Table of contents

1. Introduction

In this opening chapter the background for this thesis will be presented. Initially, the background of Tetra Pak and the development project that this thesis concerns are described. Furthermore, the problem statement, purpose and the objectives of the study is presented.

1.1 Background

1.1.1 About Tetra Pak

In May 1951, two businessmen working in Lund in the south of Sweden named *Ruben Rausing* and *Erik Wallenberg* presented a new packaging solution for milk products. The company that was formed together with this new packaging system was called *Tetra Pak*, after the tetrahedron shaped cardboard package (see Figure 1a) used, and became one of the first packaging companies in the world that handled milk.[1]

(a) (b)

Figure 1: (a) *The original Tetra Classic package.* (b) *The first Tetra Pak packaging machine.* [2]

Tetra Pak is the result of a packaging idea hatched during the Second World War, when the demand for factory-packaged products increased rapidly. The project, that needed 8 years of product development and faced many difficulties along the way, was successful much thanks to another great businessman called *Holger Crafoord*, that later worked as managing director in the company. Finally, in 1952 - one year after the company was founded, the first machine for milk packaging (see Figure 1b) could be delivered.[3]

In the following ten years the company expanded heavily, not only concerning packaging materials where the company reached one billion cartons a year in 1959, but also concerning packaging machines. During the 1960'th the expansion continued, including the first production plants outside Sweden. In 1963 the *Tetra Brik* (see Figure 2) was introduced, that later would turn out to be one of the most important steps in the history of Tetra Pak. Another milestone was the launch of the *Tetra Brik Aseptic System*, which enables producers to do the filling of for example milk in an environment free of bacteria and thereby create product with long shelf life. During the following two

[1] Vega, Daniel (2003)
[2] www.tetrapak.com>TheCompany>history (030809)
[3] www.crafoord.se/hci.htm (030809)

decades the company continues to grow, much due to contracts with large companies and governments and an expanding product portfolio. The annual production of packages hit the 40 billion mark in the late 1980'th.[4]

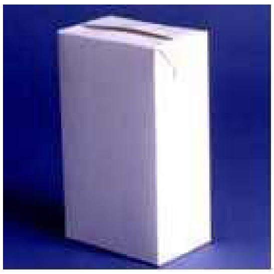


Figure 2: *The Tetra Brik packaging.* [5]

The 1990-th became a decade of change for Tetra Pak. In 1991 Alfa Laval, one of the world´s largest suppliers of equipment and plants to the food, processing and agriculture industry, was acquired. The two companies started of as independent parts, but as early as the following year they presented a common supply of services and products. By 1993 the company took the name of *Tetra Laval Group*, which consisted of four industrial groups: Tetra Pak, Tetra Laval Food, Alfa Laval and Alfa Laval Agri. At the same time Tetra Pak witnessed a strong regionalization, which lead to a dividing into four local regions: Europe, Central Asia / Middle East & Africa, Asia / Pacific and America. This movement was made in order to satisfy local requirements in a better way. [6]

At the beginning of the millennium Tetra Pak continued its expansion of product range, machinery, production lines and facilities. Today the company has 77 market companies around the world, 59 packaging material plants, and 12 packaging machine assembly factories, which all together provide more than 20000 people with work. Tetra Pak now produces hundreds of different types and sizes of packaging, from cartons to PET-bottles, which are sold in 165 countries around the world.[7]

1.1.2 The SCAP project [8]

In year 2000 a study was conducted to determine the market position of Tetra Pak´s core product, the Tetra Brik Aseptic. The study showed that the Tetra Brik Aseptic, in spite of the tough competition it faces, would still be the cash cow of the company for several years to come. However, the study showed that, in order to reach the company's growth goals, it was necessary to start developing a new product, which could supplement the Tetra Brik as a more value-adding aseptic product. An innovation process followed in order to verify the previous study and to define the commercial and technical opportunities linked to an eventual new bestseller.

---

[4] www.tetrapak.com>TheCompany>History (030809)
[5] ibid
[6] ibid
[7] Vega, Daniel (2003)
[8] All information gathered from Tetra Pak´s internal database

The final result of the innovation process was a package suggestion (see Figure 3) that consists of a lower part made of carton and an upper part similar to a PET bottle, made of plastic. Because the package was decided to be aseptic and largely made by carton, where the company has world leading technology and know-how, it was named Second Carton Aseptic Platform – SCAP. The SCAP bottle, as it is thought to be the new generation of the Tetra Brik package, will be made for both juice/nectar drinks as well as for liquid dairy products.

Figure 3: *A possible model of the SCAP-system.* [9]

This product platform, complementary to the Tetra Brik Aseptic, would have to include several shapes and types of packages with minor development changes. Thus, the time-to-market would be reduced drastically for new packaging systems and it would also allow customizing packages depending on the customers' demands.

The development team continued its research, especially by benchmarking of existing products based on plastic technology and market tests. It was found that there in several cases was a consumer wish to be able to see the product in a package. To fulfil this need it would have to be possible to manufacture SCAP packages with a transparent top. That, on the other hand, would create problems when handling milk products, which in general needs to be kept away from sunlight. However, since the market survey showed that consumers have no wish to see milk inside a package, the SCAP-tops for milk packages could also be made of non-transparent plastic.

From the information gathered by the consumer surveys, a scenario for the future market of the SCAP project in Western Europe was put together. However, as the project keeps evolving, further investigation will be necessary to define the best course of action both for the technical issues concerning production and for the logistical issues.

1.1.3 Previous studies [10]

When the SCAP project, described in the previous chapter, was started in the beginning of the year 2000, material-, product-, but above all machinery development was in focus. However, as the project proceeded the logistic area became more and more of interest, and during 2002 the company decided to initiate a subproject with the objective to investigate possible, future distribution situations for the plastic SCAP-tops in Europe.

[9] The picture is gathered from Tetra Pak's internal home page
[10] Vega, Daniel (2003)

This investigation was supposed to be a guideline for the developing team of the SCAP project and it's future work and decisions.[11]

Daniel F. Vega, student at Linköpings Tekniska Högskola, Sweden, was in 2002 given the above-mentioned task as his master's thesis. The work was to be based on computer simulations, and for that Vega used AMPL, a simulation software that enables the user to rely on a library of existing programming models, communicate easily with other programs and construct many "what if" scenarios.

As inputs Vega was given a number of assumptions. The SCAP system was then in the prototype development phase and since field tests were planned to start March 2004, that's when the simulation was assumed to start. It was also said to stop at the year 2010, when Tetra Pak estimates that the European market will be mature for the SCAP product. Seven different production plants were assumed in total, all with different capacity and introduction dates. The filling machines at the production plants were assumed to produce only three versions of the SCAP-tops: the largest one, with a height of 77 mm, a medium sized one, with a height of 57 mm, and the smallest one, with a height of 33 mm. Finally, two demand scenarios, where the first scenario meant highest demand of the 77 mm top and the second scenario highest demand of the 33 mm top, were created.

The main issue in Vegas master's thesis was to investigate, for both demand scenarios, whether it's better (concerning costs) to have a central plant for production, hole through the wall (HTW) factories or a combination of these two. The simulation, that initially calculated the optimal combination of a HTW and a central plant solution, showed that the costs for a central plant were only slightly higher than for the optimal combination (see Figure 4). It also showed that the HTW solution is far more expensive in many aspects.

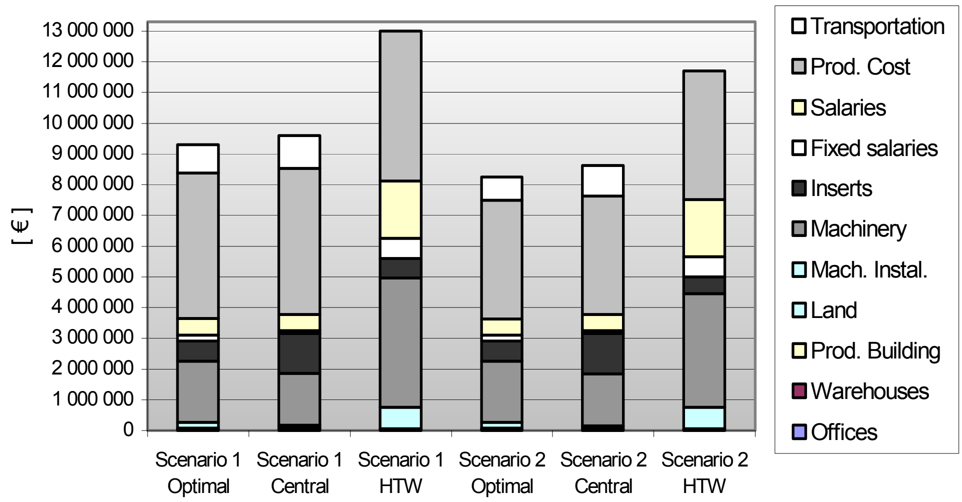


Figure 4: *Illustration of the total cost breakdown for different production scenarios of the SCAP-top.*[12]

[11] Tetra Pak internal information
[12] Vega, Daniel (2003)

1.2 Problem Statement

Tetra Pak has, as mentioned above, developed a new extrusion-blow moulding machine, producing a plastic top, and a filling machine, to be used in the new SCAP packaging system. Since the company has a long experience in handling and producing carton packages, a system for distribution of carton material already exists. This system will therefore also be used in the SCAP project. However, no efforts have yet been made in developing a distribution system for the plastic tops in the SCAP project.

The SCAP-tops are manufactured in pairs (see Figure 5) by extrusion blow moulding (EBM), which results in a circular, plastic unit filled with air that is very light and bulky. The handling of such a product raises many questions concerning filling rate, transport effectiveness, damage precautions and hygiene, which represent the main issues in the development of a distribution system for the SCAP-top. Furthermore, the SCAP-system is designed to be flexible in order to meet different customer demands. This will mean that the shape of the SCAP-tops will be different for different customers in the future.

Figure 5: *A double SCAP-top.*[13]

1.3 Purpose

The purpose of this study is to design a logistical- and material-handling system for the SCAP-tops. The system is to include all activities along the Supply Chain, starting with the ready-made SCAP-tops leaving the blow moulding machine and finishing with the SCAP-tops entering the filling machine at the customers' site. The study will include the selection of both packages and mode of transportation.

[13] Tetra Pak internal information

1.4 Objectives

The main objective is to identify and design appropriate resources and activities along the Supply Chain of the SCAP-tops. These resources and activities are then to be put together to optimise the system regarding functional, economical and environmental aspects. More specifically, this means:

- Finding the most suitable primary packaging and load carrier
- Optimising the packaging procedure regarding:
  - *what material handling activities that is required*
  - *the level of automatization*
- Examine the consequences of different modes of transportation.
- Creating a cost model for the supply chain, used in this thesis, of the SCAP-tops.

When conducting the tasks of these two scenarios we aim to investigate and evaluate what solutions already exist within the company as well as on the market. We also aim to perform risk analyses in order to increase the quality of the solutions.

1.5 Delimitations

As usual in a market introduction of a new product, the volume and sales forecasts are uncertain. The study will therefore not emphasise the introduction phase of the SCAP project, but will be based upon a scenario likely to occur six years after the introduction. In this scenario, only the European market will be included.

Some of the steps in the studied Supply Chain will interact with already existing systems, e.g. internal transportation and storage. We do not aim to change these systems, but as far as possible adapt our solutions to fit them.

The previous study[14] uses two different options in distribution to optimise the cost of the system; central production (CP) and hole-through-the-wall production (HTWP). Since the study recommends a central plant solution, this thesis will therefore assume such a scenario and not take the hole-through-the-wall scenario into account.

1.6 Target group

The main target group for this thesis is naturally concerned parties at our employer Tetra Pak. The reader is therefore assumed to have a basic knowledge and understanding of logistics and packaging technology. Our thesis is also intended for engineering students, with special interest of logistics and packaging technology.

---

[14] Vega, Daniel (2003)

2. Methodology

In this chapter scientific methodology, which is the way to achieve the purpose of the study, will be described. Along with the descriptions we will also present our choices of methodological instruments and motivations for these choices. A discussion of source criticism will also follow. Finally, the procedure of how this study was conducted will be described.

2.1 Theory of science and methodology

Methodology, a common term in scientific reports, means the description of one or many methods for performing scientific work and is distinguished by giving a number of concrete and usable tools for troubleshooting. Another related, but less common, expression is theory of science, which means the pondering of what reasons there might be to choose or not to choose a certain method. This section will deal with both of these fields, but since the objectives of this thesis are very practical, it sometimes will be impossible to fully explain both.[15]

2.1.1 Methodology approach

The major task for the researcher is to produce new knowledge, in order to describe the world around us and make it easier to understand. The results are often presented as theories or mathematical models of the reality. To be able to produce reliable and true knowledge the researcher has to conduct the study methodically. The choice of method depends on the researcher's fundamental evaluations concerning philosophical issues and world view, which affect the total scientifical process. It is thus important for the researcher to reflect upon his/her fundamental evaluations and to explain the chosen methodology approach. [16]

In the literature three fundamental methodology approaches are found; the analytical approach, the system approach and the actor approach. These will be described below.

Analytical approach

The analytical approach origins from the philosophical branch positivism and constitute the foundation of most research in natural science. The approach aims at describing an objective reality from cause and effect connections, without any subjective evaluations. The view of the reality is based upon that "the overall picture is the sum of its parts". This means that once the different parts of an overall picture are known, these can be summarized and the overall picture be obtained. [17]

[15] Andersen, Heine (2000), pg 96-97
[16] Wallén, Gunnar (1996), pg 17
[17] Wallén, Gunnar (1996), pg 27

System approach

The system approach arose in the late 1960:th partly as criticism against the positivism.[18] This approach, like the analytical approach, aims to describe the reality in an objective way. However, the system approach does not consider the overall picture to be obtained by summarizing small parts of the reality. Instead effects of synergy occur between the parts and the overall picture is obtained by observing how the parts interact with each other, taking the total system under consideration. The components of the reality have such features that they can not be evaluated individually, the interaction with other components have to be taken into consideration. This line of argument can also be held on a higher level; to explain or understand a system it is often crucial to put it into its own context. This is why a distinction between closed systems and open systems often are made. In open systems the relations and connections with the system's environment are studied, which is not done in closed system. [19]

Actor approach

The actor approach differs from the other two approaches in their assumption of an objective, by us independent, reality.[20] The actor approach assumes that the reality is a social creation where the overall picture is only understood through the included actors concept of reality. Descriptions of the reality have consequently its starting point in how different actors perceive, interpret and act in the reality. The result and outcome of a study using the actor approach are hence based upon subjective facts and observations.[21]

Choice of approach

The main purpose of this study is, as mentioned earlier, to design a logistical- and material-handling system for SCAP-tops. The system boundaries start with the blow-moulding machine at a Tetra Pak site and ends with the filling machine at the customer. Along the physical material flow the system has to fit into the existing environment of location capacity, other material flows, storage capability etc. Hence, the system that is to be developed has close relation to its environment and several demanding actors. To be able to understand the demands of the system and to evaluate different alternatives, the relations and interactions between the including parts of the system are important and must be revealed. "The chain is not stronger than its weakest link" is a common expression and describes the situation at hand in an appropriate way. If a system is developed without considering a certain part of it and this part's interaction with the other parts, the system will not work sufficiently. This motivates an open system approach for this study.

An analytical approach would be insufficient because parts, which are in physical connection with each other and thus inevitably will interact and thereby have an effect on each other, will build up the system. If instead the system, when using the analytical

---

[18] Wallén, Gunnar (1996) Vetenskapsteori och forskningsmetodik, pg 28
[19] Arbnor, Ingeman, Bjerke, Björn (1994) Företagsekonomisk metodlära, pg 80-81
[20] Arbnor, Ingeman, Bjerke, Björn (1994) Företagsekonomisk metodlära, pg 86-87
[21] Wallén, Gunnar (1996) Vetenskapsteori och forskningsmetodik, pg 54

approach, is considered as one big part, it will be almost impossible to understand and the structure will be lost.

An actor approach on the other hand will not make the results of the study objective and the designed system will thereby most likely not be suited for the total range of users.

2.1.2 Deductive and inductive approach

Usually literature speaks of two ways of dealing with societal conditions: the deductive and inductive method. These are in scientific work also referred to as "the way of the proof" and "the way of the discovery" respectively. The deductive method is the most formalized and means, a bit simplified, that hypotheses first are created from "old" theories and then tested empirically in reality to be evaluated. The inductive method, on the other hand, works from the opposite direction. It starts with a gathering of information and ends with the seeking of patterns and connections from this information in order to build new theories. With this method the development of theories does not become a starting point for the research but more like a process that helps to gather the information in a systemized way.[22]

In this thesis we have chosen to work mostly from an inductive perspective, but the practical nature of our problem (objective) means that practical solutions, rather than theories, primarily are sought. Even though some basic logistical ideas are used, which in a way represents a deductive approach, theories will not be tested and evaluated.

2.1.3 Gathering of information

When discussing gathering of information, a distinction is often made between information that already has been gathered by someone, secondary information, and new information gathered by you or someone else during the scientific work, primary information. Related to both of these information types, there are certain issues that have to be taken into consideration. Secondary information, to begin with, might have been gathered for a different purpose than the present study and is therefore not comparable to the requested information. Also, depending on definitions made and scales used in order to gather the information, it might be difficult to estimate the reliability of the secondary information. Primary information, which usually is gathered by direct observations, interviews or experiments, can on the other hand be affected by e.g. an observer's influence on an information source, misunderstandings of purposes and inaccurate measurements. [23]

There are two main methods for gathering of information - the qualitative and the quantitative method. The last-mentioned, which often means a great number of measurements, assumes that the investigated factors are measurable so that the results can be presented numerical.[24] When you aim to explain "what kind of character" a

---

[22] Holme, Idar / Solvang, Bernt (1997), pg 50-52
[23] Arbnor Ingeman / Bjerke Björn (1995), pg 241-245
[24] Darmer / Freytag (1995), pg 124-125

phenomenon has rather than "how much" of something it has and a comprehensive picture is wanted, a qualitative method is more appropriate. Since this kind of method often is based upon only a few sources, the possibilities to draw general conclusions are limited.[25] Since our project requires both flexibility and adaptation to existing material handling systems, mainly the qualitative approach will be used in this thesis.

2.1.4 Criticism of methods and information

During scientific investigations it is important to question not only the decided methods but also the results that come out from them. First, a requirement for results of a scientific research to be considered as describing actual conditions is that the observed facts are *reliable*. This means that about the same results should be found if the same phenomenon is measured in another/similar way. Furthermore, it is desired to get results that correspond with reality as far as possible, also referred to as having a high level of *validity*. This actually does not have to be a consequence of a high reliability. If e.g. two different measurements are made, each with some kind of misunderstanding of the conditions, both can reach the same incorrect conclusion and thereby a high reliability but a low validity. A result with high validity is reached when you measure the whole phenomenon that was intended to be measured and nothing else.[26]

2.2 Choice of methodology

Since this is a study with focus on finding and implementing practical solutions in a material handling system, the method used is a bit different from what is common when writing an academic report. The figure below (see Figure 6) aims to explain that, by illustrating the main steps of this study's procedure.

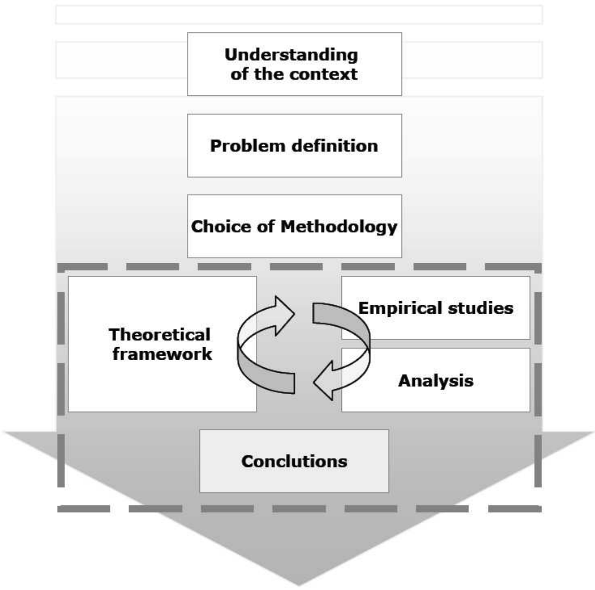


Figure 6: *Illustration of the method used in this study*

[25] Johansson, L-G (1999), pg 65-66
[26] Andersen, Heine (2000), pg 90-93

This thesis will be carried out as a development project, where the methodology is based upon the fact that several alternative solutions are developed. Also, along the process development loops will be conducted, where we move backwards in the development process and then work through certain areas again. The purpose with this methodology is to ensure that the most important factors are taken into consideration when evaluating the different alternatives and that, for the present task, the optimal solutions are chosen. This implies that we continuously have to make analyses during our work. Hence, the methodology will consist of several loops where analysis and empirical studies interact. Since it is possible that circumstances affecting the project can change and thereby change different conditions of the project, this development-loop based methodology ensures that the result of this thesis is not obsolete before it is finished.

As mentioned before, this thesis concerns areas where many conditions and parameters are unknown and also are likely to change along the project after being determined. In situations like that it is common to initially base the scientific work on qualitative methods, and eventually start using quantitative methods.[27] That procedure will also be used in this thesis. Regarding overall disposition, the work in this thesis will be presented in chronological order, to show the cause of event as logical as possible. The first three steps of the model above have already been explained, why this part of the chapter aims to explain the remaining steps, inside the dashed box.

2.2.1 Literature study

After being given the assignment by Tetra Pak, the project was started by information gathering about general material handling systems and packaging logistics. This information was found in books and articles as well as on the Internet. When seeking on Tetra Pak's internal database, little information was found concerning our specific assignment, why it became clear that this project would mean the development of something new to the company. Therefore, the next step became finding information about how to create new ideas and solutions, nowadays referred to as Idea Management. Tetra Pak R&D, with more than 50 years of development experience, proved to be a good source in this aspect.

In order to create a structured and scientifically approved way of working, it is important to choose methodology at an early stage. This was done after having read a number of methodology literatures.

2.2.2 Idea management

The first step in this part of the study, was defining what kind of logistical *needs* that would have to be fulfilled in this project, both from Tetra Pak's and future customer's point of view. To be able to do that it was necessary to define possible steps along the SCAP-top's value chain and create different logistic scenarios. After having done that the needs were used as input to an *idea generation* period. The purpose of this was to create a good understanding of the project as a whole, lift out important problems and to find a lot of ideas concerning specific areas as well as for the overall material handling system.

[27] Darmer / Freytag (1995), pg 127-128

Many different variations of idea generation, in Tetra Pak referred to as brainstorming, exaggeration, negative idea generation, trigger cards etc., were used.

In order to focus the further work on only a few ideas we then conducted a *screening* session, where the least interesting ideas were rejected. These ideas (or solutions) were then *evaluated* and compared by using for example the Kesselring matrix (see chapter 3.4.2.3).

It should be mentioned that the idea management work is very extensive and that it in this case has been carried out along the whole project, parallel to other activities. It is also something that, from our experience, should be carried out in loops in order to get the best possible results out of it. This means that it is more difficult to talk about a clear chronological order when idea management is a part of a working method.

2.2.3 Interviews

As mentioned before the qualitative approach will mainly be used in this thesis. This approach emphasises on a deeper understanding of the studied subject than a quantitative approach. Performing interviews is a common method for collecting this kind of information. In order to understand the context and the environment of the material handling and logistical system, a lot of information concerning the different, now existing, activities and resources were needed. This also includes the possibility to calculate on how different alternatives of this system affect e.g. cost and effectiveness of the total supply chain. A number of interviews were thereby carried out through the work of this thesis; face-to-face as well as by telephone and e-mail. This also means that our results to a large extent will be based on *primary information* gathered from Tetra Pak employees, retailers of material handling equipment and packaging solutions, consultants, haulage contractors etc.

