MM	16
LDPE 650X650X0.07MM EASY TEAR	17
LDPE 1200X500X0.07MM	18
PAPER FILM SPS 280X160MM	19
PE/EVOH/PE 270X400MM	20
PE/EVOH/PE 400X500MM	21
PE/EVOH/PE 650X650MM	22
PE/EVOH/PE 1200X400MM	23
RTP105 900X400MM 28130 S.COVER	24

Appendix D: Manual Excel tool

A lot of formulas in Excel cause the document to work slowly. To prevent the Excel document from not being used by the sales people, there will always have to be two documents: one with formulas in it and one that is the copied version (= no formulas) which makes it work faster.
To update the Excel document, tow documents are required:

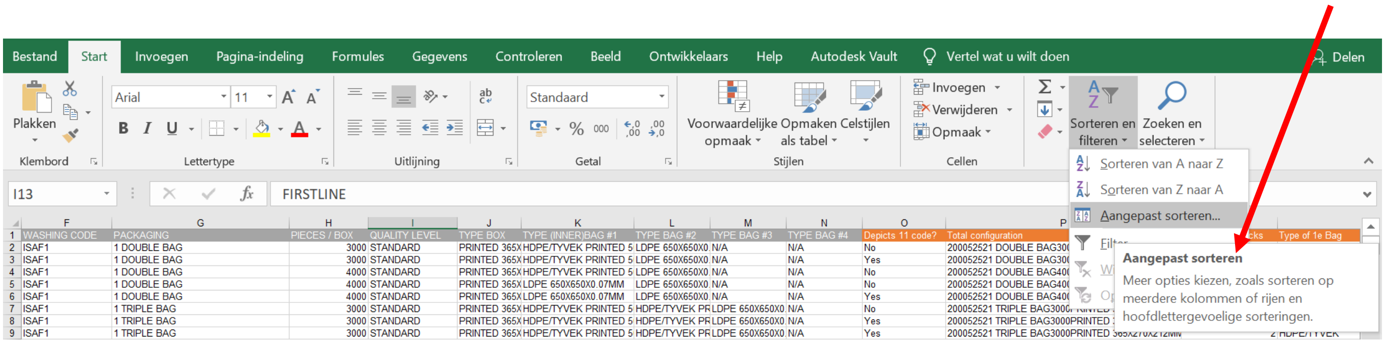
- All 11 codes with the linked packaging configuration. This document contains the following columns:

Object	Description	PRODUCTION PLANT	PRODUCT DRAWING	GENERIC NAME	WASHING CODE	PACKAGING	PIECES / BOX	QUALITY LEVEL	TYPE BOX	TYPE (INNER)BAG #1	TYPE BAG #2	TYPE BAG #3	TYPE BAG #4

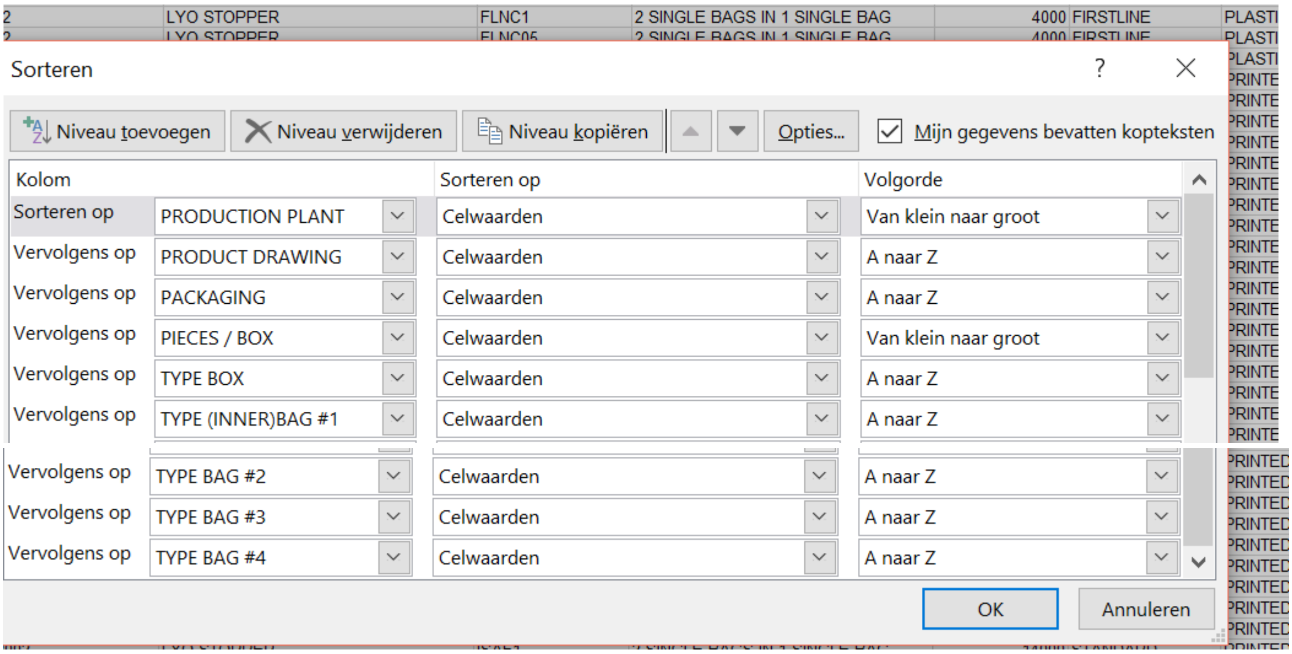
- Shipping list of the year you would like to use. This document contains the following documents.