The interview situation is a communication process where two or several persons affect each other. This is inevitable, but it is important to be aware of it and thereby hopefully reduce the influence.[28] A way of doing so is to let the interviewee talk freely and not to ask leading questions.[29] This is also referred to as non-structured[30], in addition to structured, interviews. By this reason, and the fact that we have worked closely with the interviewees, most interviews were informal and based upon a few main points, which gave the interviewee the opportunity to freely express him/herself. It also gave us the opportunity to ask relevant resulting questions. The interviews were documented by making notes.

2.2.4 Observations

We have had the benefit of being situated at Tetra Pak R&D in Lund during the writing of this report. Thereby we had always the opportunity to study the EBM-machine and the filling machine, as well as the now existing supply chain of carton material. By solely be in the environment in which the system will be existing, observations could be done which otherwise would have been missed. A "feeling" of how the other components of

[28] Andersen, Heine (2000), pg 80
[29] Holme, Idar / Solvang, Bernt (1997), pg 105
[30] Andersen, Heine (2000), pg 84

the supply chain works that can not be explained solely in numbers and specifications of demands were obtained. This also gave us the opportunity to informally ask questions and speak to the persons working at the different operations. Most observations where carried out according to what Arbnor and Bjerke (1994) refer to as *participating observations*.[31] This means that the observed individuals where aware of the fact that they where observed and the observers (our) interaction with the observed individuals where high. These informal chats also made it possible to triangulate the information gathered by the interviews. In this way the reliability of the information gathered could be increased.

2.2.5 Experiments

In order to evaluate different primary packages for the SCAP-top distribution, a number of experiments where conducted. First, we had to gather information about the characteristics of the products that should be distributed, the SCAP-tops. Experiments were carried out to determine the filling rate[32] of different top sizes and top shapes. Conclusions about whether it is the shape or the volume of the top that determines the filling rate where also made. We are aware that the chosen methodology, the system approach, does not allow experiments as a way of gathering primary information. The reason is that a correct experiment in an analytical sense requires two exactly similar start situations to be produced. Furthermore, the independent variable shall explain the change of the dependent variable, with all other factors constant. The system approach denies partly the possibility to find two exactly similar situations, partly the ability to argue in terms of causal connections with all other factors constant because all factors in the system are supposed to be affected by several variables in the system.[33] Nevertheless, the experiments were made in order to give indicators of the characteristics of the SCAP-tops.

Secondly, information had to be gathered of how different alternatives of primary packaging affected the SCAP-tops. Therefore, transport simulations and storage tests where conducted.

2.2.6 Analysis

It is common in scientific research to have a phase of experiments or some other kind of method of gathering information followed by a separate phase of analysis. Because of the nature of this thesis however, with focus on idea management and thereby constant checkpoints along the process, no separate period/phase of analysis work was conducted. Instead, there has been many, small analysis sessions along the way, which has been necessary to be able to proceed with a reasonable amount of solution alternatives for the different problems (in this thesis). The analyses are often based on qualitative facts that mostly help creating a picture of the problem and therefore lead to decisions based on common sense rather than concrete facts.

[31] Arbnor, Ingeman / Bjerke, Björn (1995), pg 242
[32] SCAP-tops/m^3
[33] Arbnor, Ingeman / Bjerke, Björn (1995), pg 244

Towards the end, however, a separate economic analysis was made in order to get a comparable cost picture of the final alternatives. This analysis included calculations of both investments requirements and running expenses such as material purchase, salaries, maintenance and capital costs. Finally, an overall analysis using the Kesselring method was conducted, which made it possible to take non-quantitative factors into consideration in a well-founded way.

3. Theoretical framework

The first part of this chapter presents the theory related to the subjects packaging and logistics. It focuses on the areas that are closely linked to this thesis. The second part describes the theories behind the methods and working tools that have been used.

3.1 Introduction

Traditionally, packaging and logistics have been regarded as two separate and independent subject fields. Both packaging and logistics are well-established disciplines and much literature and research projects, finished as well as on going, can be found on the separate subjects. But the focus is almost solely on either packaging or logistics. A usual way of looking at packaging is to presume that it is an isolated activity, separate from storage, handling and transport. A reason for having this view is the traditional way of presenting the packaging cost as the direct packaging material cost without taking the impact of packaging into consideration.[34]

According to Bjöörn[35], the cost of packaging at Volvo is between 5 and 10% of the logistic cost but once a packaging is selected, this choice will affect about 65% of the overall logistic costs. Clearly, a relation exists between packaging and logistics and if the two disciplines only are looked upon separately important counteractions amongst them can easily be missed. On the other hand, if an integrated, holistic view is taken, it is not unthinkable that the result can be higher cost efficiency in the logistical system.

3.2 Packaging

Jönson[36] defines packaging as: *"Packaging is a mean of ensuring safe and efficient delivery of goods in sound condition to the ultimate consumer followed by an efficient reuse of the packaging or recovery and/or disposal of the packaging material at minimum cost."* This section investigates the packaging with the focus on paper as material, since that is likely to be the initial choice.

[34] Johnsson, M. (1998), pg 12
[35] Bjöörn, U. (1990)
[36] Jönson, G. (2000), pg 18.

3.2.1 Packaging levels

Packaging is often divided into primary, secondary (or transport) and tertiary packaging describing the different levels of packaging. If the distribution level studied is from the manufacturer to the consumer[37], the different levels of packaging can often be defined as:[38]

- Primary packages carry the actual product and serves as the interface between product and consumer both in the store and at home.

- Secondary packages, which is also referred to as the transport packages, contain several primary packages. The main objective with a secondary package is to make the primary packages stackable, impact resistant and easier to handle at transport.

- Tertiary packages are used to stabilize a number of secondary packages on a load carrier, e.g. a pallet, during transport. Common tertiary packages are i.e. shrink film, cardboard boxes and straps for stabilizing the load.

This principle of different levels of packaging is valid not only for the retail chain but also for the preceding B2B[39] and intern distribution of raw materials and non-assembled parts. However, these packages are often build up by larger unit loads and with none or very simple primary packages.

3.2.2 Packaging functions [40]

The packaging chosen for a certain product ought to be efficient in every step of the supply chain; in production, distribution, use and recovery. The demands of a packaging are for that reason often divided into three categories: protection, distribution and information.

Protection of a product is usually considered to be the most important packaging function. Since a product carries the value of not only the material itself, but also of all earlier steps in it's manufacturing chain, it is of course necessary to try to ensure that the product reaches the user in an agreed quality. The most common factors that can influence a product during the different steps along the value chain are mechanical, biological and environmental.

Facilitating distribution, both internal and external, is another very important function of a package. Uniformity and modularity makes it possible to work with standard dimensions such as the ISO standard nr 1 (EUR-pallet dimensions) dimensions 1200x800mm. Besides, the demand of modular packaging has a tendency to increase when mixed loads are used in transports.

---

[37] See Appendix A for definition
[38] Jönson, G. (2000), pg 19
[39] See Appendix A for definition
[40] Jönson, G. (2000), pg 24

The demand for information has become more and more important since the packages today must provide necessary information at the same time as it promotes the product. The industry actually works to eliminate information documents that accompany the packages, leaving the information to appear on bar codes directly the packages. This also goes hand in hand with the increased marketing thinking that packages are experiencing – being able to get a package to "stand out" and thereby make consumers interested in it, is coming more into focus.

3.2.3 Packaging materials

A variety of materials are used for packaging around the world, some with a history of thousands of years and some are new, specially designed materials for a certain purpose. The list of different packaging materials is long; hence we focus on the basic and most common material used in B2B distribution[41]: paper.

3.2.3.1 Paper

Paper has been used as a packaging material for hundreds of years, why a variety of different types have been developed, i.e. wrapping paper, sack paper, carton and corrugated board. In this thesis we will only describe the two last mentioned since only these are relevant to the task. [42]

Carton

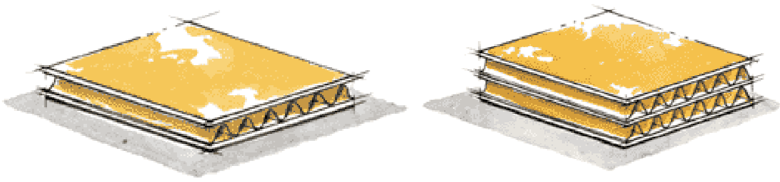
The raw material for carton is wooden fibre. The fibres make the carton stiff and strong and render manufacturing of stable packages even with very thin layers of carton possible. By lining the carton with a thin layer of clay, the surface gets smoother and more water resistant. The surface of the carton is also suitable for lamination with plastics and aluminum foil. This is done when packing liquid products because an untreated carton does not withstand moisture. Several different methods exist for manufacturing carton and which method is chosen depends mainly on what type of wooden fibre that is used. [43]

Corrugated board

In 1871, the American Albert L Jones got the first patent on corrugated board. Since then only minor changes have occurred in the design despite of the fact that corrugated board today is one of the most frequently used packaging materials in the world. At the same time as having a low consumption of material, the construction combines both strength and stiffness with flexibility and shock resistance. These features are achieved by combining two plain layers (liners) of carton with one wave shaped layer (flute), which is placed between the plain layers. When the flute is anchored to the linerboards with a starch-based adhesive, they resist bending and pressure from all directions. In this way a lightweight crossbar design (see Figure 7) is accomplished. [44,45]

---

[41] *Fakta om förpackningar och miljö* (2001)
[42] ibid
[43] ibid
[44] ibid
[45] *Fibre Box Handbook* (1999)



(a) (b)

Figure 7: *Single wall and double wall cardboard.*[46]

When a piece of corrugated board is placed on its end, the flute forms rigid columns, capable of supporting a great deal of weight. When pressure is applied to the side of the board, the space in between the flutes acts as a cushion to protect the container's contents. The flutes also serve as an insulator, providing some product protection from sudden temperature changes. At the same time, the vertical linerboard provides more strength and protects the flutes from damage.[47]

Corrugated board come in several standard shapes depending on the demands that the product put on the packaging. Fundamentally, the factors that have an effect on the characteristics of the corrugated board are the *number of liners and flutes, the profile of the flute* and *the quality of the carton*. Starting with the flute profiles, A-flute was the first to be developed and is the largest common flute profile. B-flute was next and is much smaller. C-flute followed and is hence between A and B in size. Table 1 shows the standard flute range from A to G.[48]

Table 1: *Different flute sizes.*[49]

Flute	Flute height [mm]	Nr. of flutes/m
A	4.8	110
C	3.6	130
B	2.4	150
E	1.2	290
F	0.7	350
G or N	0.5	550

In addition to these six most common profiles, new flute profiles, both larger and smaller than those listed here, are being created for more specialized boards. Generally, larger flute profiles deliver greater vertical compression strength and cushioning. Smaller flute profiles provide enhanced structural and graphics capabilities for retail packaging.[50]

Different flute profiles can be combined in one piece of corrugated, combined, board. For instance, in a double wall board (see Figure 7b), one layer of flute might be B-flute while the other layer may be C-flute. Mixing flute profiles with up to 4 layers of flutes in

---

[46] *Fibre Box Handbook* (1999)
[47] ibid
[48] *Fakta om förpackningar och miljö* (2001), pg 9
[49] ibid
[50] *Fibre Box Handbook* (1999)

this way allows designers to manipulate the compression strength, cushioning strength and total thickness of the combined board.[51]

When the corrugated board is finished the next step is the conversion, where the board is processed to make it easy to fold into a box. When the box is slotted in the conversion process, material is cut away to shape the box and when it is creased an indentation for the fold (into a box) is made. Two types of boxes are the most common: slotted boxes and die-cut boxes. The slotted box is a double folded corrugated sheet, which simply folds into a four-sided box. The bottom flaps are sealed and the box is ready for packing. The die-cut box is a simple sheet of corrugated board, which can be in any number of shapes: from a sheet that is wrapped around the goods to a box consisting of several parts, e.g. lid and bottom. Both slotted and die-cut boxes can be erected manually or in automatic packaging machines.[52]

3.3 Logistics

3.3.1 Logistical systems

Transportation of objects between different locations is often illustrated by network models containing *sources* and *sinks*. Sources are points in a network where material is produced and therefore a material flow starts out from, whereas sinks are points where material is consumed and therefore the destination of a material flow. By connecting all of these points to each other and to *terminals*, points where transshipment occur, it is possible to get a theoretical model which describes the movements of goods in a distribution system (see Figure 8a). Since the main issue with distributions systems is to stipulate how many objects that should be transported from the sources to the sinks in the model in order to reach a maximum of profitability and utilization of resources during the current conditions, network models can be very helpful tools. [53]

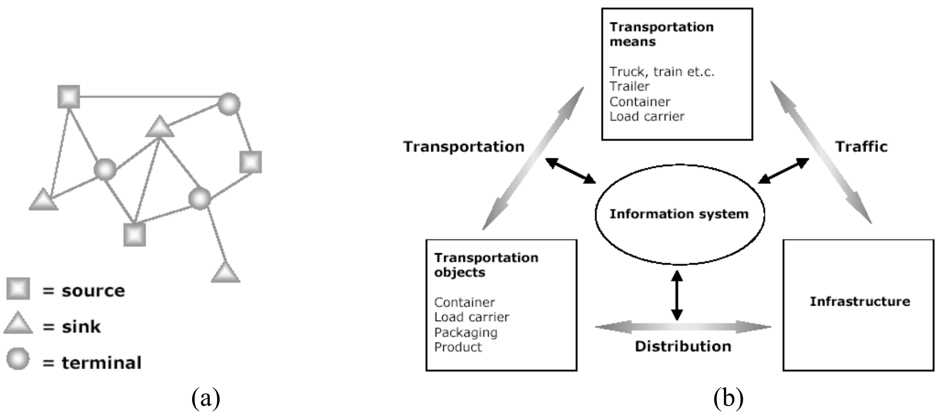


Figure 8: (a) *Illustration of a network model.* (b) *Illustration of the logistical components that build up the overall logistic network model.*[54]

---

[51] *Fibre Box Handbook* (1999)
[52] Schönbeck, Olle, *Boxing – The Noble Art of Packaging*
[53] Tarkowski, Jerzy / Irståhl, Bo / Lumsten, Kenth (1995), pg 201-204
[54] ibid

In order to get a better picture of overall logistic systems with movements of goods, it is appropriate to start out from a system approach. The figure above (see Figure 8) illustrates how such a model can look, in this case built on three sub systems marked by gray arrows: one distribution system, one transportation system and one traffic system. These sub systems handles three kinds of fundamental elements: transportation objects, transportation means and infrastructure. Holding the different parts together, an information system is placed in the center of the model. By using both of these kinds of models together, analysis of how goods are transported, what activities occur and how information affects the flow can be done. [55]

Co-ordination of good flows mean that different flows become dependent of each other, and this can be done theoretical in many ways. In its simplest form, the co-ordination is about bringing many flows with the same direction together to a single flow. Practically, this occur when small flows of goods are added to greater ones with the same direction, even though they only travel a limited distance together and thereby does not have the same final destination. Another kind of co-ordination occurs when flows with a common direction are mixed with flows with an opposite direction, which often is the case with return transports. This kind of co-ordination implies that the transportation flow must be modified in some way, often so that the stake of resources that was needed for the transportation diminishes. Co-ordination in general can in other terms be a measure to adjust unbalance in goods flows, even though it does not necessarily have to be in a positive direction. [56]

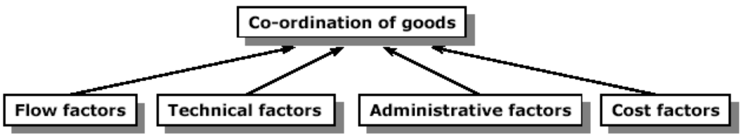


Figure 9: *Illustration of the summarized factors that have to be fulfilled in order to reach a useful co-ordination.*

If co-ordination of goods flows is to be considered as possible in practice, there are usually a number of conditions that have to be fulfilled, which can be divided into the categories flow factors, technical factors, administrative factors and cost factors (see Figure 9). Concerning flow factors, it is first of all important that the flows are extensive. The necessary size of the flows that are tried to be co-ordinated can normally not be determined in advance, why estimation with focus on the dominating, existing flows must be done. Also, it is desired to have as small differences in the frequency of the transports as possible and to find the goods that are being shipped from and delivered to the same location. It is sometimes acceptable to have a certain spread concerning the locations involved and still work for co-ordination, but reorganizing and thereby moving parts of an organization can also be an interesting opportunity.

Closely linked to the flow factors, there are a number of technical restrictions that can play an important role in co-ordination. The most important one is usually considered to be the aim for one common load carrier for all goods, or at least versions that mean

[55] Tarkowski, Jerzy / Irståhl, Bo / Lumsten, Kenth (1995), pg 203-208
[56] Tarkowski, Jerzy / Irståhl, Bo / Lumsten, Kenth (1995), pg 210

common carrier systems for as large groups of goods as possible. This can be heavily affected by the characteristics of the goods.

The last two factors in the model are administration and costs. Administration of co-ordination, to start with, is today often handled by a transport company or a shipping agent. A consequence of that is that relations and attitudes in partnership become more and more important, which in the long run also affect the costs. A high level of close co-operation with administrators can result in efficient transports and thereby low costs, but also a higher service level towards customers that can result in higher receipts.[57]

3.3.2 Production Logistics

Design and planning of a production system, which is the total system of production and internal distribution of a product, involves decisions concerning the production process and the layout of the plant. The objective is generally to achieve a high utilization of capacity, short lead times and a high level of flexibility with respect to the products that are to be produced and distributed. The internal material handling systems is a part of the total production system, hence it must be designed to interact with and support this system.[58]

3.3.2.1 Factors influencing the choice of material handling equipment

According to Lumsden[59] a number of factors should be taken into consideration in the design process of a new material handling system:

- The product
- Transport frequency
- Possibility of mechanization
- Technical demands
- The direction of the material flow

The product

The features of the material, the product, that is to be moved generally has the most significant influence on the choice of material handling equipment. A number of characteristics of the product can be pointed out as critical:

- Volume
- Weight
- Length
- Size
- Shape
- Fragility
- Consistency
- Aggressiveness (chemical-)
- State (e.g. hot or cold)

How the material handling system shall be designed depends thus on the unique combination of the products characteristics. These together determine the manageability of the product. Often one or a few characteristics are dominating, or the "weakest link" of the product, and thereby define the material handling system. A complicated issue

[57] Tarkowski, Jerzy / Irståhl, Bo / Lumsten, Kenth (1995), pg 211-215
[58] Knudsen, Daniel (2002)
[59] Lumsden, K. (1998)

arises when the products characteristics are changed (which in fact is common) during the flow in the plant. Then different material handling equipment have to be used in different steps of the process.

Transport frequency

The transport frequency is the intensity of which transports occur in the plant. When analyzing this frequency it is important to notice whether it is constant or fluctuating. If the flow is constant and uniform the material handling equipment can precisely be adapted to the transport frequency that in turns increases the ratio of utilization. However, the frequency is seldom constant but changes due to seasonal variations, trends or simply irregular volume of orders from the costumers.[60] In these situations the choice arise whether to dimension for the maximal frequency, which will be expensive and will imply low utilization of labor and equipment, or to dimension for the average value, which on the other hand will mean long stops and delays at high transport frequency. Obviously the solution is a trade-off that preferably is based upon a profound cost analysis.

Possibility of mechanization

The demand for a sound working environment and for stimulating working tasks together with increasing direct and indirect labor costs contribute to the generally growing amount of mechanized production/material handling lines in the industrialized countries around the world. But the most conclusive reason for the growing mechanization is the constant strive for cost reduction and time efficiency. Traditionally the interest for industrialized mechanization has been focused on tooling processes because these have been easiest to imitate. Assembly, storage and transportation is now the challenge for further mechanization.[61]

Technical demands

Certain demands, wishes and requirements from the operator, or from the customer of the system, put technical demands on the material handling system. A number of such demands can be defined in a specification of requirements. This document often deal with factors as:

- Reliability in operation
- Environmental effects (e.g. noise level, risk for personal injuries)
- Maintainability (e.g. accessibility, replaceability)
- Resistance against external environmental effects

---

[60] Axsäter, Sven (1991) *Lagerstyrning*. Studentlitteratur. Lund.
[61] Lumsden, K. (1998) *Logistikens grunder*. Studentlitteratur, Lund.

The direction of the material flow
The demand for a continuous material flow through the production plant can lead to a material handling layout that is divided into several different solutions, depending on the dimensions of the plant as well as where bottleneck operations are situated. Straight (see Figure 10a), divergent or convergent (b), returnable (c) and overtaking (d) flow are usual variations which all have their benefits and drawbacks.

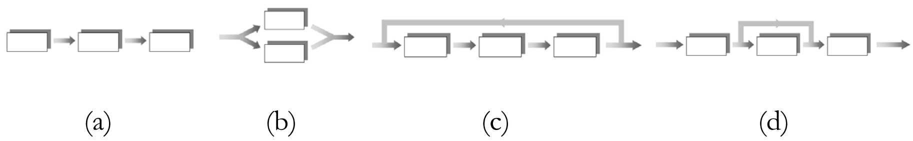


Figure 10: *Different types of flow in a material handling layout.*[62]

3.3.2.2 Tied up capital

Material that is stored in stock, in production or as finished goods ties up capital. The cost for this tied up capital depends mainly on the cost of capital, i.e. the financing of procurement of raw material. Additionally though, costs for warehouse area, material handling equipment and personnel, insurance of material in storage, obsolescence etc. add up to the total cost of stored material. During the gradual product processing the tied up capital of the product increases since different resources are used along the way. Hence, the product ties more and more capital on its way to the customer.[63]

Figure 11 shows how costs for tied up capital can be minimized by reducing the storage of finished goods. However, when doing so the safety level of the storage is also reduced and orders will more often be delayed or not fulfilled, leading to unsatisfied customers.[64] Hence, the solution is either to find an acceptable safety level and thereby an acceptable level of delayed orders, or to continuously improve the production and handling processes which leads to shorter lead times and a reduced need of storage of finished goods.[65]

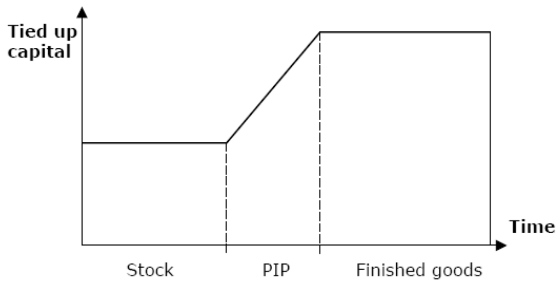


Figure 11: *Schematic description of how the tied up capital changes in storage (stock and finished goods) and production (PIP = products in production).*[66]

[62] Lumsden, K. (1998)
[63] ibid
[64] Axsäter, Sven (1991)
[65] *Tillverkningssystem* (2000)
[66] Lumsden, K. (1998)

3.3.2.3 Production effectiveness and lead time

As mentioned in the earlier chapter, a reduction in lead-time not only in the production but in all included parts of the supply chain means less storage and also often better customer service.[67] The lead-time is defined as the time between an order is placed by a customer until the product has been delivered and includes therefore all activities within this chain of actions. Standardization of processes, simplification of set-up procedures, more efficient scheduling, procurement of integrated processing machines etc are possible changes that can shorten the lead-time.[68]

Within and between activities waiting times can occur depending on queues. The waiting-times often amount to between 95 and 99,5% of the total lead-time. Furthermore, intermediate storage or buffers occur which also add to the total lead-time. It is often argued that the imbalance between processing-time, transport-time and waiting-time is the reason for long lead-times and it is obvious that much can be done within the industry to improve this balance and thereby reduce lead-times and storage levels.[69]

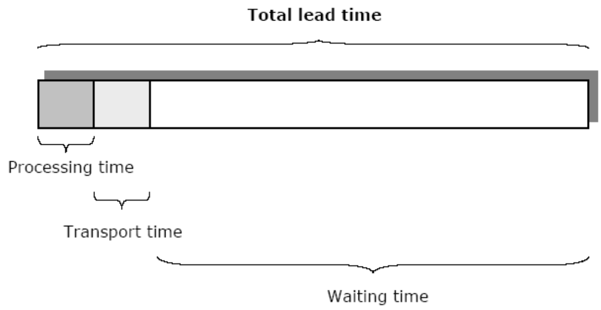


Figure 12: *The components of the total lead-time.*[70]

3.3.3 Distribution in the EU

In January 1:st 1993, the twelve members of the European Community (later changed to the European Union) formed an internal market in order to make it possible for people, goods, capital and services to move freely over the nationality borders. This meant great changes for the economy, and thereby also for the transport industry, not only by improved conditions for locating of industries, development of common distribution systems, ability to compete on new markets, warehousing and information systems, but also by factors regarding psychology, trends and expectations.[71] Since the start of the SCAP project will include only Europe and the distribution of the SCAP-tops will demand quick, regular and light transports, we make the assumption that all transports will be handled by truck. This section will therefore only cover trucks as mode of transportation.

[67] Lumsden, K. (1998)
[68] *Tillverkningssystem* (2000)
[69] Lumsden, K. (1998)
[70] ibid
[71] *Internationell Distributionsteknik* (2003)

Truck appearances

What vehicle dimensions that are allowed for transports in, and between, the EU countries are regulated in the EU directive nr 96/53. However, the directive gives a EU member that fulfils certain requirements the possibility to allow special vehicles and vehicle combinations. For example, Sweden and Finland have used that possibility by allowing the so called "module system", with vehicle combinations up to 25,25 m length. An extract of the general EU regulations of trucks are displayed below (see Table 2). [72]

Table 2: *Extract from the EU directive nr 96/53, which regulates dimensions and weights of trucks.*

Section of EU dir. 96/53	Factor	Max value of factor
1.	**Max dimension of vehicle**	
1.1	Length	
	- motor vehicle	12,0 m
	- trailer	12,0 m
	- articulated vehicle	16,5 m
1.2	Width	
	- all vehicles	2,55 m
1.3	Height	
	- all vehicles	4,0 m
2.	**Max weight of vehicle**	
2.1	Weight of vehicle that is part of a vehicle combination	
	- two-axled trailer	18 tons
2.3	Weight of motor vehicle	
	- two-axled motor vehicle	18 tons
	- three-axled motor vehicle	25 tons

Apart from these technical restrictions, transportation by truck inside the EU is surrounded by a number of laws and regulations concerning working time for the drivers, overloading fees, speed regulations, trip logs, load-settlement curves and securing of goods. [73]

Damages with transport by truck

The largest amounts of damages in truck transport appear during manual handling at loading/unloading and stowing. Few damages appear during the actual transport when the goods just stand in a cargo space, but even the manual handling is normally included in the transport and is therefore also to be considered as transport damages. However, the damages that do appear during the actual transport is not to be ignored, which the following rule of thumb indicates:

The number of damages is greater at manual handling than at the actual transport,
but the damages that appear at the actual transport are more costly.

A hint about the magnitudes of transportation damages can be found among the Nordic countries, where the transportation of non-sensitive goods on well-developed routes has

[72] www.vv.se/yrkestraf/regler/gods (031120)
[73] ibid

a damage rate of 0,25%. If different modes of transportation are involved, in cases of for example mixed cargo or many long-hauled transports, the damage rate is higher. [74] [75] Apart from where in the distribution chain damages occur, it is relevant to have insights about what part of the good that is most likely to be damaged so that preventive actions can be taken. A five years old study concerning shipments of furnaces (both complete and non assembled) show that 40% of the damages occur at the bottom. In total, about 70% of all damages were caused by rough handling, such as bad handled forks or drops, and the remaining 30% by vibrations during the actual transport. [76]

The costs for these kinds of transportation damages are usually divided into two groups, direct and indirect. The direct costs refer to the costs of the good that was damaged and the extra handling that is needed, while indirect costs refer to costs due to lost customers, reduced goodwill, production disturbances etc. During a workshop in Brussels in February 1996, it was estimated that the direct damage costs only represent the tip of a cost iceberg and that the indirect costs, caused by inadequate packaging or transportation, has become an increased problem for companies, as the fight for market shares is getting tougher. [77]

3.4 Working tools

This chapter presents the theory about the different working methods that have been used in our thesis. The main part concerns idea management, which concerns how new ideas are developed and realized.

3.4.1 QFD – Quality Function Deployment

Quality function deployment was developed in Japan by Shigeru Mizuno and Yoyi Akao in the 1960s under the umbrella of total quality management (TQM). In the 1980s and 90s the method spread to the USA and Europe and is now a method used worldwide in a variety of industries.[78]

QFD is a structured method for translating customer requirements into appropriate technical requirements for each stage of product development and production.[79] The method is a guideline for developing a design aimed at satisfying the costumer. Instead of minimizing negative quality, as traditional quality systems do, QFD focuses on costumer requirements and maximizes positive quality that creates value.[80]

---

[74] Trost, Thomas (1988), [report nr 121] pg 14-17 & 31
[75] **Notice**: Even though the figures that this report is based upon are 15 years old, they give a fair picture of today's situation according to original author Thomas Trost 031119.
[76] Trost, Thomas (1998), [report nr 183] pg 27
[77] Trost, Thomas (1998), [report nr 183] pg 8-9
[78] Akao, Yoji / Mazur, Glenn H. (2003), pg 20
[79] Johnson, Corinne N. (2003) pg 104
[80] www.qfdi.org (030808)

3.4.1.1 Conducting the house of quality

The method is conducted by cross-functional work of a group consisting of personnel from different departments of the organization, e.g. marketing, product planning, construction, production and service. All gathered data that is collected are put together and documented in matrices witch in turn together constitute the "house of quality"[81] (see Figure 13). It is important that the different matrices are filled out in a certain order to obtain an unbiased result. First the customers are asked for their opinion and preferences about the current product and the different requirements are rated. These opinions are then first evaluated in comparison to competitors' products on the market, and then interpreted into technical product measures. Depending on the correlation between the specifications rating and the costumer requirements of the product, the method lifts out what characteristics are the most important in the development of the product. The knowledge of these characteristics early in the development process helps to eliminate expensive changes of the product after the market introduction.

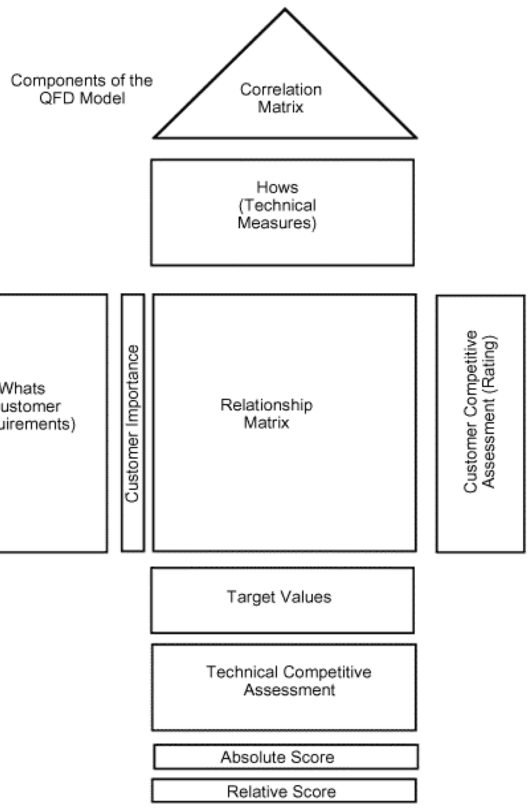


Figure 13 : *A schematic description of the different parts of the QFD model.*[82]

[81] Akao, Yoji / Mazur, Glenn H. (2003), pg 25

[82] www.masetllc.com/products (030808)

3.4.2 Idea Management

Superb products, in this context new ones, that delights customers and propel manufacturers to market leadership and increased profits, do not come into existence over a night or by coincidence. They are the result of a long term work, driven by a high-level process often called product creation, which is made of six interlocking and mutually reinforcing sub processes (see Figure 14).

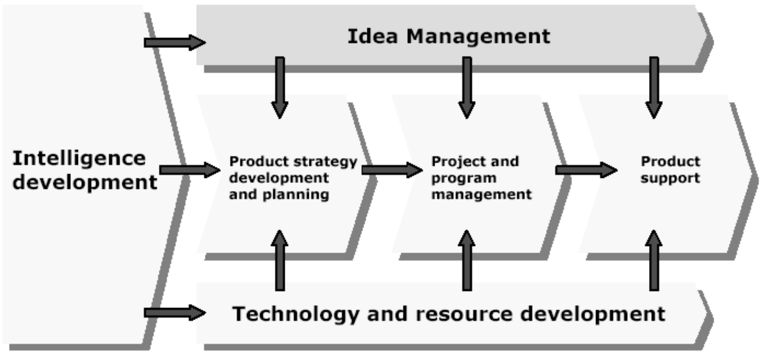


Figure 14: *The processes in product creation.*[83]

These sub processes should work together in balance, with intelligent development as a base, forming a structure that leads the way to a well worked-out and competitive company environment. Even though the intelligence enriches the soil from which ideas will grow, product creation cannot be fed ideas at random, in a scattershot manner. In today's society, where the turnover of new products continues to increase, idea management has therefore become more and more important. Through this process, that contains three main steps (see Figure 15), companies generate, collect, evaluate, screen and rank ideas continually. This chapter will focus on the second step. [84]

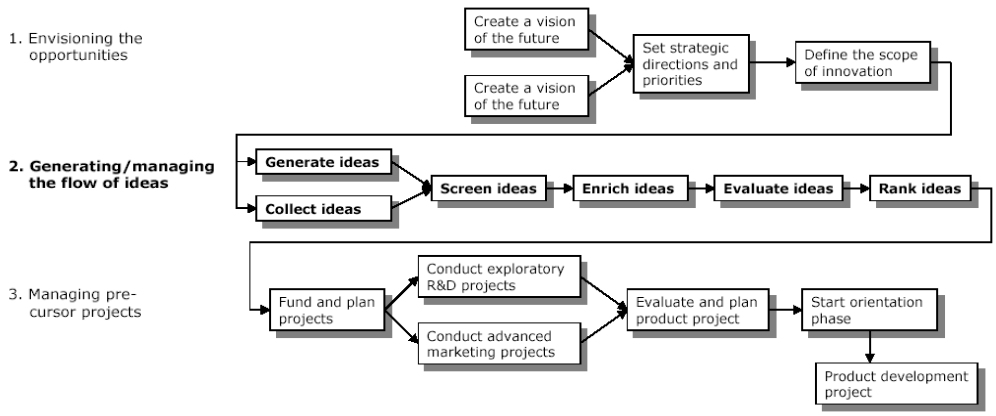


Figure 15: *Overview of the Idea Management process.*[85]

[83] Deschamps, J-P (1995), pg 12-15
[84] ibid
[85] ibid

3.4.2.1 Defining the needs of a new product

The first step (or phase) of the idea management process concerns the creation of an environment where innovations easily arises, and is something that constantly has to be developed. When an overall vision is set, the strategic direction and priorities for the creation of new business is established, usually only as a broad corporate development guideline. Even though the definition of strategic priorities for innovation clearly is a top management responsibility, it can be desirable to also set up a so-called strategy board, containing for example heads of marketing and R&D, with a dedicated agenda to steer the innovation process. The strategy board should focus on two missions, with the innovation areas determined of top management (see Figure 16) as a starting point: formulating an innovation strategy and supervising innovation programs. [86]

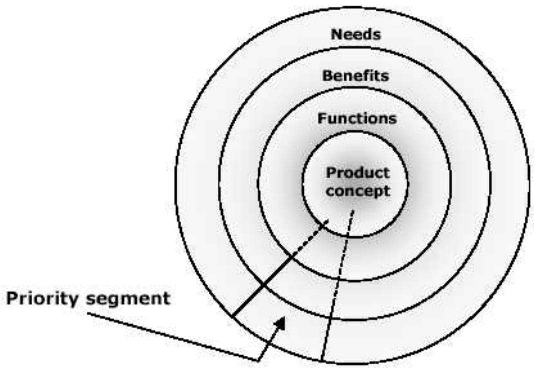


Figure 16: *Mapping prioritized innovation areas.*[87]

When a specific innovation project is launched, one of the most important things in the beginning is to define the needs of the new product. The needs should be as comprehensive as possible, including factors to reach customer satisfaction, gain competitor advantages and make company profitability possible. As the needs become the target to which the work is aimed, it is important to try to verify the needs in practice. Also, a presentation or control list should be made, in order to keep the needs in a way that facilitates monitoring and modification, if the circumstances of the project change. This is made preferably by setting up a relation matrix, where needs of the same character are put together in clusters and the relations between them are determined. [88]

3.4.2.2 Idea generation

The second level of the idea management process is also called seeding. It is rarely fully recognized and therefore seldom structured or managed, with exceptions for R&D divisions/companies. The seeding process begins with the generation (and/or collection) of ideas, an activity that, because it involves getting people creative and thinking in new ways, is associated with difficulties that often are underestimated. [89]

[86] Deschamps, J-P (1995), pg 135-137
[87] ibid
[88] Tetra Pak's internal database
[89] Deschamps, J-P (1995), pg 137-138

A common name for the process of generating ideas is brainstorming. Surveys show that many businesspeople see brainstorming as a check box or a threshold variable, like "Can you ride a bicycle?", and thereby overlook the possibility that brainstorming can be a extremely useful and powerful skill.

There are many methods for conducting idea generation, of which we will describe the ones we have been in contact with briefly;

- **Associations:** A powerful idea generation tool when dealing with focus areas that help the participants to associate very freely. First, one of the participants is asked to say a word – any word. The word is written down on a whiteboard, and then the next person is asked what he/she thinks of when hearing the first word. That word is then written down and the procedure is continued until the group has created 30-40 different words. Finally, the participants are asked to "bounce" the gathered words one by one against the problem definition, making the group associate new ideas.

- **Brain faxing:** This exercise, which normally is done from a negative scenario perspective, is quite easy to conduct. After having explained the negative scenario, the participants are split up into sub-groups. Every person writes down a possible reason why this scenario could happen and then they "fax" away the sheet to another participant who writes down (on the original) one avoidance idea. Then they "fax" it away to the next person who has to come up with another reason and so on. After having done that a couple of times the faxing stops and a general discussion is held.

- **What if?:** A useful method when you need to "get out of the box" and look into the subject/issue/problem from different angels, such as persons, professions, brands and so on. It starts with a presentation of the problem/theme and asking the participants to suggest different "What if…?" perspectives - the more crazy the better. Then, after giving every perspective a post-it colour of there own, the participants are asked to create ideas, one perspective by one, on the post-it notes and place them on the wallpaper/white board. A high tempo is very important. When the energy of one perspective feels low, a total different perspective is chosen.

- **Exaggeration:** This is a good method for product/service development. The purpose is to exaggerate all things concerning the problem/theme or the thing that you are trying to improve. After a presentation of the problem/theme, the participants are asked to exaggerate different features and functions of the product/service or the theme itself. All suggestions are written down on a whiteboard, and the suggestions are then used to generate ideas of how to improve the product/service in a positive way.

- **Negative idea generation:** This technique uses the power of humour as a jump-off point to get great ideas. A positive focus area is presented and the group is asked to reformulate the focus into a negative sentence – something that usually creates a lot of laughs in the group. After 15-20 minutes the group is asked to start thinking about turning the negative ideas into positive ones, using many negative ideas as stepping stones to positive ideas rather then of just turning them around one by one.

- **Trigger photos:** Some people become triggered by words and some people are triggered by visuals. This technique is aimed at the second category and starts with a selected group of photos that can be totally random or picked with a specific association in mind. For one picture at the time, the participants are asked to first say what they see initially, and then what they see when expanding the view outside the photo. The photos can be rotated in the group and the exercise continued with the other senses (smell, taste, feel, sound etc). Finally, the group is given the focus question (need) and is asked to do new associations with help of the photos.

3.4.2.3 Screen ideas

Idea generation is valuable as long as the ideas are sorted, revised and further developed after the generation level. If no process is available to sort out the good or even excellent ideas from the bad ones, the whole intension with Idea Management will come to a halt. This is what the Screening process is about. As seen in Figure 17, the input of the process is a lot of unsorted ideas. Through a few steps these ideas are then clustered into groups, sorted, and evaluated. For those ideas remaining, investigations are done regarding usefulness of the ideas, correlation with the initial need etc. The output of the screening process is hopefully good, developed and sorted ideas described with text and sketches. An important part of the process, however, is to always be open for new ideas along the way. When working with the ideas, new ones will inevitably come up. In this way bad ideas are sorted out and new ones, which perhaps can be successful, are coming to the surface. Consequently, the quality of the ideas increase, while the number of suitable ideas are reduced. A possible procedure of a screening process is described below.

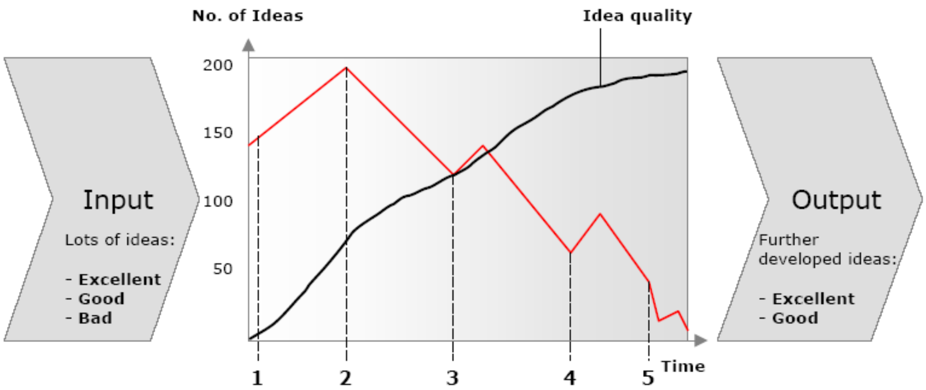


Figure 17: *A schematic description of the Screening process.* [90]

Step 1. Create clusters

The unsorted pile of post-it notes, which is the result of the idea generation process, must be classified and sorted to be easy to handle and overview. This can easiest be done by putting all the post-it notes on a white board. The participants then together sort the different ideas into clusters with similar solutions or ideas. At the end the participants together come up with headlines for every cluster.

[90] Constructed by information from Tetra Pak's internal database

Step 2. Compare ideas with the need
Although the need is clearly specified in the beginning of the session and all ideas are meant to fulfill this need, the openness and freedom of mind that the session brings will inevitably create a certain amount of ideas that are too ”far out” and hence will not fulfill the need. These ideas, which maybe could be excellent ideas in another application, must be removed.

Step 3. Matrix evaluation
In this step all ideas more or less fulfill the original need. To be able to compare and rank them in order to further diminish the amount of ideas to proceed with, a matrix can be used. Depending on what is the most important factor for the product that is to be created, different factors can be placed on the axis of the matrix. Common factors are possibilities of market penetration and fulfillment of the functional need. The post-it notes that end up in the upper right corner obviously fulfill these factors the best and hence these ideas will continue to the next step.

Step 4. Kesselring evaluation
With around 10-20 ideas left the next step is to halve this number. A more thorough evaluation than the matrix evaluation is the Kesselring evaluation matrix. This matrix is built up by the (around ten) most important factors for the product on one axis and all the different alternatives that shall be evaluated on the other axis. Each factor is weighted from 1-5 depending on how important this factor is considered to be. The different alternatives are then evaluated from 0-5 with the different factors and the grade is written down in the empty boxes in the matrix (see Table 9 for an example). When this is done the grade is multiplied with the weight of the factor and finally a summarized value for each of the alternatives is written down in the column to the right.

The 5-10 alternatives that have the highest summarized values have shown to be the best regarding all factors and thereby continue to the enrichment phase.

3.4.2.4 Enrich, evaluate and rank ideas [91]

So far every idea is very draft outlined. To be able to evaluate what idea is the most suitable for the project, further investigations about how to implement it and if an implementation is possible, must be made. This is what the enrichment phase is about. Once further investigations together with more thorough descriptions as well as drawings of the idea are made, the final evaluation can be initiated. This is done with the Kesselring matrix, as been described above, and in the end one winning idea remains.

[91] Tetra Pak’s internal database

4. Empirical studies and analysis

As mentioned in the methodology chapter, the empirical studies and the analysis will conflate in this thesis. Initially in this chapter, the scenario that has been used as a basis for our work is presented. Then, in chapter 4.2 the overall limitations and demands of a future material handling system, some determined by Tetra Pak and some by us, are discussed. In the following part, chapter 4.3, the first of two system development loops is presented. This includes working methods such as idea generation, screening and enrichment of ideas, presentation of ideas and whole system solutions, and finally evaluation and testing.

During development projects conditions have a tendency of changing along the way, which happened in this case. After a discovery related to the storage of SCAP-tops, a new system development loop as described above was therefore needed. The methods used for that and the results that came out of it are presented in chapter 4.4. In order to be able to compare different system solutions with measurable factors, a number of financial calculations are then made and presented in the following chapter.

The last part of this chapter concerns the choice of a single SCAP-top material handling system solution to be recommended to Tetra Pak. This choice is made after having weighted different criteria against each other in a Kesselring matrix.

4.1 Scenario description and system conditions

In order to be able to start thinking of the design and dimension of a material handling system for the SCAP-tops, it was necessary to have a production and customer scenario to work with. Tetra Pak provided us with the basic scenarios, but to match them with our ideas and the limitations of our thesis some adjustments were made.

4.1.1 SCAP-top production

As mentioned before, the SCAP-tops are manufactured in pairs by an extrusion blow moulding process. The pairs of SCAP-tops, henceforth referred to as "SCAP-tops"[92], leave the EBM-machine sitting together, forming a so called log, with a different amount of SCAP-tops depending of their height. When waste plastic has been removed and the SCAP-tops have been cut apart, they are placed in a capping machine, where an aseptic sealing process follows. The capped SCAP-tops finally leave the production unit rolling out on rails, ready to be packed.

According to the result of the preliminary study of SCAP-top production scenarios (see chapter 1.1.3), it is most likely that Tetra Pak will start by a central plant factory. This thesis therefore also assumes a central plant factory, placed in Dijon, France, which geographically is more or less in the center of the company's expected customers (see next chapter). The possible manufacturing capacity of this factory is shown below (see Table 3).

[92] If something refers to the SCAP-top that is needed for one package (half a double SCAP-top), "single SCAP-top" or "single-top" will be used.

Table 3: *Data for different EBM machine alternatives*

	Cycle time (s)	Log length (mm)	Logs/h	Top height 33mm			Top height 57mm			Top height 77mm		
				Single-tops/log	Capacity	SCAP-tops/s	Single-tops/log	Capacity	SCAP-tops/s	Single-tops/log	Capacity	SCAP-tops/s
Shuttle 2+2	10	344	1440	10	14400	2	6	8640	1,2	4	5760	0,8
Shuttle 4+4	10	344	2880	10	28800	4	6	17280	2,4	4	11520	1,6
Wheel	8	464	5400	14	75600	10,5	8	43200	6	6	32400	4,5

Efficency: 85% Shifts: 3 Yearly production: 47 w

The standard SCAP-top (also referred to as the "pilot test SCAP-top") in this thesis, the one we base our scenario on, has a height of 57mm and is manufactured in a wheel machine. When nothing else is stated, that is the one we assume. However, the SCAP concept is based on a flexible idea, which means that it for dimensioning etc sometimes will be necessary to take other SCAP-top models into consideration.