Producing Plant(s)	Pack list	Name 1	Material	Material Description	IncoT	Incoterms (Part 2)	Transport	Customer	Cty	Bill. Date	Billed Quantity	Boxes	Pallets	Gross weight	Net weight	Amount

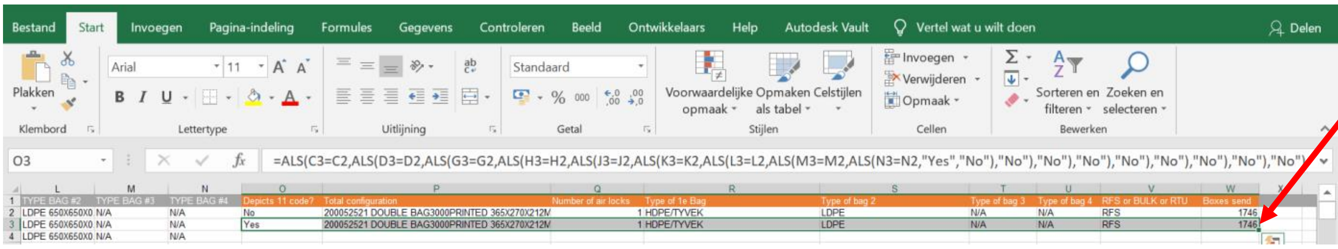
Step 1: Export the 11 codes from SAP.
Step 2: Stand in A1 (of the exported document) and press Ctrl + A → copy the selected cells.
Step 3: Open the tool document
→ Go to the tab SAPdoc11codes
Step 4: Stand in A1 → paste the copied cells.
Step 5: Press Sort and Filter → then press Custom Sort



Step 6: Sort as below + press OK.

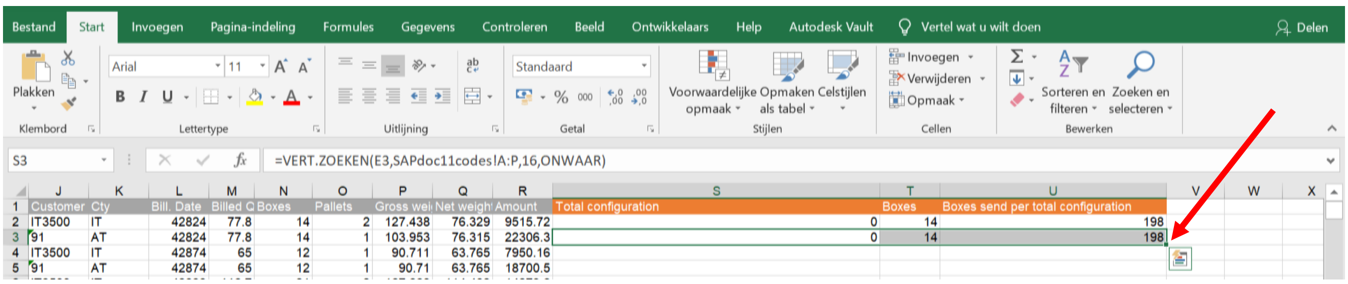


Step 7: select O3-W3 and then double click on the square (this will extend the formulas to the bottom).

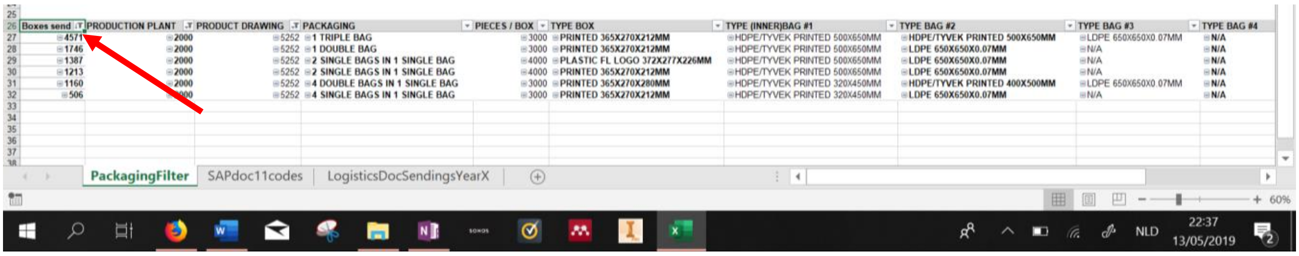


Step 8: export of SAP the shipping list of the year you would like to use.