4.1.2 Customers

With the help of market experts, a future scenario for the customers of SCAP products has been estimated. The scenario starts with a field test in March 2004 and a commercial release in May 2005. At this point, a fully working logistic system for the handling of SCAP-tops, good enough to fulfill the customers' demand, must exist. About 3-4 years after introduction the production volume is expected to reach 1 billion packages with an estimated yearly increase of about 100%.

This thesis assumes, based on the future scenario mentioned above, seven customer locations around Europe (see Figure 18): Malaga and Pamplona in Spain, Paris in France, Berlin and Düsseldorf in Germany, Munich in Switzerland and Rome in Italy. The customers at these locations are assumed to have the same demand, which with an estimated total demand of 680 million single SCAP-tops makes 65 million single SCAP-tops per customer. Finally, no consideration will be taken of the fact that the mix between JNSD and LDP (see Appendix A) will mean that different SCAP-tops will be needed.

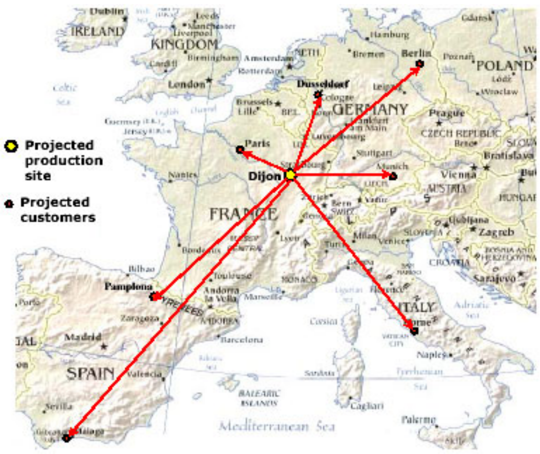


Figure 18: *Illustration of the assumed customer locations*

The scope of this thesis includes all SCAP-top handling up to the filling machine, placed in a filling hall at a dairy. The handling at the dairy site, which is the first step where the SCAP-top is in contact with Tetra Pak's customer, make great demands on flexibility since it is very likely that the SCAP filling machine will not be the only machine in the filling hall. It is common that the warehouse at a dairy that handles aseptic packages is separated from the filling hall in order to avoid bacteria and particles to damage the product being packed, and this risk is an important factor in this thesis.

In the pilot SCAP filling machine, which we have been in contact with, the SCAP-tops enters the area where the package is put together and are thereafter aseptically filled through a metal pipe. That pipe thus makes the outer system boundary of this thesis. To get the SCAP-tops in the pipe, the filling machine uses a vibrating table that orient them on their way to the pipe with one of the caps first.

4.2 Visualizing the overall material flow

The first step of our work was to get an overall view of what parts the SCAP-top material handling system would have to contain and what these parts would have to be able to do. This chapter presents these things, and is the result of an initial brainstorming process.

4.2.1 Supply chain model

After having studied the conditions of the SCAP-top production and listed a number of more or less necessary activities and resources, we constructed a simple supply chain model of the SCAP-top material handling system (see Figure 19).

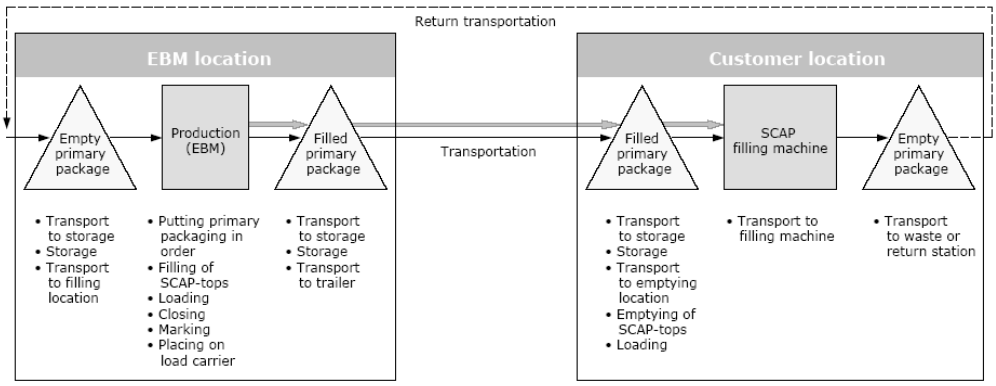


Figure 19: *Illustration of a supply chain model of the SCAP-top material handling system.*

The bold arrows represent the flow of the SCAP-tops, while the thin arrows represent the flow of the primary packaging. This model, although simple, gives a quite good picture of how the material handling of the SCAP-tops has to be looked upon. As mentioned before, the system boundaries of this thesis is chosen to be from where the SCAP-tops leave the EBM and capping machine to where the SCAP-tops enter the filling machine at a customer location. However, in order to be able to follow the SCAP-top along that flow, the model clearly shows that it will be necessary also to take into consideration the flow of the primary packaging, which has much wider boundaries than the SCAP-tops.

The activities written in the EBM and customer box (bulleted) can be placed in different order depending on how the system is designed. Each activity can also be divided into sub-activities, creating a large activity system with many possible combinations. By determining the lead-time for each arrow (transport), box (operation) and triangle (storage), it will be possible to calculate the total cycle time for the whole supply chain.

4.2.2 System needs and demands

When the necessary activities were listed and the overall supply chain model was determined, possible customer needs were discussed together with people from different departments at Tetra Pak. This was done in order to increase the understanding of the systems complexity and to make further choices easier. Below is a list of the system needs that we found most important.

Needs	
▪ **Flexibility**	The framework of the SCAP-project, which idea is to make a product that can be fit to please any customer why also the logistical systems behind the finished product must be flexible - *Module thinking*: standard equipment and materials should be used as much as possible - *Flow thinking*: material handling system must be able to adapt to already existing flows and to expand to fit greater volumes - *Automatization*: companies in industrialized countries will probably demand a higher level of automatization
▪ **Cost effectiveness**	A big part of the total cost of the SCAP-top will probably derive from handling, which makes cost effectiveness of the system extra important
▪ **Environmental friendly**	Handling (especially transporting) unfilled plastic bottles mean in itself that a lot of "unnessecary" air is transported, making the demands for environmental thinking even more important
▪ **Hygienic**	Since SCAP is an aseptic concept, hygienic factors become more important - aseptic dairies usually do not allow wooden products in the filling machine zone, why emptying of primary packages must be able to be handled outside the machine zone

When a new application is to be developed, it is important to have expected customers in mind from the very start. To do so we started to work with QFD (see chapter 3.4.1), with the aim of being able to create a specification of requirements for each activity in the supply chain model above, which would satisfy the customer. By doing so, you narrow the number of possibilities a bit, create a focus on factors that matter most to customers and therefore diminish the risk of putting a lot of effort on ideas that never will fulfill the system demands. However, we soon found out that working with QFD requires very good knowledge about the customers, something that we did not have and also was very difficult to get, much due to the fact that no customers exist yet. Furthermore, QFD theory says that it usually takes months of customer mapping before a house of quality can be properly constructed and the results from it can be assumed reliable[93]. Therefore, both the QFD forms and the specification of requirements that we put together turned out to be based exclusively on our own thoughts and ideas, if we managed to complete them at all, why we decided to leave the method. An example of a specification of requirements is showed in Appendix B. Although this work did not result in any concrete means, we still felt that it had not been a total waste of time. Forcing yourself to think from the customers' point of view is always important and can make you aware of things that you might not had thought about otherwise.

4.3 Initial development loop

At this point we have started to get a fairly good picture of what a SCAP-top material handling system broadly must be able to do, and the next step is to get more specific solutions of the different steps along the system. The first half of this chapter explains how we acted to gather ideas about these steps and our experiences from that work. The second half then presents the results we found and some tests that we felt necessary to do in order to be able to evaluate them.

4.3.1 Internal brainstorming

The first idea generation work we conducted by ourselves in our logistic office. For each activity we formulated a number of questions, such as "How could this activity be handled?", "What problems could come out of it?" and "What factors are the most important?". We then started to write possible (and not possible) solutions on post-it notes that we put on our white board. When the ideas had been placed into groups and documented, the procedure was repeated for the next activity. This way not only many solutions of different problems came up, but a picture of how activities could be connected in different ways and what consequences that would give started to come out.

Our experience from this work is that it is important to have a medium where you can let your ideas come to shape in a comfortable way. We used whiteboards and big papers a lot, mostly to sketch how we thought the ideas could be shaped. This made it easy to explain both small details and overall solutions and also led us back many times to areas that we had left earlier, creating small idea generation loops. Furthermore, trigging each other by discussing, drawing parallels and asking questions about the ideas that came up had a very positive effect on us.

[93] Ottosson, Stefan (1993), pg 24

4.3.2 Idea generation at LTH

When you have been working with the same ideas for a while it is easy to get stuck in a certain way of thinking, something we experienced very clearly. Therefore, in order to get some new inputs and helping thoughts, we organized an idea generation meeting at LTH where we gathered PhD students from the division of Packaging Logistics and mechanical engineer students.

The meeting that was lead by us and began with a short introduction of the SCAP-top, lasted for about three hours and contained four exercises. In the first one we wanted the participants to think of basic ways of transportation. To do that, each one of the participants got a mission to write down how they would solve the whole transportation of 10000 SCAP-tops from LTH to Mallorca. After about 10 minutes of thinking and writing on post-it notes, all ideas were gathered on a whiteboard and read out loud. Then, working together the participants placed the notes in clusters of similar type and finally a discussion about the result was held. After a short coffee break a similar exercise was held, but this time with focus only on the activities at the EBM factory, starting with a manufactured double SCAP-top and ending with a closed package filled with SCAP-tops.

After two quite concrete exercises, we wanted to make the participants totally let go of their usual way of thinking, why we changed to a "what if" exercise. Each one was given a picture of a their new character, which varied from a Smurf to the Hulk, that they would be for the following 30 minutes. Then, they were simply asked to solve the problem of transporting the SCAP-tops using their new personal talents in the best possible way. The results were once again gathered on a whiteboard and from the common discussion further suggestions were written down.

As the last exercise, we chose to do a very guided one. The participants were paired together, and given one paper per pair with an illustrated flow of activities. During a 7 minutes period, they wrote down as many possible problems they could imagine, and then the papers were passed on one step. Each pair had then received a new paper with problems thought out by the previous group, and for the following 7 minutes they were asked to write down solutions of these problems.

In total, the meeting did not give a great deal of new concrete ideas. However, a big gain of it was to hear other people's way of thinking and get a confirmation of that we were not missing any big parts. Something that we learned from the meeting was that getting people creative can be a difficult thing, even though you try hard to make sure that everybody is having fun and feel relaxed. Our opinion is now that a group of people that have no or little experience of idea generation and do not know each other too well before, need as guided exercises as possible in order to reach any results. In spite of this, we feel that idea generation methods can be a very powerful and useful tool in the development process and therefore should be a standard procedure for every engineer.

4.3.3 Results of initial development loop

It is of natural reasons impossible to work with too many ideas at the same time, why all development projects are associated with screening processes in different steps. This has also been the case in our project. During the initial screening process, the ideas have simply been chosen by comparison of how well they match the general needs defined earlier and from what we have thought reasonable. The remaining ideas for different activities have then been put together to form six solutions for the whole material handling system, and this part of the chapter will present these solutions. A more thorough screening process, for putting solutions in relation to each other, will be presented later in this report.

At this point, only the functionality of the solutions will be presented. What effect they will have in volume capacities, costs, demands of dimensioning etc. will be presented later.

4.3.3.1 Stochastic orientation – Corrugated board box alternative

Considering the SCAP-tops design and the fact that they will be produced in several different shapes, the already determined way of transporting them in pairs, but most of all their light weight, an obvious principle for the handling and transport of the SCAP-tops is to handle them as bulk material. This has also been the pilot way of handling so far. Hence, the pilot filling machines have already been equipped with an orientation table that orients and feeds the filling machine with SCAP-tops. Consequently, many resources can be saved if a system that is compatible with the now existing filling machine set-up (though in an improved version) is shown to be effective. In this first alternative the primary packaging constitutes of a box made of corrugated board.

As stated in the theoretical framework, corrugated board is one of the most utilized packaging materials in the world. A reason for this is the flexibility in strength and design it entails. Hence, the primary packaging in this alternative could be designed in a number of ways, which also was manifested during the Idea generation. However, a further study of the alternatives from the Idea generation revealed two corrugated board box designs as the most interesting for further investigation, mainly due to their simple, already well-known and thereby probably economical, design: a simple slotted box and a die-cut box with separate lid and bottom.

The slotted box

The primary packaging of this alternative of logistical- and material handling system consists of a simple slotted box with a plastic bag inside to protect the tops from external particles. The box will be placed on a EUR-pallet. The box is sealed with strapping tape in bottom and top, which is the most common way of sealing this type of packages.[94] The fact that the tape is adhesive makes it of course difficult to remove after use so it is probably a one-way system, hence no return transport from the customer is needed. Considering the light weight of the SCAP-tops a 210BC (7mm) corrugated board should be sufficient even during transport with triple stacking.[95] A height of the box between 0,8-1,2m is probably most efficient in order to fit the boxes into the trailer for transport but also to utilize efficient manual handling. As seen in the figure below the width of the unfolded box will of course increase as the height of the folded box increases, making the handling more and more difficult.

---

94 Duckert, Anders, SCA Packaging Sweden, Malmö (031021)

95 ibid

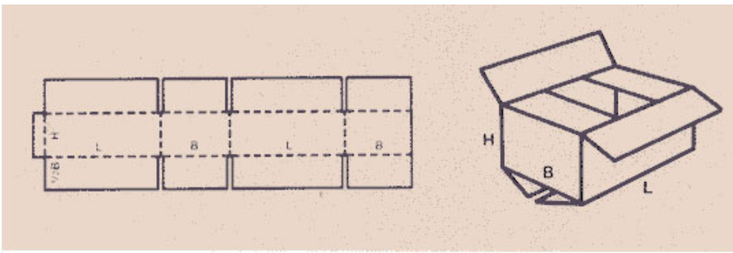


Figure 20: *Sketch of the principle of a slotted box.*[96]

The die-cut frame box
This alternative of a primary packaging constitutes of a top, a bottom and a frame, all made of corrugated board (see Figure 21). Inside the box a plastic bag is placed as in the slotted box and the box will then be placed on a EUR-pallet. According to Anders Duckert, the top and the bottom can be made of the quality 170C and the frame of 210BC. This combination will fulfil the demands earlier described for the slotted box. For sealing the box no stapping tape is needed; the top and the bottom is pressed together with non-adhesive straps, which will be described later. The fact that these straps are non-adhesive makes it possible to remove them easily, why there is a possibility to make this system a return system. The top and the bottom are difficult to fold out again from being erected, and they are made of a single corrugated board, why the frame probably is the only part of the return system. The height of the frame is as the slotted box 0,8-1,2m.

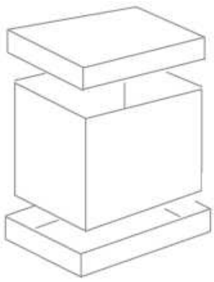


Figure 21: *A die cut box with a frame, a top and a bottom.*

Handling system at the EBM-factory
Let us now enter the EBM-factory and approach the EBM-machine. The SCAP-tops are leaving the EBM-machine, after being capped, stochastically on a belt conveyer (see Figure 22). Here is the system boundary. All the included activities of the material handling system as well as the equipment after this activity will be described below. The system is assumed to be operated by one operator, also having tasks at the EBM-machine.

[96] https://catalog.scapackaging.com/fps_se (031011)

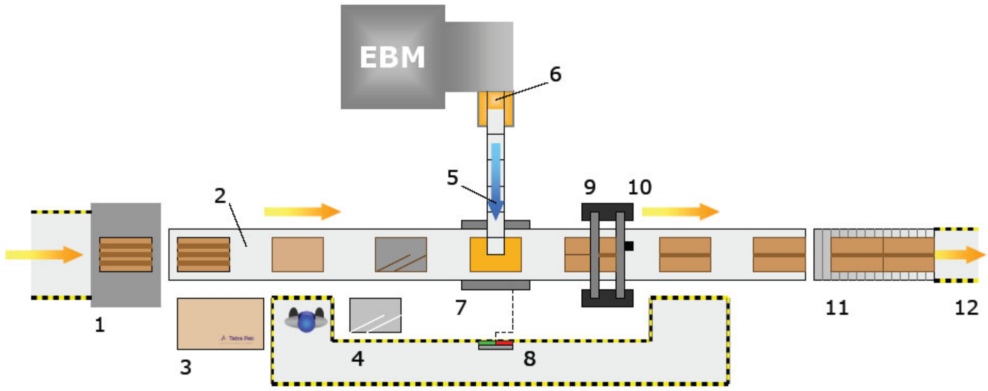


Figure 22: *A schematic description of the material flow out of the EBM-machine and the material handling equipment proposed to handle this flow.*

1. Pallet magazine. The system starts with a pallet magazine, which is fed by a fork truck. A rough estimation at this point is that each corrugated board box can be filled by 5000 single SCAP-tops. Given the production speed of the EBM-machine of our scenario this means that a new pallet will be needed in every 4 minutes (or 15 pallets per hour). Tetra Pak Distribution Systems Ltd, a corporation within the Tetra Pak Group, sell a pallet magazine, called the "Tetra Pallet Magazine 10" to their customers. This unit has a capacity of 90 pallets/hour and a storage capacity of 15 pallets. This means that the magazine has to be refilled 1 time/hour with a fork truck, which certainly is an acceptable level. Although Tetra Pak does not manufacture the magazine themselves, it is reasonable to calculate with a price cut-off of around 10 % of the customer price[97].

2. Driven roller conveyer. To be able to carry out the different steps sequentially and with an even flow, a conveyer is needed. This conveyer is driven with the ability of step-wise feeding in sequence of 4 minutes. To fit in all the steps, the length will be approximately 10m. The conveyer must have a width of 0,8m to fit a EUR-pallet lengthwise and be able to carry approximately 100 kg/m. The height of the conveyer depends on what height is determined for the box and if the slotted or the die-cut (frame) box is chosen [see activity 3]. In round numbers, a height for the conveyer should be as low as possible with a 1m slotted box and around 0,4m with a 0,85m frame box to make the working position for an operator as good as possible. The feeding activity of the conveyer must be able to be initiated by the scale weighting machine [7].

3. Erection of the box. Both the slotted box and the frame box are possible to erect automatically. Though, the relatively large sizes of the boxes imply that no simple standard solutions can be used and the machine has to be built "custom made" with presumably high costs and a use of large production area as a result. Considering the frequency of around 4 minutes the utilization of this machine will be very low, hence, the operation will probably be carried out manually. For the slotted box, strapping tape must be available for the operator. When the box is strapped in the bottom and erected, the top flaps stand right up, increasing the height of the box. One EUR-pallet takes 140 un-

[97] Edström, Johan (031104)

erected boxes[98], which means that this pallet must be replaced by a new one every 9 hours. This is obviously more than one shift and does not oppose any problem.

4. Application of the plastic bag. Directly after the erection of the box a plastic bag should be placed inside. This operation is, as the erection of the box, preferably performed manually. For both types of boxes the plastic bag should be slipped over the top edge of the box.

6. SCAP-top buffer. The flow of SCAP-tops from the EBM-machine is constant. The flow of boxes on the belt conveyer [5] to be filled has to be intermittent to enable weighting of the filled box [7] as well as the feeding of a new box. This situation requires a buffer. A buffer capacity separating the material handling system downtime with the EBM-machine is also desirable – to be forced to shut down the EBM-machine only because the operator e.g. has forgotten to fill up with plastic bags is highly ineffective. This buffer does not have to be very large; a capacity of 2 minutes production, or a little less than 0,5m^3 should be sufficient. It is important that this buffer is adjustable so that if it is not used, the SCAP-tops should pass right through it to avoid being exposed for the possibility of being scratched.

7. Filling and scale weighting machine. When the SCAP-tops drop into the box, a scale-weighting machine continuously counts the number of tops in the box. When the number of tops reach a predestined filling level, the unit for handling the start/stop signal [8] stops the belt conveyer [5] and starts the driven belt conveyer [2] for feeding of a new box. Then, the start/stop signal tare the scale-weighting machine, indicates for the pallet magazine to unload a new pallet and finally starts the belt conveyer [5] again. The time for these activities is far below the capacity of the buffer [6]. An industrial scale-weighting machine that can handle around 150 kg has normally an approved reading of 50g, which give an accuracy of measurement of ±3 tops, which probably is accepted. [99]

9. Box closing. This activity will differ between the two different boxes. The slotted box will be taped with strapping tape and the frame box will be closed by putting the top on and then strapping the whole pallet with two non-adhesive plastic straps. For both boxes these activities can be accomplished both manually and automatically. The most likely scenario, though, is that the slotted box will be closed and taped automatically. The top of the frame box will probably be put on manually while the strapping activity will be performed automatically. These assumptions are based upon approximate investment costs and what coefficient of efficiency that can be presumed for the machines.[100]

10. ID-marking. An automatically operated labelling machine provides the ready made box with a EAN-code telling the destination, time of manufacture, type of SCAP-top etc.

11. Undriven roller conveyer. When the filled box has been labelled it continues onto an undriven roller conveyer with a small incline. This conveyer holds two or three boxes

[98] Palm, Sandra (031110)
[99] www.exaktvagteknik.se/spider (031009)
[100] Duckert, Anders (031104)

(5m long) in order to constitute a buffer for the fork truck operator fetching the ready for storage packages in the picking zone [12].

Handling system at the customers site

The transport (which will be presented and analysed for all alternatives together in a later chapter) is now done and the products have arrived to the warehouse of the dairy. Below, a presentation of the material handling system for the SCAP-tops from warehouse to the filling machine will be done.

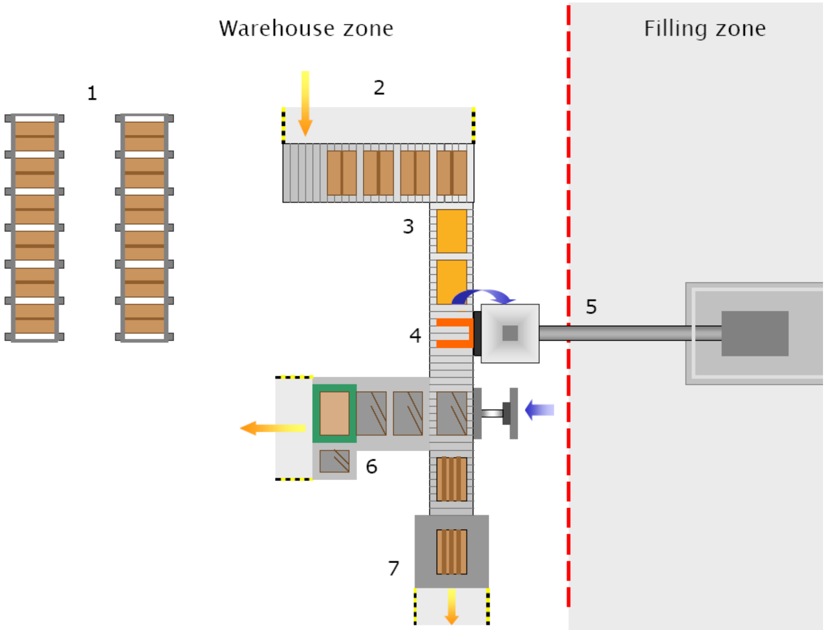


Figure 23: *A schematic description of the material flow from the warehouse to the filling machine at the customers site and the material handling equipment proposed to handle this flow.*

1 - 2. Storage and truck transport. This activity can be adapted to different customer specifications. If store racks are available these can be used, but it is also possible, and in a warehouse area saving sense also recommendable, to use deep stacking.

3. Driven roller conveyers. The truck operator loads the boxes onto a driven roller conveyer and opens the box. This conveyer is in turn connected to another, similar, conveyer orthogonal to the first one. By this configuration the truck operator has the ability to, in a short period of time, build a buffer on the first conveyer. He will thereby not be occupied with this work constantly but can go for other missions needed at the warehouse in between the "buffering sessions". The length of the first conveyer should be adapted to fit four or five EUR-pallets abreast, making it around 4m long and 1,2m width. The second conveyer will have an intermittent flow and three activities (see below) are supposed to be connected to it, making it around 10m long and 0,8m width.

4. Box emptying unit. The boxes are sequentially feeded towards the box-emptying unit. This grabs in turn hold of both the box and the EUR-pallet underneath and tips the box around 150º round a fix axis. The SCAP-tops then fall into a stainless steel funnel and end up on a covered belt conveyer.

5. Covered conveyer into filling zone. This conveyer transports the SCAP-tops into the filling machine in the filling zone of the dairy. The conveyer is a regular rubber belt conveyer with the addition of a fully covering "roof" in order to protect the SCAP-tops from particles and bacteria. In this way the warehouse and the filling zone are separated fully.

6. Briquette press. Once the box is emptied it is further transported by the conveyer to a pushing device, which separates the box and its plastic bag from the pallet. The plastic bag is then removed from the box and put into a wasting bin manually by the truck operator and the slotted box is further pushed into a briquette press. This press is fully automated and presses around 100 boxes/hour[101] into recyclable briquettes. For the frame box alternative the bottom will go into the briquette press and the frame will be stacked on a pallet. When this pallet is filled it will be stored in the warehouse waiting for return transport.

7. Pallet magazine. The pallet continues into a pallet magazine. The same type of magazine as mentioned for the EBM-machine, the Tetra Pallet Magazine 10, can easily be used in this application.

4.3.3.2 Stochastic orientation – Wooden box alternative

This alternative is based upon a primary packaging constituting of a recyclable wooden box (see Figure 24), which is foldable and stacks 1:20. The box is made of 6 mm birch plywood. Inside the box a plastic bag is placed and a EUR-pallet is used for transport packaging. Because the height of the box makes up the short side of the pallet when the box is unfolded, the height is limited to 0.8m.

Figure 24: *A foldable wooden box on a EUR-pallet.*[102]

Considering the material handling system connected to this alternative, only minor changes will occur in comparison with the prior presented alternative of a corrugated board box. The wooden box will e.g. not be compressed into briquettes but will be stacked on top of each other waiting for return transport. The box weights 22kg, which is a lot more than the corrugated board box, but since the products (the SCAP-tops) are lightweight, this extra weight should not affect the demands for the material handling system, except for larger stress at manual handling, which of course is an important

[101] www.eleiko.com/html/industri (030811)

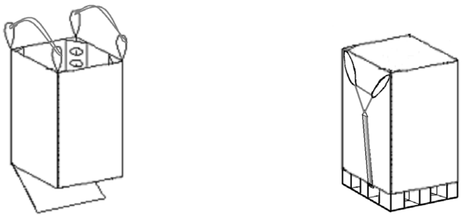
[102] www.nefab.se/default.asp?lang=se (030812)

factor. Only when it comes to return transport the weight of the wooden box will matter. It will unfortunately not be possible to have full trailer transports as return transports, due to the maximal weight a trailer is allowed to carry.

This type of foldable and returnable box can of course be made of other materials such as plastics or even steel. Though, the material handling systems for such boxes will not differ consederably from the above presented system of the corrugated board box. The major factors separating different material choises of re-usable packages are investment cost, cost for return transport and the number of return transports they can manage. These alternatives will therefore be left out here.

4.3.3.3 Stochastic orientation – Stable sack alternative

The cost of the primary packaging is likely to play an important role in determining the total distribution cost. Hence, incentives for making the primary packaging as cost effective as possible are strong. An alternative to the earlier described proposals of primary packaging is therefore a lightweight and returnable sack. The sack is also stable, e.g. it keeps its original shape even when filled with a product. This feature is due to transversal stabilizers in the corners (see Figure 25a).



(a) (b)

Figure 25: (a) *A stable sack without a top cover in order to show the transversal stabilizers.* (b) *A stable sack with stabilizing rubber cords.*

The sack can be custom-made in a variety of sizes and shapes[103]. This means that the sack can be handled by the straps in the top as a hanging unit, but it can also be placed on a EUR-pallet and handled by a regular truck. The sack we propose is either a 1200x800x1300mm or a 1200x800x2000mm (depending on what kind of trailer is used) woven polypropylene bag with sealing clamps in top and bottom. Both the top and the bottom are further protected by woven lids, which are fastened by belt clamps. When the sack is placed on a pallet its height in cooperation with the lightness of the SCAP-tops make it a bit unstable. This can be solved by pulling down the straps and attaching them to rubber cords, attached to the pallet on both sides (see Figure 25b). A few different actors on the market manufacture these kinds of bags. Our information come primarily from Jari Lehto, seller at Boxon Bags AB.

The transversal stabilizers make it impossible to have a plastic inner bag in the stable sack. Obviously questions about hygienic matters arise due to this fact and a way to ensure a certain cleanness of the stable sack must be developed if a return system is to be

[103] Lehto, Jari, Boxon Bags AB (030927).

possible to implement. A solution could be radiation treatment of the sacks together with a washing procedure in order to reduce the amount of bacteria and particles. Due to the comprehensive sterilisation process in the filling machine the most crucial kind of contamination on the SCAP-tops is particles, simply because these cannot be neutralized by the sterilisation process.[104]The cost and extent of this cleaning process can be crucial in the question if the stable sack is a reasonable alternative as the primary package for the SCAP-tops. Further investigations must be carried out concerning this question.

Handling system at the EBM-factory

If we now enter the EBM-factory and approach the EBM-machine again, the layout for the stable sack handling units will be similar to the earlier described units for the corrugated board box and the wooden box, in many ways. The SCAP-tops are leaving the EBM-machine, after being capped, stochastically on a belt conveyer (see Figure 26, [5]). All the included activities of the material handling system as well as the equipment used, that differs from the earlier described activities and equipment for the corrugated board box and the wooden box, will be described below. The system is assumed to be operated by one operator, also having tasks at the EBM-machine.

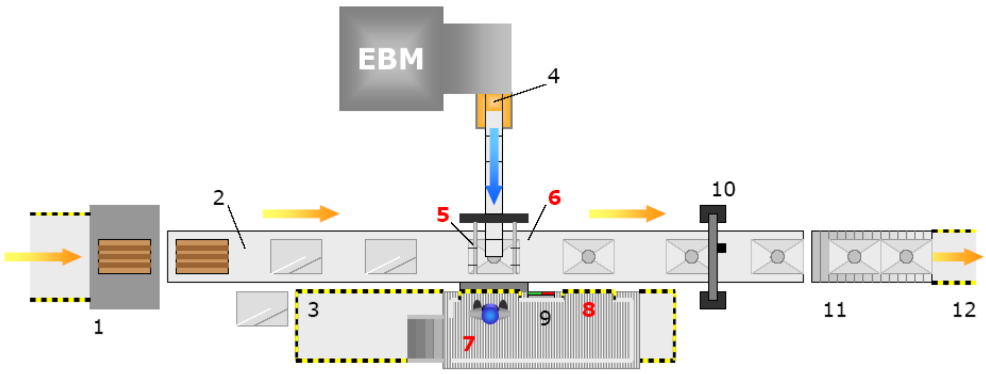


Figure 26: *A schematic description of the material flow out of the EBM-machine and the material handling equipment proposed to handle this flow.*

The sacks come compressed with about 40 sacks/EUR-pallet and are manually put [3] on a EUR-pallet standing on the belt conveyer [2].

5. Erection unit for sack

To be able to fill the sack it must be erected. This is done by having an erection unit with two forks, which the straps of the sack are slipped onto. This is done manually. When the straps are fixed and the collar of the sack is fixed outside a filling funnel of the erection unit, the operator starts a process by clicking the start button on the operation panel [9]: the forks are lifted until the sack is fully erected.

[104] Mårtensson, Lars (030925)

7. 2:nd floor working platform. Meanwhile the operator goes up the stairs to the 2:nd floor platform and starts closing the earlier filled bag [8]. When the bag is fully erected the conveyer connected to the SCAP-top buffer [4] starts and the filling begins. The operator can then go down the stair and load another empty sack onto a pallet. The time for these activities is far below the capacity of the buffer [4]. This 2:nd floor working platform is probably made of steel and has the dimensions of about 1500x2500x2000mm. To be able to go up and down it has a stair/ladder on one short side.

6. Filling and scale weighting machine. When the SCAP-tops drop into the box, a scale-weighting machine continuously counts the number of tops in the sack. When the number of tops reach a predestined filling rate and the sack is full, the unit for handling the start - stop signal [9] stops the belt conveyer. The forks of the sack erection unit are automatically drawn out of the straps of the sack and the driven belt conveyer [2] feeds the pallets one step. Then the procedure is repeated.

8. Box closing. This activity has to be carried out manually. It involves two activities: strapping the sack with the sealing clamps and fasten the lid with the belt clamps.

Handling system at the customers site

The transport is now done and the products have arrived to the warehouse of the dairy. Below, a presentation of the material handling system for the SCAP-tops from warehouse to the filling machine will be done.

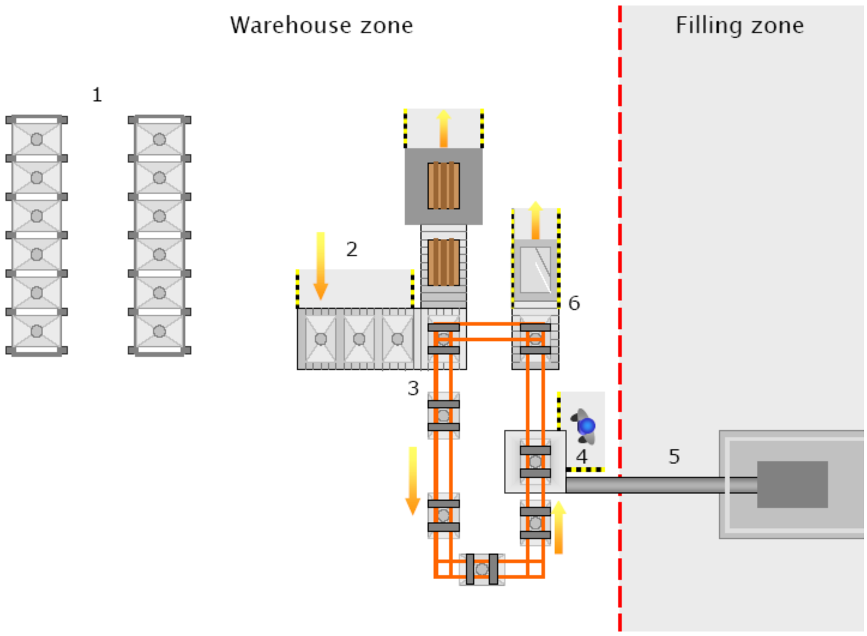


Figure 27: *A schematic description of the material flow from the warehouse to the filling machine at the customers site and the material handling equipment proposed to handle this flow with the stable sack as the primary package.*

1 - 2. Storage and truck transport. Unlike the earlier described alternatives, the stable sacks can not be deep stacked more than one layer in height. This indicates a need of store racks at the customer location. The truck operator puts the sacks standing on EUR-pallets on a driven conveyer.

3. Overhead rail conveyers. Because of the straps on the top of the stable sacks the sacks can be transported hanging from an overhead conveyer. The sacks, standing on the conveyer, are in this activity manually attached to hooks on the overhead conveyer. To be able to do this, an elevator table is placed under the overhead conveyer. The operator elevates the table, attaches the straps on the hooks, then the overhead conveyer is feeded on step. The overhead rail conveyer works as a elevator for the filling of the SCAP-tops into the funnel [4], but also as a buffer for the truck operator. The length of the conveyer can be made according to customer needs but will probably not be as long as seen in the illustration above.

4. Box emptying unit. The boxes are sequentially feeded towards the box-emptying unit. This is a manually performed activity where the operator (probably the truck operator) opens the bottom of the sack. The SCAP-tops then fall into a stainless steel funnel and end up on a covered belt conveyer.

5. Covered conveyer into filling zone. This conveyer transports the SCAP-tops into the filling machine in the filling zone of the dairy. The conveyer is a regular rubber belt conveyer with the addition of a fully covering "roof" in order to protect the SCAP-tops from particles and bacteria. In this way the warehouse and the filling zone are separated fully.

6. Unloading of sacks. When the sacks have been emptied they are unhooked manually and put on a pallet for return storage.

4.3.3.4 Ordered orientation - "Single pipe" alternative

Obviously, the easiest way of distributing the SCAP-tops is the stochastic alternative. As further testing will show, the stochastic alternative is also the most favourable, in comparison to any ordered alternative, in terms of filling rate. But despite these facts it is possible that big advantages can be gained by having the SCAP-tops in an ordered, controlled position during transport. It is possible that this can provide better protection, both from inner and external forces. It is also possible that the filling machine can be made more compact and with a better cost-effectiveness if the SCAP-tops already are ordered when they arrive. The Idea generation generated mainly three ways of conducting distribution with ordered SCAP-tops. First, the alternative called the "single pipe" will be described.

The "single pipe"-alternative is based upon the principle of having the SCAP-tops positioned on a long row in a thin plastic film tube. The tube is then folded at certain places and put in a box. This box can be of any type of the earlier described boxes for stochastic orientation. The tube will, beside positioning the SCAP-tops in a ordered way, protect the SCAP-tops from external particles an bacteria. Because the tube will be sealed, the air-pressure will probably also protect the SCAP-tops from both internal and external forces. The tube can probably be made of a 30-50μ LDPE-film, which can be manufactured in a cost-efficient way.[105]

Handling system at the EBM-factory

The filling principle that was first introduced by the Tetra Classic-machine has been the inspiration to a possible filling method for the "single pipe"-alternative. After the SCAP-tops have been capped, which is a procedure direct after the EBM-process, they are fixed in a known position. The fact that they are oriented can be utilized by letting the SCAP-tops drop into a pipe, leading them vertically oriented to the filling station for the plastic tube (see Figure 28). Here the plastic film, which comes on a roll, is welded into a tube at the same time as the SCAP-tops are inserted from the pipe. A spot welding unit a bit further down welds the folding marks for the tube to fit into the box. A weld is made after every 10-14 SCAP-top.

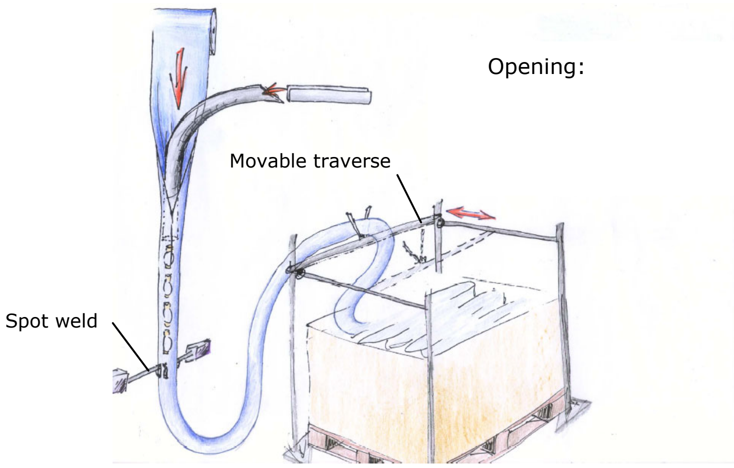


Figure 28: *Illustration of how SCAP-tops are put into a plastic tube and put into a box.*

The tube is continuously transported to the box in which it will be placed. In order to place the tube as optimal as possible in the box, a small traverse unit is placed above the box. This leads the tube into place and folds it at the welding seams. When the box is full and a new one is needed this is solved by having two traverse units beside each other that can, after the tube has been cut, change to the new box automatically. The full box is then further transported by a conveyer to box-closing and ID-labelling units for further transport to storage by a truck operator.

Handling system at the customers site

Manual handling will undoubtedly be necessary when opening the boxes as well as for feeding a new tube from a new box into the system. Otherwise, most activities can be performed automatically. The tube is put on a narrow driven conveyer, transporting it directly from the warehouse zone to the filling zone. When entering the filling machine the tube is split open by a cutting unit (see Figure 28). The plastic film from the tube is winded up on a roll for recycling and the SCAP-tops are falling into a pipe, oriented.

---

[105] Fällström, Arne (031109)

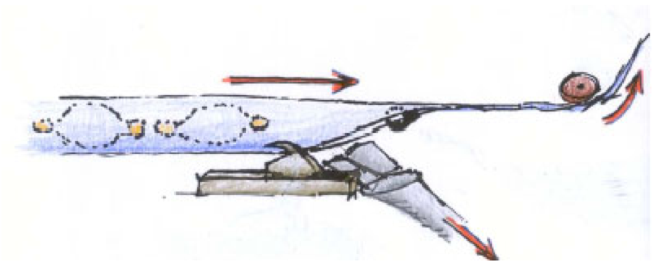


Figure 29: *Illustration of how the filled tube is opened before emptying of SCAP-tops.*

To make the filling machine less sensitive for disruption, a buffer is placed in the filling machine just before the cutting process. Different suggestions of how this buffer can be constructed are presented in Figure 30.

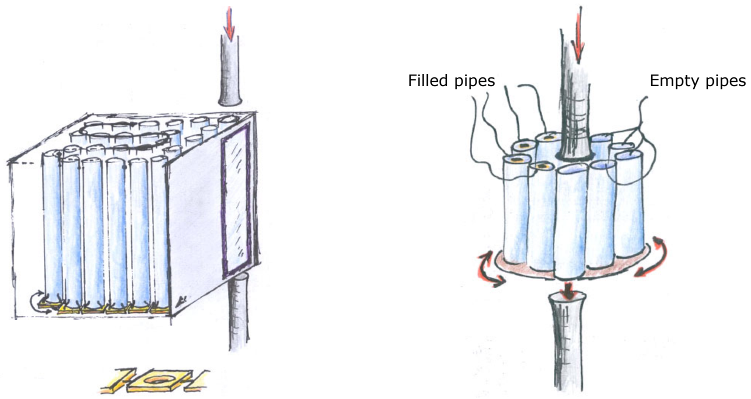


Figure 30: *Two alternatives of SCAP-top magazine just before the filling machine.*

4.3.3.5 Ordered orientation - "Parallel pipe" alternative

Imagine the "single pipe" alternative with the SCAP-tops in a plastic tube with the difference that the tubes are cut at its welding seams and these short tubes are attached to each other by their long sides, forming a long curtain (see Figure 31) This is the principle of the "parallel pipe" alternative.

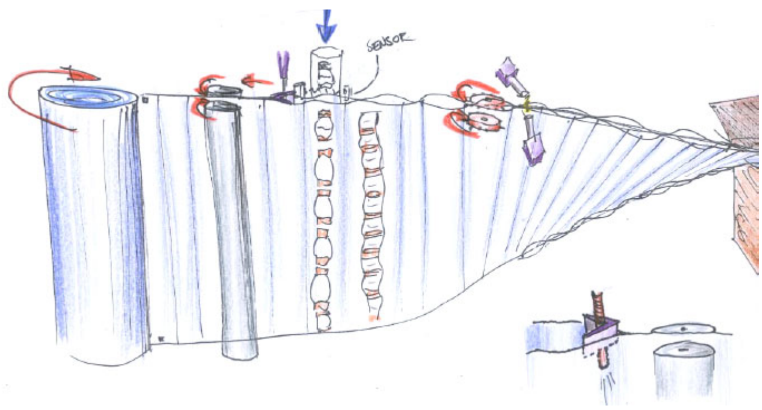


Figure 31: *Illustration of how the SCAP-tops are filled in parallell cells.*

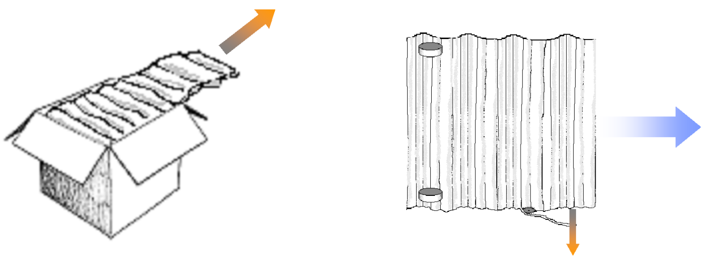
Handling system at the EBM-factory

The plastic film curtain is produced by a 50-70µ LDPE-film[106] with pre-welded cells and it is delivered on a roll. Like the "single pipe"-alternative the SCAP-tops are ordered in a pipe after being capped. An overhead rail conveyer drives the plastic film curtain forward sequentially, with spikes grabbing hold of the upper segment of the curtain. Meanwhile a wedge opens up the cells from above and with help of a compressed air nozzle, letting the SCAP-tops fall down into the cells from the pipe. When around 10 SCAP-tops have been filled, a sensor indicates for the conveyer to feed one sequence forward. At the same time the flow from the pipe is blocked.

After a spot-weld unit has sealed the top of the cells, the curtain continues towards the box and is rolled down into it by a similar traverse as being used for the "single pipe". When the box is full and a new one is needed this is solved by having two traverse units beside each other that can, after the curtain has been cut by an alongside knife, change to the new box automatically. The full box is then further transported by a conveyer to box-closing and ID-labelling units for further transport to storage by a truck operator.

Handling system at the customers site

Manual handling will, as for the "single pipe"-alternative, undoubtedly be necessary when opening the boxes as well as for feeding a new curtain from a new box into the system (see Figure 32a). Otherwise, most activities can be performed automatically. The curtain is put on a similar overhead rail conveyer as in the EBM-factory, transporting it directly from the warehouse zone into the filling zone. As the curtain enters the filling machine, a fixed knife opens the bottom of the cells (see Figure 32b) letting the SCAP-tops fall into a pipe. Henceforth the process is exactly the same as for the "single pipe"-alternative; with a buffer before the cutting process.



(a) (b)

Figure 32: (a) *Parallel pipe curtain being feeded manually from a box.* (b) *Illustraion of how parallel pipe curtain is beeing cut open for emptying of SCAP-tops.*

Clearly, this alternative, as well as the "single pipe"-alternative, needs much development before it can be implemented. What this presentation show, however, is that it probably can be done with relatively small means. Much plastic film is needed but in return this film is not very expensive and can be recycled. The technology of welding plastic film for the "single pipe" is known within Tetra Pak. Much emphasis much be put on minimizing disruptions of the processes, though, because this is vital for a continuous flow of SCAP-tops to the filling machine. Furthermore, if any of these two alternatives are

[106] Fällström, Arne (031109)

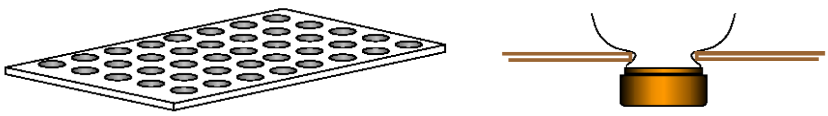
decided to be implemented, an early analysis whether the filling/emptying of the plastic cells can be made at the required speed must be done. The time for development of the methods is also critical due to the approaching field test of the SCAP project.

4.3.3.6 Ordered orientation - Robotized alternative

When the SCAP-tops leave the capping machine, right after the EBM, they have a certain orientation. Since the SCAP-tops also must be inserted in the filling machine with a certain orientation, an obvious idea is to keep the orientation during the transport from top production to filling machine and thereby get rid of the problem with orienting the tops in the filling machine.