Step 9: Stand in A1 (of the exported document) and press Ctrl + A → copy the selected cells.
Step 10: Open the tool document
→ Go to the tab LogisticsDocSendingsYearX
Step 11: Stand in A1 → paste the copied cells.
Step 12: select S3-U3 and then double click on the square (this will extend the formulas to the bottom).

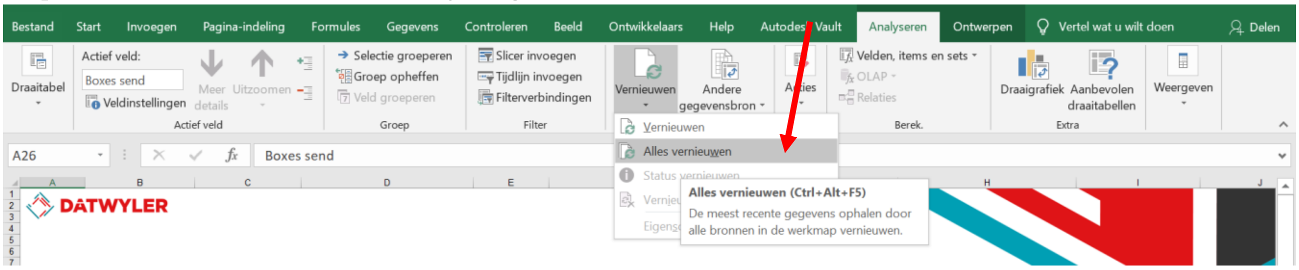


Step 13: Go to the tab PackagingFilter and stand on "Boxes send".



Step 14: Click on Analyze

Step 15: Click on renew + renew everything.



The Excel-document can be used now. The disadvantage is that the formulas the Excel-document contains will make the document slow. Therefore it is easier to do the following:

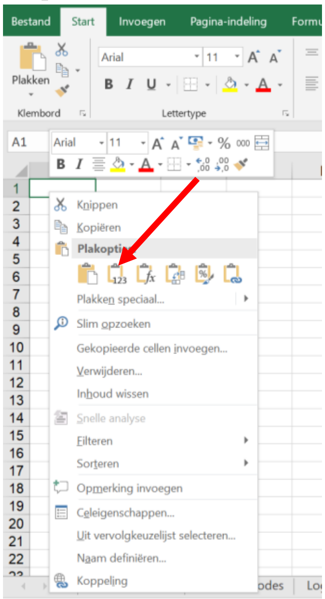
Step 1: Copy the created Excel document.

Step 2: Delete all data in tabs SAPdoc11codes and LogisticsDocSendingsYearX from the copied document.

Step 3: Select all the data in tab SAPdoc11codes in the original document (with formulas): Ctrl+A and copy the data Ctrl + c

Step 4: Move to A1 in Tablet SAPdoc11codes in the copied document.