Primary packaging

The initial idea about how to get the SCAP-tops in a certain, fixed position was to let a robot device grab the tops right after they leave the capping machine and put them in a position tray. These position trays (see Figure 33) are thought to be made of corrugated board or corrugated plastic, depending on price, reusability and hygienic demands at the filling machine. Together with corner protectors, that apart from protecting the tops from impacts and shocks will make multiple stacking possible, and a surrounding plastic film, they form the primary packaging in this alternative.



(a) (b)

Figure 33: (a) *Illustration of a position tray.* (b) *Illustration on how SCAP-tops are positioned in the trays.*

The design and material choice of the position trays will affect both functionality and costs, why it is a highly interesting matter. This alternative is for a start founded on a tray size that more or less is equivalent to one quarter of a EUR-pallet (591x780mm). Even though this way of transporting SCAP-tops does not mean any risk of overhang, it is preferred to leave some safety space at the pallet edges in order to avoid damages and to make room for corner protectors and cover plastics. However, since there are SCAP-tops with many different diameters and the experiments we have conducted show that the outermost holes on the position tray (corrugated board B with thickness of 2,4mm) needs to be placed 13mm from the edge at a minimum, the packaging pattern will differ between different top models and probably result in position trays of different diameters. The placing of the holes affect not only the filling rate, but also the risk of getting SCAP-tops that touch each other, for example during bumpy transportations, probably with surface scratch marks as a result.

Two factors that concern the physical handling of the position trays and goes hand in hand are the cutting pattern of the holes and the stiffness of the material that the position tray is made of. The cutting pattern, especially the slits around the holes, affects the force that is needed to drive the SCAP-tops in the hole and to pull them out of the same. A long slit makes it of course easier to position and remove the SCAP-tops, but also result in a SCAP-top that is less stuck to the position tray with greater risk of unwished movements. Another type of unwished movement can be obtained if the position tray, which must be handled by a picking robot with a grip device for each side of the tray, bends down from the weight of the SCAP-tops. Therefore, the stiffness of the tray must be chosen to minimize the downward bend without making the requested force for putting the SCAP-tops in the tray to great.

This alternative means that a lot of material for position trays is needed. If we take the SCAP-top with a height of 57mm for example, there is room for nine layers of positioned SCAP-tops (see Figure 34) on a EUR-pallet with the total height of about 1m, which means that each package will contain 9x4=36 position trays. Being able to reuse the position trays would probably save a lot of money and is therefore very desirable. In such a case, the position trays would have to be made of something more durable than corrugated board – maybe some kind of light plastic with rubber circles at the holes, to allow the SCAP-tops of being put in, removed and kept in position in a good way.

Figure 34: *Illustration of how a position tray package is built up.*

Filling positioning trays with SCAP-tops by robots

Our robotized alternative assumes that the SCAP-tops leave the capping machine rolling on parallel rails (see Figure 35). When a certain number of SCAP-tops have reached the end of the rails, a counter-controlled stop device goes up and prevents more SCAP-tops of rolling on. Then, a two-part grip device (1) grabs the cap of the SCAP-tops and, after the end stop device of the rails has been lowered, make a horizontal movement. At the final position, another grip device (2) of similar appearance grabs the caps on the other side of the SCAP-tops, allowing the first grip device to let go and return to it's starting position. The second grip device then rotates 90 degrees downwards and drives the row of SCAP-tops in a steady held position tray by an ejecting movement. When this grip device has let go of the positioned SCAP-tops, it returns to its first downward position and rotates another 90 degrees in the same direction, making it ready to receive a new row of SCAP-tops from the grip device on this side. The operation is repeated, this time with rotations towards the opposite direction. The position tray is lying at a plate, which has holes that are slightly bigger than the caps of the SCAP-tops, in order to minimize the risk of bending the tray. A grip device attached to the plate is also holding the position tray tight along its long side edges. Since the rows of SCAP-tops must be placed in an overlapping way to increase the filling rate, both the position tray and the underlying plate has two degrees of freedom in the horizontal level. This way, the grip device that drives the top in the position tray does not have to move sideways. When a position tray is filled with SCAP-tops, it is left to a conveyer that takes it to a palletizing device, and a new position tray is fed from a hopper.

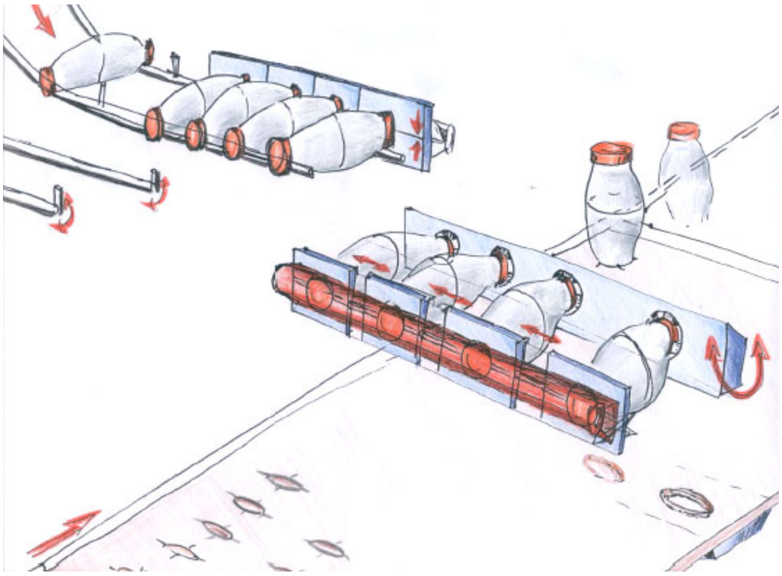


Figure 35: *Illustration of how SCAP-tops are put in position trays.*

An important factor when discussing a robotized version of handling the SCAP-tops is cycle time. As can be seen in Table 3 (chapter 4.1), the maximum flow speed of SCAP-tops out from the EBM and therefore also the capping machine is 10,5 double tops/s (wheel machine and SCAP-top height of 33mm). Since each log of that version contains seven double tops that rolls out on one pair of rails each, every pair of rail will receive 1,5 double top every second. A market search showed that it would be more or less impossible to find a robot that would be able to grab one SCAP-top at a time and put it in the position tray that fast. From this the evident idea of grabbing many SCAP-tops at a time to increase requested cycle times arose. Also, our basic idea was to create a solution where the last function, when the SCAP-tops are put in the position tray, needed as few degrees of freedom as possible and thereby making it possible to run with high speed. This alternative means that the second grip device, which serves two pairs of rails, must have a maximum cycle time of 1,3 s, which we believe will cause no problems.

Something that could cause problems however, is the risk of SCAP-tops ending up obliquely in one of the grip devices, possibly resulting in system stop or damaged tops. We know that SCAP-tops with caps that have not been put on correctly occur, and this could be one reason for the above-mentioned problem. To solve this, the second grip device could be made with grip claws instead of with two holders that come together. This would mean that the first grip device would have to be able to move in one more degree of freedom - a movement orthogonal to its first movement, that takes the caps of the SCAP-tops inside the range of the grip claws – something that we also believe could be done without any greater problems.

Palletizing, loading and package protecting

When the filled position trays come out from the "positioning machine" (see the layout in Figure 37, [2]), they all have the same pattern of SCAP-tops. The packaging of the trays is based on the idea that the lower caps of one layer of SCAP-tops is put in the same level as the upper caps of the layer beneath (see Figure 36), resulting in a stabilizing locking effect and a higher filling rate. This means that every other position tray must be rotated 180 degrees on its way to the palletizing device [4], most likely by a simple lift-and-turn mechanism, placed in the conveyer system.

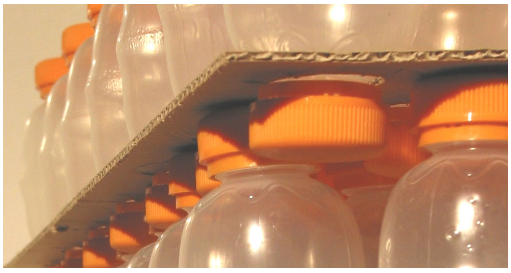


Figure 36: *Picture of SCAP-top layers overlapping each other.*

The palletizing device is either chosen to be a Tetra Pallet Loader 10, which also adds a covering cardboard sheet at the bottom of the pallet, or constructed as a small traverse crane with two long and thin grip devices. When the pallet is filled, it continues to a device that puts corner protectors on the pallet load and then wraps it in plastic [6]. Before being put in some kind of intermediate storage, the packing finally receives an ID label [7].

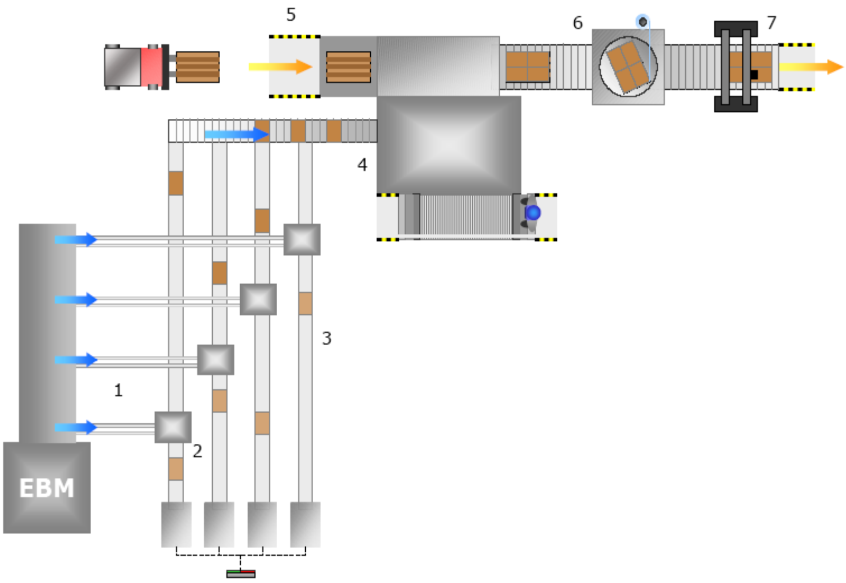


Figure 37: *Illustration of how position trays are filled, transported and put together to a package.*

Emptying primary packaging and transport to filling machine

In the warehouse of the dairy (see Figure 38), the packing is put on a driven pallet conveyer [2], leading to a place near the filling zone, where the plastics and the corner protectors are removed [3]. This can be done either manually or automatized, depending on the size of investment that the dairy is willing to make. To support the a standard filling machine, about 2,7 pallets (57mm SCAP-top, nine layers high) of double SCAP-tops would be required every hour, which means that one packing must be cleaned from plastic and corner protectors every 22 minutes. If a manual handling is chosen, an operator could get for example three packings in order at the same time and then have a whole hour to do other things, why the cost of such an option would be proportionately low. Another argument for choosing a manual handling is that a quick visual check of the position trays would lower the risk of getting poorly oriented tops into the filling machine area.

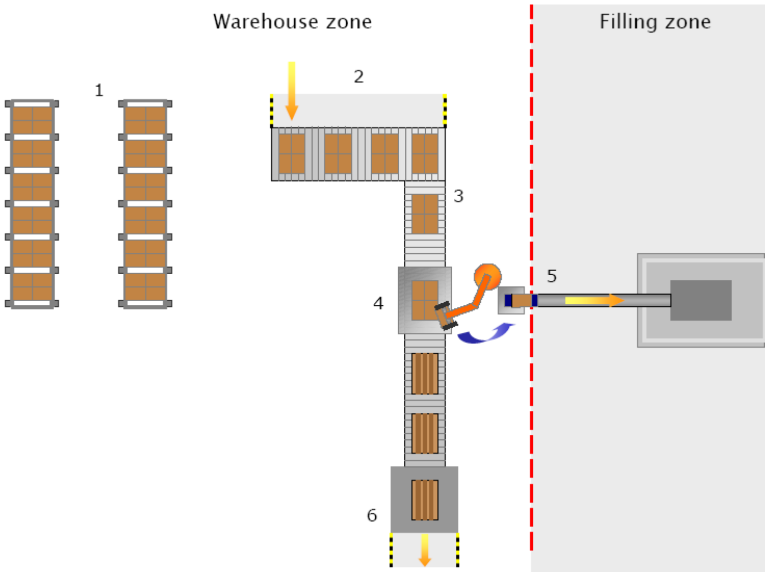


Figure 38: *Illustration of how position trays are removed from a package by a robot.*

The pallet conveyer system ends with a vertically adjustable lifting device [4], where a picking robot puts the position trays one by one with the fixed ends down on an elevated belt conveyer [5]. The belt conveyer, that is covered in order to protect the SCAP-tops from particles and bacteria, goes initially up towards roof height and then leads all the way to the filling machine. It is possible that some kind of locking device, for the position trays not to tip, will be needed on the elevated belt conveyer.

Supply filling machine

After being transported through the filling hall, the position trays reach a hopper, placed on the second floor of the filling machine. There, the trays are fixed at the long sides and become lowered in order to fill the hopper from below. By making the hopper about 1m high, a buffer of SCAP-tops large enough to support the filling machine for about five minutes is obtained. When a signal is sent to the hopper, the lowest position tray is released on an undriven, downward sloping conveyer. A stop device similar to the one in the tray filling sequence then keeps the position tray in place, before it releases the tray, letting it continue to a position rack. In order to facilitate the removal of the SCAP-tops from the position trays, they must be carefully fixed, for example by two parallel locking devices at the sides and possibly some kind of rail straight across the position tray. When this is done, the position rack rotates in a half circle curve, changing place with a similar rack, ending up below two pick and place robots. The robots empties the position tray and provide one metal pipe each, which leads down to the area where the packages are put together, with SCAP-tops. The position rack makes another half circle rotation, changing place with a rack loaded with a full position tray, and is finally released on a conveyer that lead it down to a transportation box at ground level.

Each pick and place robot must be able to have a maximum cycle time of 1,2s, which might be too fast to make this application work properly. To increase the demanded cycle time, we believe that robots with two arms could be used instead. Another argument for this is that it would facilitate the changing of position trays. A position tray will be emptied in about 38 s, which means that the crucial step of the procedure is likely to be the changing of trays. By using robots with two arms each, valuable tenth of seconds would be saved.

4.3.4 Evaluation and testing

To be able to create a foundation for an economical as well as a technical and environmental evaluation between the different alternatives, certain parameters are needed. Much of this information was given by our supervisor at Tetra Pak, Åke Persson, or could be found from other persons within the company. However, after searching for information, above all two questions remained unanswered;

- What is the filling-rate of the pilot-test SCAP-top and how does this differ from other SCAP-top designs and sizes?
- What happens to the SCAP-tops when they are being transported by truck stochastically put in a box?

In order to answer these questions, two tests were performed that are discribed below.

4.3.4.1 Filling rate determination

This test was carried out 030925.

Method

For this test three different SCAP-top designs, all with different volumes and shapes where used, including the pilot-test SCAP-top. Tops of similar kind were put ad-hoc in a corrugated board box with the dimensions 500x400x800mm and where then counted. This procedure was repeated for all three SCAP-top variants. We obtained the outer volume of the different SCAP-tops by simply lowering them into a beaker with water and reading the difference in surface level. Knowing the volume of the box as well as the volume of the different SCAP-tops, the different filling-rates could be plotted against the different volumes of the SCAP-tops in a diagram. A regression line was then inserted in the diagram.

We also performed a test aiming to investigate the filling rate of different ordered patterns of the SCAP-tops in a EUR-pallet sized box. For this test we only used the pilot test SCAP-top. To our help about 30 tubes of paper where made in which the SCAP-tops where put. We put the tubes in different patterns and calculated the filling rate/m³. An "interlocking" pattern alternative was also tested.

Results

The retrieved stochastic fill-rates and the diagram are presented below. The R^2-value of the regression line is: 0,981. Finally, a table of the ordered filling rates is presented.

Table 4: *The stochastic filling-rate of three different SCAP-tops.*

	Pilot test top	"Miraculix" top	White top
Stochastic Fill-rate (single tops/m3)	6360	5310	5240

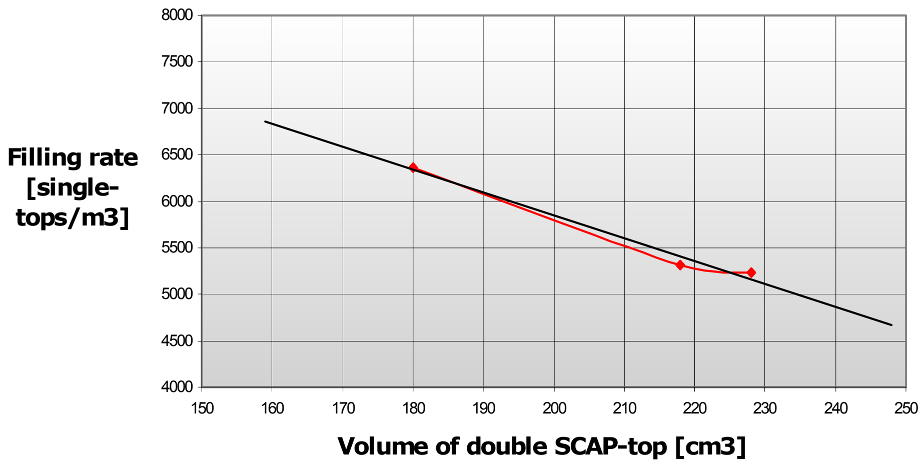
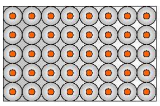
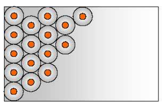
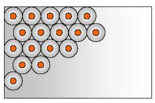


Figure 39: *The relation between the stochastic filling-rate and the volume of different SCAP-tops.*

Table 5: *Ordered filling rates of the pilot test SCAP-top, in comparison with the stochastic filling rates.*

				**Robot alternative -** see Figure 36
	1. Straight rows	**2. Overlapping A**	**3. Overlapping B**	**4. "Interlocking"**
Ordered filling rate (SCAP-tops/m³)	3986	4304	4245	4536
% of Stochastic filling rate	66,9	72,2	71,2	**76**

Conclusions

Except from the fact that the fill-rates were received for the three different SCAP-top designs, another conclusion could with a little cautiousness be drawn from the results. The regression line, with an R^2-value of 0,981 (indicating a good correlation between the values and the regression line), implies a linear relation between the volume of the SCAP-tops and the filling-rate. The shape of the tops, on the other hand, does not seem to affect the filling rate considerably. To draw a conclusion from only three values is of course entailed with difficulties but the result undoubtedly gives an indication of what factor affects the filling-rate the most. This experience can be used when new SCAP-top designs are introduced and an estimation of the filling-rate of this specific top is needed.

When the different ordered filling-rates were compared, the "interlocking" method was the most favourable. However, in general the ordered filling-rates are significantly lower than the stochastic filling-rates.

4.3.4.2 Transport simulation

According to the overall scenario of this thesis the SCAP-tops will almost exclusively be transported by truck in Europe, which is the initial market for the product. Knowledge of how the SCAP-top is affected by this transport is therefore important. At the Tetra Pak site in Lund, there is a transport simulation equipment suitable for this type of test. The equipment consists of a vibration table connected to a software program, simulating truck transport according to the ASTM[107] standard. The following test was carried out 031005.

Method

To our disposal was a wooden box (1000x1000x900) with an inner plastic woven sack, which is the present pilot storage solution for the SCAP-tops. The sack was filled with around 3000 pilot-test SCAP-tops with a manufacturing date of 030625. Because the tops had an almost 3-month-old manufacturing date, the tops were counted and inspected before 2750 of them was put in another wooden box (1200x800x900) and an inner plastic inner bag, to make sure that the SCAP-tops in the test had no defects before the test. In this process new information was found regarding the characteristics of the SCAP-tops. These findings will be presented in the chapter 4.3.5 below. We placed the box, standing on a EUR-pallet, on the vibration table and a simulation program corresponding to around 600 km truck transport was carried out. Afterwards the tops in the lower half of the box were inspected.

Results

Two types of deformations were found on the SCAP-tops after the transport simulation: scratches and dents. The scratches were found on the surface on nearly every SCAP-top but only 7 small dents were found out of the 1427 SCAP-tops inspected, consequently 0,5% of the bottom layer.

Table 6: *The results of the inspection after the transportation simulation.*

Total	2750 tops
Counted	1427 tops
Small dents detected	7 tops
% Of bottom layer	0,5
% Of total wooden box	**0,25**

[107] The ASTM D4728Truck-module, which is a standard in transport simulation, was used. The program was run by Robert Hellsten, responsible for the transport simulation equipment at Tetra Pak Lund.

Conclusions
The 7 dents detected cannot undoubtedly be derived from the transport simulation. Because we found several dents when inspecting the SCAP-tops prior to the simulation (which will more closely be explained below) and thereby sorted these out, it is not impossible but rather likely for us to have missed a few SCAP-tops in this inspection. Most scratches, on the other hand, derive from the transport simulation. The conclusion that can be drawn out of this test is that the biggest problem during transport probably will be scratches on the surface of the SCAP-tops.

4.3.5 Storage related problems for the SCAP-tops

When inspecting the SCAP-tops prior to the transport simulation, several dents where found on the surface of the tops. These SCAP-tops had not been exposed to any other transport than a round-trip to Samhall AB in Eslöv for pilot test capping, a trip of about 40 km in total. They had, on the other hand, been subjected to three months of storage, having a manufacturing date of 03-06-25.

During the inspection a relation between the height of the box and number of detected dents where found: The frequency of detected dents where increased the closer to the bottom of the box we came. Obviously, dents on the SCAP-tops are not a desirably phenomenon because an end customer does not like and consequently does not buy a product with a visible, even though small, defect. Bigger dents can even cause problems in the filling machine, reducing the efficiency. Consequently, it is important to learn more of the dent phenomenon, which leads us to the following questions;

- How do the dents arise?
- In what frequency do the dents occur?
- When do the dents initiate?
- What height of the box is crucial?

The first question is important but unfortunately of a material technological nature, why it will be left out of this thesis. In order to answer the other three, inspection-tests were carried out on SCAP-tops with different manufacturing dates. These tests are presented below.

4.3.5.1 Test: Presence of dents on SCAP-tops after storage

Method
SCAP-tops from three boxes stored at constant temperature and constant humidity in 3 months, 1.5 months and 4 weeks respectively were inspected.

Uncapped tops in the lower half of a box, stored less than a week, were also inspected before being capped at the Samhall production site in Eslöv.

Results
At the inspection at Samhall in Eslöv about 12 SCAP-tops out of 2000 had some very small dents.

The dents were almost exclusively found in the lower half of the boxes, at all inspections. Dents start to occur between 1 and 4 weeks and according to Figure 40, the build-up of new dents decrease after 3 months. However, the dents that already have been formed, steadily increase in size.

Table 7: *Results of the inspection tests.*

	Nr. counted	Deformations		
		nr.	%	% of bottom layer
3 months (03-06-25)	2300	197	8,6	21
1,5 month (03-08-12)	1480	120	8,1	20
4 weeks (03-09-19)	1650	89	5,4	8

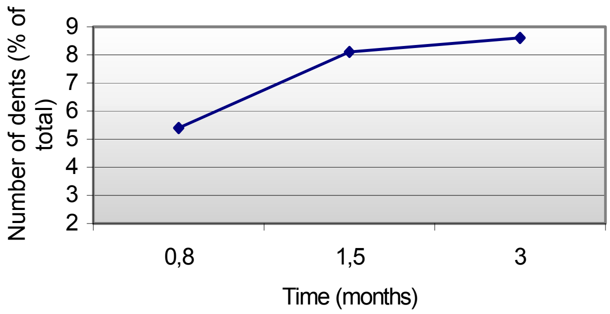


Figure 40: *The emerging of dents on the SCAP-tops in relation to time*

Conclusions
The dents are probably caused by the dead weight of the SCAP-tops in cooperation with the storage time. Because the dents were almost exclusively found in the lower half of the boxes, a restriction of a box height of 0,5m should probably be sufficient for the primary packages.

This is totally new information for the project and because the 0,5m height restriction puts a new demand on the primary package, a new development loop has to be done.

4.4 Second development loop

People that have worked many years in development projects at Tetra Pak R&D have told us that when a product reaches as far as a market introduction, it usually does not look very much like the first drawings of it. Many things can in other terms, and usually does, change along the way, why the discovery of damaged SCAP-tops at long-time storage should be look upon as a common development situation.

However, the new fact meant that some of our alternatives could not be used and therefore we took the obvious decision to go a couple of steps backwards in our process and do a re-loop with the new condition, starting by a new idea generation session. This chapter initially presents a short account for how that session was conducted, while the last part of it presents the new ideas that came up concerning the whole material handling system.

4.4.1 Idea generation at Tetra Pak R&D

Not long after the new condition was found, we got the chance to conduct another idea generation session, this time at Tetra Pak. Apart from four persons from Tetra Pak R&D, two persons from a logistic consultancy firm[108] located in Helsingborg and an associate professor[109] from the division of packaging logistics at LTH attended the meeting. Since these persons were all well up in the project, we could use methods that slightly differed from the ones used during the first meeting at LTH.

After a short warm up where each participant received a funny hat, we started with the same exercise that we started with on LTH, with the exception that every one was told to imagine the transportation of a different amount of SCAP-tops. The idea of that extra condition was to make sure that no limitations were set in their minds concerning what the transportation could mean and also to try and get different ideas out of every person that in turn could trig the others to new ideas. After that exercise, we put a number of "trigger photos"[110] on a whiteboard, and asked everybody to say what first came to their mind when they saw each picture. Out of these words, the participants were asked to form transportation strategies that finally were discussed jointly.

Figure 41: *Grown-up men having fun at work!*

The last exercise was also similar to the last one at LTH, but instead of focusing on general activities, we this time asked the participants to write down as many damage risks as possible for different primary packages illustrated on papers. After about 7 minutes

[108] Network Logistics
[109] Jonsson, Mats
[110] The pictures were chosen with the intention to lead to good ideas and represented a cluster of grapes, a Zeppelin and a fancy cabriolet, among others

the papers were passed on, and each one was now asked to write down solutions to the damage risks written on their paper.

Even though we also this time felt that the exercises did not give as many concrete ideas as we had hoped, the discussions that followed after each exercise turned out to be much more profitable than expected. Still, our idea that you should be as specific and guiding as possible, without locking peoples mind, when you conduct brainstorming sessions seems to be good guideline.

4.4.2 Results of screening and enrichment

After having put the results from the idea generation session together, we started to do a coarse screening. This was done along with an enrichment phase, were ideas were checked more thoroughly by for example benchmarking and checking of practical possibilities and possible dealers. The first half of this chapter presents the new screened and enriched ides that we decided to look more deeply into.

4.4.2.1 Stochastic orientation - "Small box"

The most obvious "new" idea was of course to use a box with a maximum height of 50 cm. This would however require a lot more boxes than with the earlier mentioned box, and therefore an EBM layout (see Figure 42) that would differ from the earlier showed version.

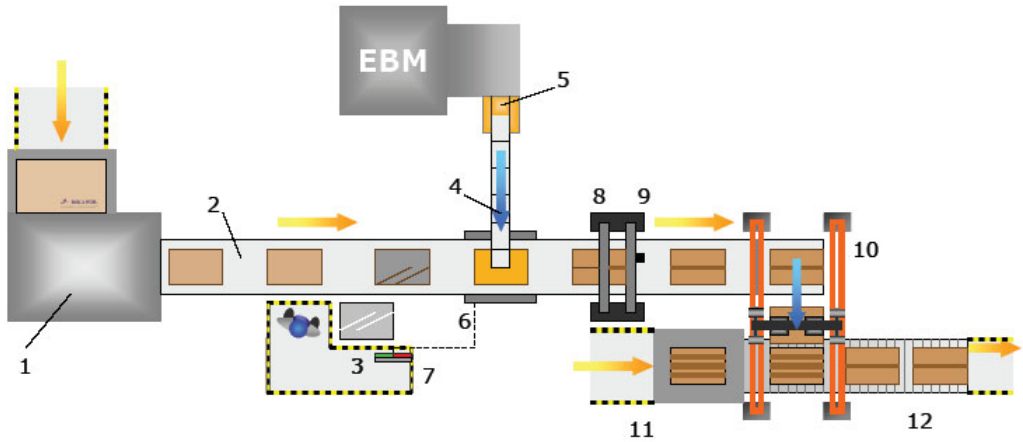


Figure 42: *Illustration of the EBM layout for small boxes (h=0,5m).*

There are two main differences with this EBM layout compared to the original one. First, it is possible to erect the boxes automatically [1] since they must have a maximal height of 50 cm. The double amount of boxes that has to be erected per hour will also probably make it economically defensible. Secondly, this layout has an automatic, hydraulic lifting device that piles two or three filled and closed boxes on a load carrier. The only thing that the operator has to do with this layout is in other terms to put a plastic bag in each box and monitor the system, given that an industrial truck driver provides the erecter with un-erected boxes and the pallet magazine [11] with pallets.

At the customer site (see Figure 43) the only difference from the original layout is that a similar lifting device as at the EBM site lifts the boxes off the load carrier one by one. An operator handles the opening of the boxes [5] here too, which we believe is necessary considering that the inner plastic bag has to be opened and put in a position that makes the emptying [6] reliable.

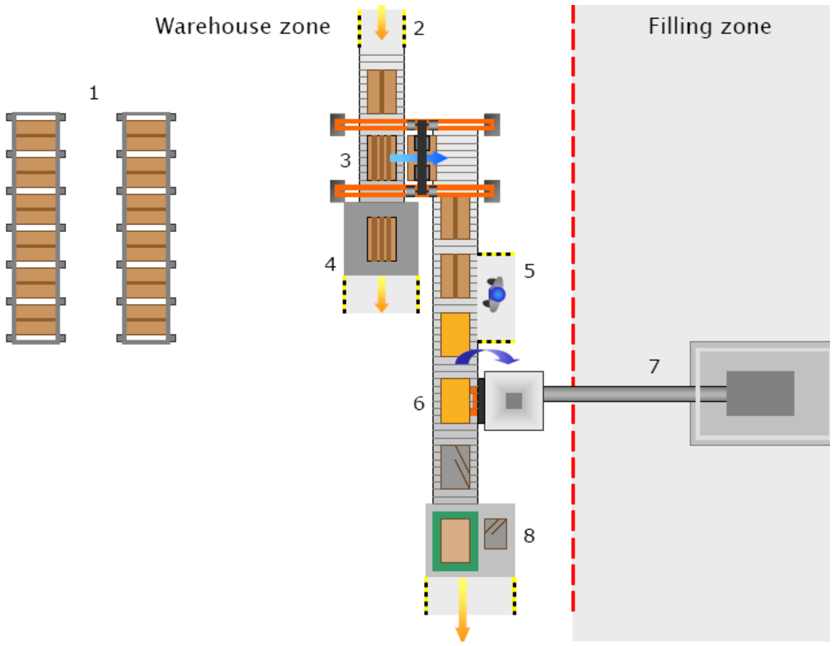


Figure 43: *Illustration of the customer layout for small boxes (h=0,5m).*

4.4.2.2 Stochastic orientation - Divider

How is it possible to maintain having a stochastic orientation of the SCAP-tops in the same boxes as introduced earlier with heights of 0,8-1m, when the SCAP-tops cannot stand the pressure of more than 0,5m in height? The solution is obviously to take up the vertical force from something else than the SCAP-tops underneath. Then what is to our disposal? Clearly the sides of the box, the top of the box and the bottom.

This solution uses the bottom of the box to take up the force. Except from the box itself, which can be any of the earlier mentioned, the solution consists of a dividing plane placed at half the height of the box (see Figure 44a). If there is a small air gap between the dividing plane and the lower layer of SCAP-tops, the divider will take up half the vertical force.

The divider is made of corrugated board 170C, a quality recommended by Anders Duckert[111] to be efficient, and has the dimensions (1170x770x500) for a box with the height of 1m (see Figure 44b).

[111] Duckert, Anders (031021)

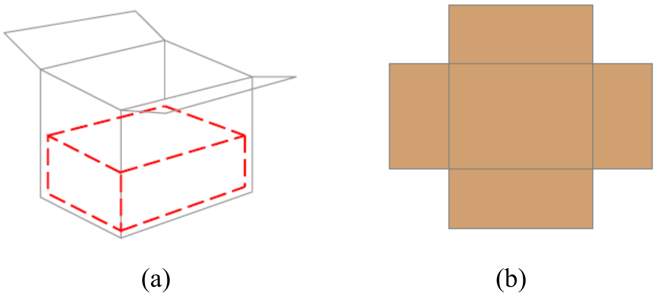


Figure 44: (a) *A dividing plane placed at half the height of the box will obviously take up half the vertical force.* (b) *An unfolded divider*

It is vital that the air gap between the divider and the underlying SCAP-tops is retained. It is also important that the second layer of SCAP-tops is easy to access, probably by an automated process. This is why sealed plastic bags is used. The plastic film can be the same as for the earlier mentioned non-sealed bags but the film will be delivered as a large tube. To erect some question marks, let us enter the EBM-factory.

Handling system at the EBM-factory

The SCAP-tops are leaving the EBM-machine, after being capped, stochastically on a belt conveyer (see Figure 45, [5]). All the included activities of the material handling system as well as the equipment used, that differs from the earlier described activities and equipment for the corrugated board box and the wooden box, will be described below. The system is assumed to be operated by two operators, also having tasks at the EBM-machine.

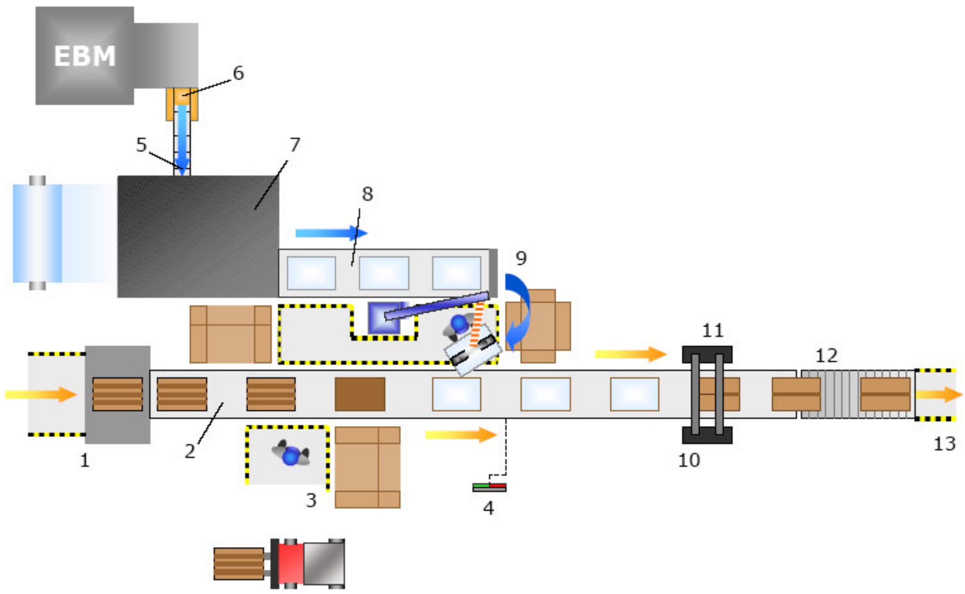


Figure 45: *A schematic description of the material flow out of the EBM-machine and the material handling equipment proposed to handle this flow for the divider solution.*

7. SCAP-top filler and plastic bag sealer.
In this automated unit the plastic film is rolled in, as the SCAP-tops are transported by the belt conveyer [5] into the unit. The film is wrapped around to form a tube and is sealed in one end, the SCAP-tops are filled inside the tube and the other end is thereby sealed as well. When finished, the sealed bags continue on a driven belt conveyer [8], approximately 6-8m.

9. Filling of the box. This must, due to the complexity of putting the divider into a box, be a manual activity. With the help of a manual vacuum-lifter, the operator first puts one sealed bag into the box, and then he puts the divider on top of the bag. The last operation is to put the top bag into the box. When this is done the conveyer [2] feeds one sequence. After the boxes have been automatically closed [10][112] and ID-labelled [11] they continues to a un-driven conveyer [12] for further truck handling to storage.

Handling system at the customers site
The transport is now done and the products have arrived to the warehouse of the customer. All activities for the divider solution at the customer is the same as for the earlier described solution without a divider, except for the SCAP-top emptying activity:

4. Automated, vacuum controlled box-emptying unit. As the divider is easy to pull out of the box, this activity can be automated. A vacuum-lifter, attached to a traverse lifts the top bag out of the box and moves it to the filling funnel. Here, an integrated knife opens the bag and the SCAP-tops fall into the funnel and onto a covered conveyer towards the filling-machine. Next, the divider is pulled out of the box and released on the opposite side of the conveyer [3]. Finally, the bottom bag is pulled out and emptied.

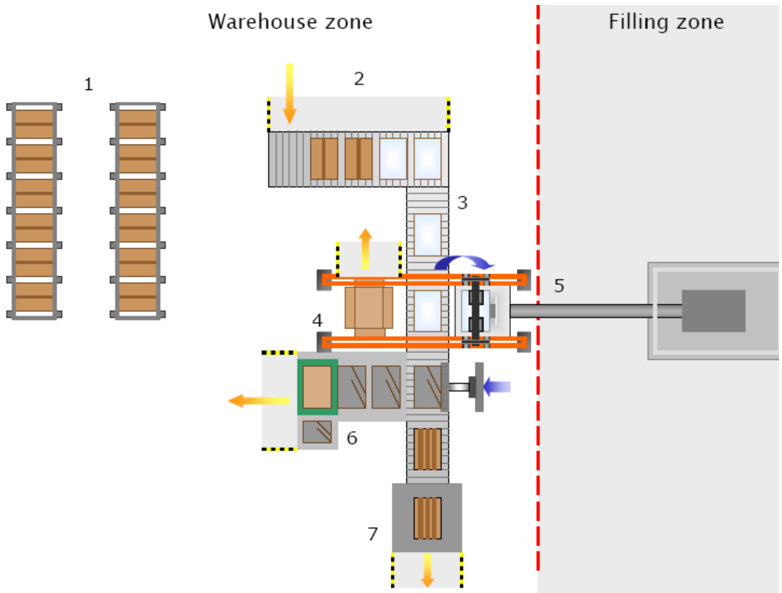


Figure 46: *A schematic description of the material flow from the warehouse to the filling machine at the customers' site with the divider and the corrugated board slotted box.*

[112] This is valid for the corrugated board slotted box only. For the die-cut box and the wooden box this activity will be manual, as described earlier.

4.4.2.3 Stochastic orientation – Corrugated board "Tower"

Another solution to take up the vertical force from the overlying layers of SCAP-tops is to use the "chips bag"-principle. When an airtight bag is filled with a product and an even force in applied on top of it the air inside the bag will compress slightly and thereby take up the load. The similar principle is used for e.g. chips in the retail industry.

This solution uses this principle and consists of a die-cut box of corrugated board with a high frame unit. The frame is made of a (1200x800x2200) 210BC corrugated board and the top and bottom of a 170C corrugated board. Inside the frame around 5 sealed, reasonably airtight plastic bags filled with SCAP-tops is placed on top of each other (see Figure 47). The plastic film is an 80µ[113] LDPE-film, delivered as a long tube (Ø≈0.9m) to the EBM-site. The frame will be placed on a EUR-pallet.

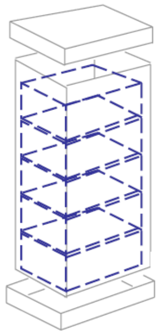


Figure 47: *A corrugated board "Tower" with 5 sealed and reasonably airtight, plastic bags inside.*

Handling system at the EBM-factory

The activities for handling the SCAP-tops in the EBM-factory for this alternative does not differ much from the earlier described system for the divider alternative. However, some differences do exist and these will be explained below. The system is, as for the divider solution, assumed to be operated by two operators, also having tasks at the EBM-machine.

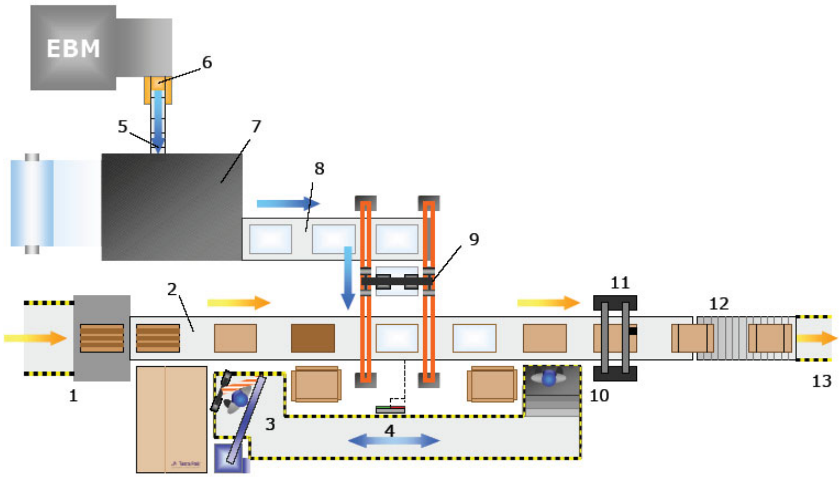


Figure 48: *Possible layout for the corrugated board "Tower" alternative.*

[113] Fällström, Arne (031109)

3. Erection of the frame. Considering the size of the corrugated board frame, the operator for this activity has a manual vacuum-lifter to improve the ergonomic situation.

7. SCAP-top filler and plastic bag sealer. In this automated unit the plastic film is rolled in, as the SCAP-tops are transported by the belt conveyer [5] into the unit. The film is wrapped around to form a tube and is sealed in one end, the SCAP-tops are filled inside the tube and the other end is thereby sealed as well. Unlike the divider solution, the amount of air inside the bag must be controlled when the bag is sealed. This process is, however, not yet developed. When finished, the sealed bags continue on a driven belt conveyer [8], approximately 6-8m.

9. Corrugated board frame filler. This activity can be automatically preformed by an vacuum-lifter on a traverse since the only movements involved are in two dimensions. The automatic lifter fills 5 plastic bags in a frame, then the driven conveyer [2] feeds one sequence.

10. Closing of the box. This is probably a manual activity since the top is complex to fold automatically but also because it is carried out about 3m above ground level.

11. Strapping unit. An automated strapping unit seals the corrugated board frame box with two plastic, non-adhesive straps.

Handling system at the customers site
The transport is now done and the products have arrived to the warehouse of the customer. The equipment for further handling of the SCAP-tops is, as seen in Figure 49, nearly the same as used for the divider solution.

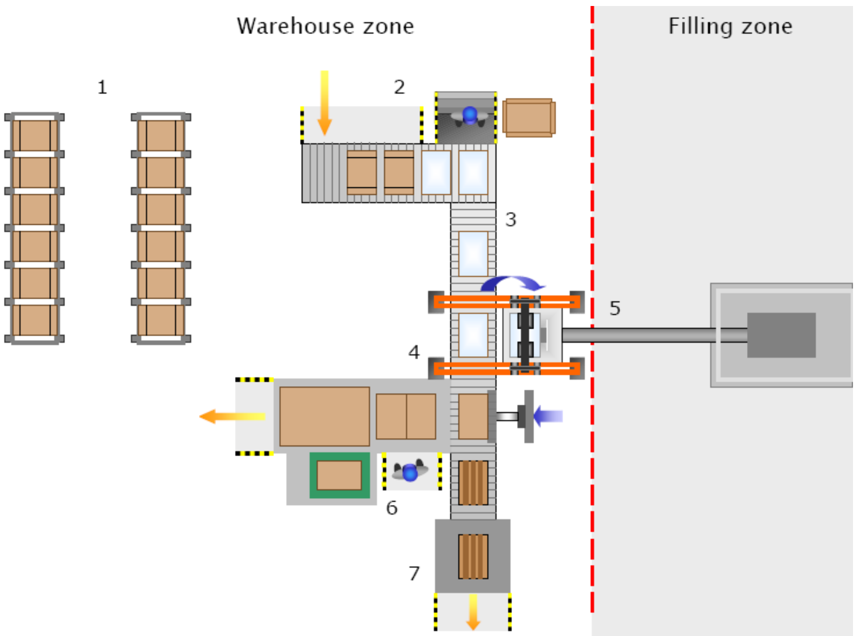


Figure 49: *A schematic description of the material flow from the warehouse to the filling machine at the customers site and the material handling equipment proposed to handle this flow with the corrugated board "Tower".*

Investigations concerning possible problems with airtight bags
Since this solution is based on a technique not yet developed, we conducted an investigation aiming to answer the question: How much air must there be in the plastic bag when it is sealed and what major implications are connected to this technique? The results or our investigation are presented below.

Principally two factors will have an effect on the air volume: the permeability of the plastic and the temperature of the air.

- The relatively high permeability of the plastic (LDPE @ 20°C=100-200cm^3/[m^2/0.01m/24h]) will allow air from the inside of the bag to diffuse out into the surrounding air. Calculations, in cooperation with a chemist[114] at Tetra Pak R&D, show that for the bottom bag, the one with the highest vertical force (approximately 900 Pa) and thus the highest internal pressure, around 0,35 dm3 of air will be lost in 7 weeks (storage time in average) due to the permeability of the plastic film.

- Changes in air temperature will have the following effects:
    - An increase in air temperature will lead to an increase in the permeability of the plastic film, hence there is a reciprocal action between the two factors.
    - An increase in air temperature will lead to an expansion of the air inside the bag. Calculations show that at a 20°C change in temperature, the volume will change 7 %.
    - An increase in air temperature will lead to an increase of the elasticity of the plastic film; hence the risk of plastic deformation of the film will increase.

Consequently, this solution probably will be sensitive for climate changes. A draft calculation and a simple test with a miniature model of a corrugated board "tower" (see Figure 50), show an around 15% loss of filling-rate in comparison to the stochastic solutions. In cooperation with a safety-level of 7 % due to changes in temperature and thus air expansion, the total filling-rate will probably be 20-25 % below the stochastic alternatives.

Figur 50: *The miniature model of the corrugated board "Tower" we used for the filling-rate calculations*

[114] Spjuth, Lena (031210).

4.4.2.4 Jumbo truck - a truck for lightweight goods

Whatever primary packaging is being used for the SCAP-tops, the filled packaging will be very light and voluminous, due to the characteristics of the tops. If a regular EUR-trailer is used, the SCAP-top and its packaging will only constitute of around ¼ of the maximum load[115]. As most transporters tariffs for FTL (Full Truck Load) are fixed for a certain destination, no discount is given with respect to the light weight, making the transports for the SCAP-tops ineffective and expensive.[116] The theoretical solution for this problem is easy: fit more goods into the trailer by heightening the roof a few meters. In practice this is impossible though, due to regulations mentioned in the theoretical framework. However, there is another solution. Instead of expanding the trailer upwards, the bogie construction of the trailer can be made lighter and thereby allow for the total load volume to increase. Of course such a trailer already exists and it is called a Mega- or Jumbo trailer, henceforth in this thesis called a Jumbo trailer.