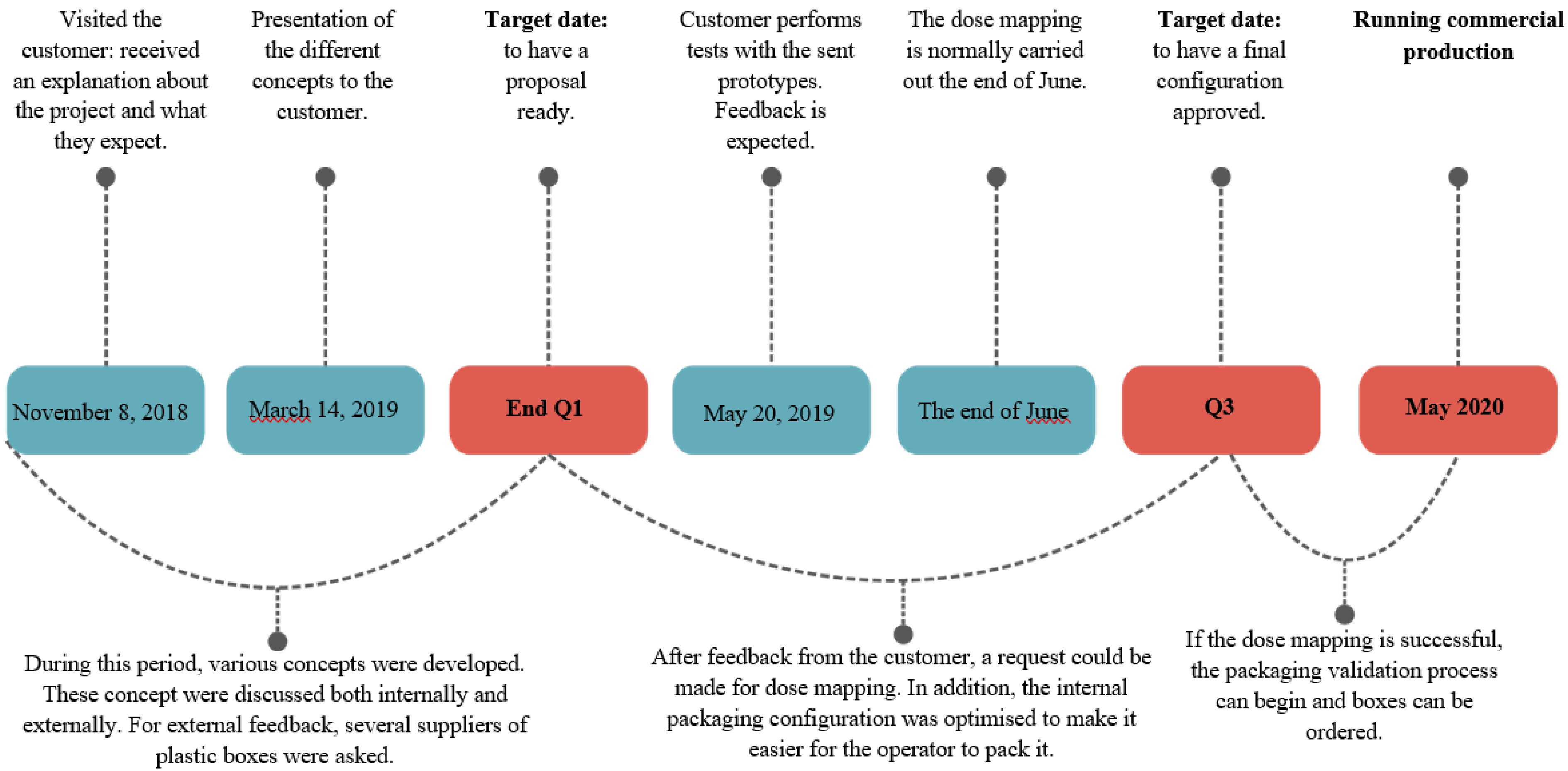
Step 5: Paste the data as follows



Step 6: Do the same for the LogisticsDocSendingsYearX tab.

Now the document is less heavy and easier to work with.

Appendix E: Project timeline



Appendix F: Work instruction

Step 1: Put the RTP port on the empty bag.

Step 2: Put the RTP bag in a plastic box as follows, see figure 2.

Step 3: Fill the RTP bag with the correct amount of sealing solutions, see figure 3.

Step 4: Seal the RTP bag. **ATTENTION**: Do not push the air out of the RTP bag, only the part where the seal will be made may be squeezed.

Step 5: Remove the RTP bag from the plastic box and place it as follows, see figure 4.

Step 6: Pull a PE/EVOH/PE bag (650.650 mm) sideways over the RTP bag.

Step 7: Seal the PE/EVOH/PE bag slightly vacuum.

Step 8: Pull a PE/EVOH/PE bag (650.650 mm) sideways over the RTP bag.

Step 9: Seal PE/EVOH/PE bag vacuum.

Step 10: Pull one LDPE bag (650.650 mm) sideways over the RTP bag.

Step 11: Push the air out of the LDPE bag and seal the LDPE bag.

Figure 1: step 1

Figure 2: step 2

Figure 3: step 3

Figure 4: step 5

Figure 5: step 6

Appendix G: Customer review

First review (packaging configuration, see test 3)

Dear Datwyler team,

I have already received positive feedback on your solution today, including on the plastic box.
They just thought the bag was a bit heavy but we are going to test it at the FAT in May with the sample bags.
I expect it won't be too bad if we can place the bag on the filling line holder.
They also understood that it was a compromise between frequency, weight and as much as possible in a bag because of the high cost of the RTP bag.

Second review (packaging configuration see test 4)

Dear Peter,

Yesterday we opened a box and we were very pleased with the new packaging method.
You can see that the bag is nicer in the box and makes better use of the corners. I also have the impression that the stoppers have more space and are looser in the bag.
This is a good improvement because the experience is that the looser the stoppers are, the smaller the chance of sticky stoppers.