By having smaller wheels than a normal trailer and by making the bogie more lightweight, the Jumbo trailer can be made with a loading height of 3m instead of, for the standard EUR-trailer, 2,5 m.[117] In other words a 20% increase in loading volume. But in practice the increase can be bigger than this. Suppose that, as for e.g. the wooden box alternative, the box and the pallet make up 80+15=95cm in height totally. Hence, they can be double-stacked in the EUR-trailer with unused height of 0,6m (minus 0,15 in handling height) on top. But in the Jumbo trailer they can be triple-stacked and thereby increase the loaded volume with 50%.

Jumbo trailers are today used by companies transporting lightweight products such as the Swedish postal service, Skogaholmsbröd (a bread manufacturer) and ICA (the major retail chain in Sweden). For the special needs these different companies have, special solutions have been made to customize the Jumbo trailers. The trailer manufacturer DFDS Dahlqvist AB have e.g. made a special trailer for Skogaholmsbröd where the roof can be heightened during the loading and unloading process to allow the volume of the trailer to be utilized near 100%. This trailer is also, similar to the trailers used by ICA, divided into two floors where the second floor is elevated to around 1,60m after being loaded.[118]

The obvious downside to the Jumbo trailer is that it is relatively unusual on the transport market, why the cost for transport with such a trailer is higher than a regular trailer. At Schenker, which is Tetra Paks major transporter, an estimation of a 15% increase in cost for the Jumbo trailer relative the regular trailer is calculated for most destinations.[119]

---

[115] See chapter 3.3.3

[116] Jäderberg, Magnus (031103)

[117] Sivertsson, Håkan (031030)

[118] Lindberg, Mats (031030)

[119] Jäderberg, Magnus (031103)

4.4.2.5 Slip Sheet

The idea of dividing the volume of stored SCAP-tops, in order to eliminate the damages of them, will of course diminish the filling rate. When this fact was fully realized, thoughts about how to use the trailers during transportation in the best way for obvious reasons became more interesting. At a packaging fair in Gothenburg called SCANPACK (October 2003), we then found an interesting alternative to the EUR-pallet, called Slip Sheet, which would increase the amount of goods that can be transported in trucks.

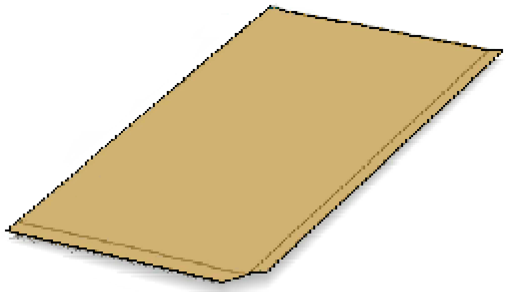


Figure 51: *Illustration of a Slip Sheet.*

Function

A Slip Sheet[120] (see Figure 51) is basically a rectangular sheet, made of a multilaminated kraft liner board, with one or more jutting lists. This of course means that the handling differs a great deal from the handling of a EUR-pallet. When the Slip Sheet has been loaded with goods (see Figure 52), a fork truck with a special adapter (see Figure 53a) grabs the list and pulls the package (see Figure 53b) up on the thin and flat forks of the adapter. Usually, the truck is also driven ahead slowly during this procedure. At unloading, the vertical plate in the front of the adapter pushes the package away, without holding the list, at the same time as the truck slowly goes backwards. If the ground is free from any greater irregularities, the package can be unloaded without the truck having to go backwards.

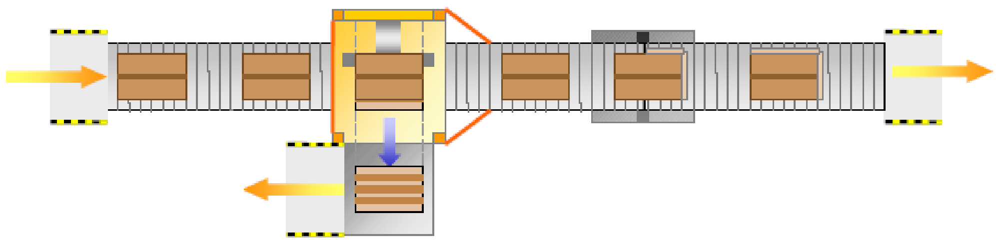
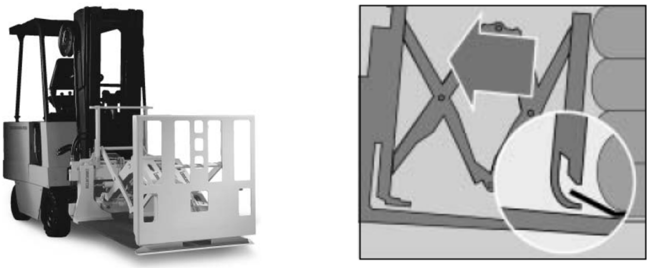


Figure 52: *Illustration of how goods can be placed automatically on a Slip Sheet. When the internal pallet (which often is used) has been removed, the goods are transported on a driven conveyer. At the joint between two conveyers, a hydraulic device then feed the Slip Sheet from below.*

[120] Slip Sheets are sometimes also referred to as "push-pull pallets".



(a) (b)

Figur 53: (a) *Illustration of Slip Sheet adapter, mounted on a fork truck.* (b) *Illustration of how he Slip Sheet adapter handles goods placed on a Slip Sheet.*[121]

Structure and usage advantages

The thickness of the Slip Sheet varies from 0,6mm up to 2mm depending of the weight that will be loaded on it. Also, the design and location of the lists can be chosen according to transportation and warehousing needs. For example, if a version like the one in the picture above is chosen, piling and removing can be done from two sides. Since the Slip Sheets consist of a laminated material, including plastics, they are durable to friction, tear and moist. They are, unlike the wooden EUR-pallet, also insect-resistant, which can be positive in dairy areas and when being transported between countries with different kinds of pests.

Slip Sheet usage has many advantages, where the increased amount of goods that can be transported in trailers naturally is the most valuable one. Since the thickness of a Slip Sheet normally is less than 1mm, about 15cm of load height is saved in every truck layer compared to cases where the EUR-pallet is used. In a standard EU trailer, 30cm of loading height would thereby be saved given two layers of goods, which correspond to 13% [122] of the fillable volume. The possibility of saving a lot of money is evident. Another advantage that also concerns economics is the purchase price. A standard, EUR-pallet sized, Slip Sheet with a thickness of 0,9mm costs about 10 SEK, which should be compared to the wooden EUR-pallets that costs more than 100 SEK. If the Slip Sheets furthermore can be reused, the cost of each transport in this connection would be very low. Even the EUR-pallet is of course reusable, but needs expensive return transports (because of its heavy weight) or connection to a pallet pool.

Experience from users

During our work, we have been in contact with two Swedish companies that use Slip Sheets during transportation: The Absolut Company[123] (V&S Vin & Sprit AB) and Wasabröd AB[124]. The first mentioned company uses the Slip Sheets mainly for container transports of their products to the USA, where Slip Sheet handling is very common. They load up to 800kg on each Slip Sheet, why only one layer with the height of about 1m can be put in each container (because of maximum allowed weight). This means that

---

[121] www.cascorp.com/dowloads/links, 031112

[122] The trailers that TP uses (by carrier) has an inner height of 2,5m and demands 15cm of "safety room" to the trailer roof; 30/(250-15)=0,1277≈13%

[123] Ericsson, Mikael (031128)

[124] www.wasabrod.se (031114)

only the weight of one layer of pallets, and no great fillable volume, is gained. For Wasabröd however, the situation is different. They ship huge amounts of crisp-bread, which is a very light product, to the USA each year and have gained one layer of crisp-bread for each EUR-pallet changed to a Slip Sheet. Since the weight of their products is never conclusive for how much that can be filled in a container, great profits have been made. Compared to the situation before the usage of Slip Sheets, every fifth container is now shipped for free.

Negative sides

The most evident disadvantage with the Slip Sheet is that it requires an adapter for industrial trucks, which costs about 90000 SEK. The adapter can though be connected to the compressed air system of the industrial truck and changed to its regular forks in only a couple of minutes. The handling of the adapter also differs from regular EUR-pallet handling, why some time of education and practice for the drivers is needed. The operation that needs the most training is grabbing a Slip Sheet lying directly on the ground. The reason for this is that the adapter in its lowest position partly conceals the list of the Slip Sheet, making it more difficult to grab. The higher up a Slip Sheet is, the easier it is to grab though, which means that double or triple stacking cause no problems. Furthermore, if a Slip Sheet package is placed in front of a trackpad (see Figure 54), the handling becomes at least as fast as with EUR-pallets. The information we have got from our contacts with Slip Sheet users is that there, in total, is no real difference in handling speed after a while, compared to the EUR-pallet case.

Figure 54: *Slip Sheet packages placed in front of a trackpad in order to facilitate handling.*

Another negative side is that the Slip Sheet does not make regular warehousing with store racks possible. Either an internal pallet[125] has to be used, or each floor of the warehouse must be equipped with a plate at the bottom. Though, the usage of an internal pallet, or rather the adding of a Slip Sheet after having removed the internal pallet, can be handled automatically and causes no problems at The Absolute Company.

[125] The Absolut Company uses an planed, internal wooden pallet that costs about 250 SEK

Optimal usage conditions
The main reasons to why the Slip Sheet is not used more than it is in Europe, is the need for a special adapter to industrial trucks and the old tradition of EUR-pallet usage, with many established material handling systems. However, we believe that an important factor also is that to little energy has been spent on logistics with the result of not many people knowing the existence and benefits of the Slip Sheet.

From our investigation of Slip Sheet we have come up with a number of conditions that should be valid in order to be able to benefit from the advantages that Slip Sheet handling can give:

- Products light enough to make the packaging volume dimensioning for transportation cost
- Regular deliveries
- Transport volumes large enough to motivate the purchase of Slip Sheet adapters
- Few customers

The way we see it, all of these conditions are fulfilled in the SCAP project. Our scenario is based on seven customers around Europe, and even if they most likely also will have other kinds of dairy machines demanding other kinds of material deliveries, about one FTL with SCAP-tops will arrive every other day. The purchase of Slip Sheet adapters would in other terms be highly motivated, and even if Tetra Pak would bear the cost of them, we get the feeling that the investments would pay off very fast (calculations of this will be done in chapter 4.5).

4.5 Financial calculations

No matter how brilliant or useful a product or an idea of a product is, it will in today's business world never see daylight if it is not economically defensible. In order to be able to evaluate different material handling solutions, we therefore constructed a financial calculation model in Microsoft Excel. This chapter presents how these calculations were made and the results of them. Since all data concerning this project is confidential, the figures in the following calculations are all ficticious.

4.5.1 Calculation objects

The SCAP-top material handling system, as most supply chains, consists of many components or variables that affect each other. Studying one of these variables *ceteris paribus*[126] is therefore impossible, why we have constructed eight overall solutions (see Table 9) to do financial calculations and further evaluations on.

[126] *ceteris paribus* means that all other factors are kept constant

Table 8: *The eight overall material handling solutions that will be evaluated further.*

Primary packaging	Height		Pallet type	Trailer type
Frame"tower"	2,2 m		EUR-pallet	Regular
Corrugated board box	1,0 m	divider	Slip Sheet	Jumbo
Corrugated board box	1,0 m	divider	EUR-pallet	Regular
Corrugated board box	2 x 0,5 m		EUR-pallet	Regular
Corrugated board box	3 x 0,5 m		Slip Sheet	Jumbo
Die-cut Frame box	1,0 m	divider	Slip Sheet	Jumbo
Wooden box	0,8 m		EUR-pallet	Jumbo
Robot version	1,0 m		EUR-pallet	Regular

The packaging material in the first six alternatives is a corrugated board of model 210BC (thickness of 7 mm), with the exception of the divider that is of model 170C (thickness 3,6 mm), while the material of the last two is plywood and corrugated board as mentioned earlier.

The financial calculations are based on the supply chain model in chapter 4.2.1, and therefore consist of three parts: EBM, transportation and customer. All calculations of running expenses are done from Tetra Pak's point of view, why only EBM and transportation have been looked at. Investments on the other hand, has been calculated both from Tetra Pak's and the customer's point of view. Since Tetra Pak outsource all transports, no investments will be done concerning the transportation. Investments at customer sites have been separated in mandatory and optional, in order to show how great investments the customer must make, or in other words how much will at least be added to the price of the SCAP filling machine. Optional equipment will probably also be sold or leased by Tetra Pak, but might differ depending on where in the world the filling machine will be put.

4.5.2 Assumptions

When doing calculations on a supply chain, which usually is a broad and circumstantial system, it is necessary to do a number of assumptions. The main assumption we made was that all production of SCAP-tops occurred in one factory with two wheel machines, situated in Dijon in the west of France. As mentioned in chapter 4.1.1, we also assume only one size of SCAP-tops. The other most important overall assumptions are listed below:

Customer demand	680 millions single SCAP-tops/year
SCAP filling machine production capacity	18000 packages/hour
Rate of storage turnover	16 days
Total supply chain leadtime	60 days
Machine uptime	47 weeks/year
Return packaging wastage	5 %
Number of return cycles	3
Capital interest	8 %
Storage capital interest	15 %
Unit load area dimension	EUR-pallet (800x1200 mm)
Mode of transportation	Trailer

Costs for equipment, packing material, transportation, salaries, warehouses etc. have as far as possible been gathered from Tetra Pak internally or their suppliers, and the most of them are presented in Appendix C-E.

4.5.3 Procedures and results

Since our thesis first of all concerns Europe, all calculations have been made in EUR (€). In order to get results that can be compared to other investigations within Tetra Pak, all running expenses have been presented in the unit EUR/1000 single SCAP-tops. The table below shows the total results of our calculations.

	Investment and cost summary							
	Stochastic							Ordered
	Frame "tower" (h=2,2m) EUR-pallet Regular Truck	**Corrugated board box** (h=1,0m) with devider Slip Sheet Jumbo Truck	**Corrugated board box** (h=1,0m) with devider EUR-pallet Regular Truck	**Corrugated board box** (h=2x0,5m) EUR-pallet Regular Truck	**Corrugated board box** (h=3x0,5m) Slip Sheet Jumbo Truck	**Frame box** (h=1,0m) with devider Slip Sheet Jumbo Truck	**Wooden box** (h=0,8m) with devider EUR-pallet Jumbo Truck	**Robot version** (h=1,0m) EUR-pallet Regular Truck
Investments								
EBM site								
Equipment	323 304	344 348	290 696	276 565	330 217	290 000	214 609	673 674
Warehouse	3 706 336	3 714 803	3 714 803	3 718 148	3 718 148	3 711 218	3 711 218	3 716 242
Customer site								
Mandatory equipment	77 174	77 174	77 174	120 652	120 652	77 174	77 174	282 609
Optional equipment	58 543	81 370	103 109	75 935	54 196	54 196	75 935	43 326
Σ [EUR]	**4 165 358**	**4 217 695**	**4 185 782**	**4 191 300**	**4 223 213**	**4 132 588**	**4 078 936**	**4 715 851**
Running expenses								
EBM site								
Purchase of PP	0,857	1,907	1,907	2,167	2,167	1,005	1,792	2,358
Personnel	0,328	0,542	0,542	0,473	0,366	0,585	0,814	0,375
Warehouse	0,160	0,111	0,111	0,110	0,110	0,111	0,131	0,120
Maintainance	0,130	0,132	0,128	0,128	0,132	0,128	0,123	0,157
Transportation								
Of SCAP-tops	4,962	3,451	4,492	4,446	3,416	3,451	4,371	4,986
Return transport	0,088	0	0	0	0	0,366	0,934	0
Pallet purchase	0,027	0,072	0,144	0,142	0,047	0,072	0,182	0,160
Σ EUR / 1000 single SCAP-tops	**6,553**	**6,216**	**7,325**	**7,466**	**6,238**	**5,718**	**8,347**	**8,155**

4.5.3.1 Investments

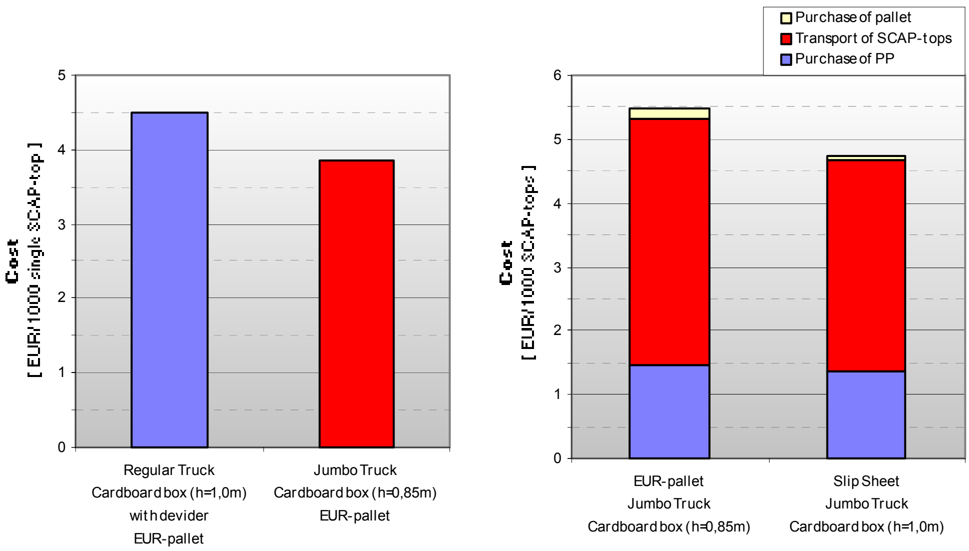
As can be seen in the table, the total investments do not differ much between the alternatives. The main reason for this is that the investment cost of the warehouse building, which amount to some 3,7 MEUR, is about the same for all alternatives. A graph of the EBM investments without the cost for warehouse buildings can be found in Appendix F, as well as a graph of the customer investments.

4.5.3.2 Running expenses

The biggest item of the running expenses (see Appendix F for a graph) is transportation of SCAP-tops, which in average represents 62% of the total running expenses. This was, as mentioned before, expected, considering how low grade and light the SCAP-top is. The second biggest post is purchase of primary packages (PP), and the reason for its great variations is that the two "Frame" alternatives mean re-usage of the primary packages and therefore lower yearly demand. Below, these two posts are discussed more thoroughly.

Transportation of SCAP-tops

As can be seen in the table with the total results, alternative number two, five and six from the left have the lowest total running expenses. When looking in the "name field" of these alternatives, you see that they all include transportation with jumbo trailer as transportation mode and Slip Sheet as load carrier. These two factors mainly result in lower transportation costs, which besides have the biggest potential of cost reductions. If you plot a diagram over transportation costs for two alternatives that apart from the mode of transportation are the same (see Figure 55a), the pattern becomes clear. Even though the Jumbo Trailers are about 15% more expensive in general, the greater amounts of SCAP-tops that can be transported[127] reduce transportation costs by 14%.



(a) (b)

Figure 55: (a) *Diagram of comparison between regular and jumbo trailer.* (b) *Diagram of comparison between EUR-pallet and Slip Sheet.*

A comparison between the EUR-pallet and the Slip Sheet (see Figure 55b) leads to a similar conclusion. The increased height each primary package can have due to the thin Slip Sheet leads to a much higher filling rate in the trailer and 13,5% lower transportation costs.

---

[127] The height of the primary package is of course chosen to optimize the number of packages, and thereby the number of SCAP-tops, in each transport.

Primary packaging return system

As mentioned above, the costs for primary packages in the SCAP-project can be reduced by using a return system. By plotting cost curves as a function of number of re-usages for the different primary packages alternatives that can be re-used (see Figure 56), it is possible to get a picture of how to optimize a return system.

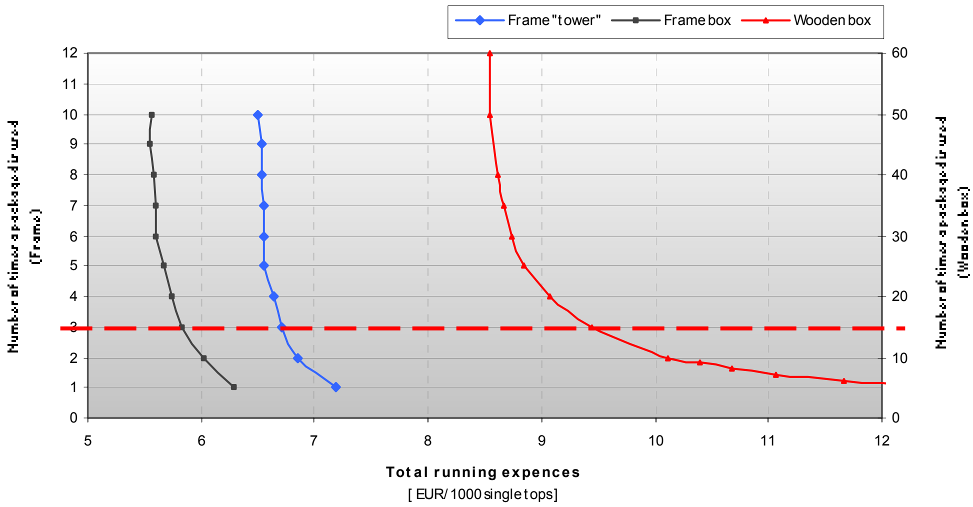


Figure 56: *Sensitivity analysis of re-usability of primary packages.*

If the wooden box is ignored (because of unreasonable high costs), it becomes obvious that the total running expenses decline quite a lot for every additional re-usage in the beginning. However, after about six times of re-usage, the running expenses cease to diminish. The reason for this is that all parts of the package are not re-used, and that theses expendable supplies such as plastic bags and ID labels after a while add up to more than the re-used part. Our calculations are based on the assumption that the primary packages are used three times, why there is potential to lower the costs even more. Still, these three times of re-usage correspond to 60-70% of the possible savings due to re-usage, which amount to 9-11% of the total running expenses!

It should be mentioned that no cost have been added for damaged SCAP-tops. It can for example be assumed that the ordered alternative results in less damages than the other alternatives, why it probably has lower costs for rejected SCAP-tops and possibly also for rejected ready-made bottles. The reason for why this has not been regarded is mainly that it would be very difficult to estimate the value of a damaged SCAP-top. It would for example be difficult to estimate how the machine uptime would be affected by damaged SCAP-tops and how much "badwill" this would generate from customers and consumers.

4.6 Criteria evaluation

The main objective of this thesis has been to identify and design appropriate resources and activities along the Supply Chain of the SCAP-tops. Now the different alternatives of these resources and activities are to be evaluated regarding functional, economical and environmental aspects. While earlier screenings and eliminations of solution alternatives along the way have been relatively draft and often based upon intuition, the structured Kesselring method will be used for this last evaluation. The Kesselring chart will propose a winning solution alternative, which will be the recommended alternative of this study for Tetra Pak to implement.

To make a profound evaluation the economical and functional categories have been split up into sub-categories. Every category have then been weighted from 1 to 5 with 5 being the most important, which as mentioned in the theory chapter, is a step in the Kesselring method. Let us take a look at what these categories represent.

4.6.1 Economical criteria

A. Investment requirement and system development
As can be seen in Appendix F (investments) the investment costs differ significantly between the different solution alternatives. However, the system development cost for making a few of the systems, i.e. the robotized alternative and the corrugated board "tower" alternative work satisfactory probably exceed the direct investment cost considerably. These costs are not easily forecasted but since, for the Kesselring evaluation, it is not the absolute value but the relative values between the different alternatives that are needed, qualified guesses should be sufficient. Since this is a once-for-all cost, the weight for this criterion will be 2.

B. Procurement of Primary Package
The total procurement costs for the different solution alternatives can be found in chapter 4.5.3. Since this is a relatively high direct running cost and thereby will affect the system as long as it is in operation, the weight for this criterion is set to 5.

C. Transportation costs
The total transportation costs for the different solution alternatives can be found in chapter 4.5.3. Since this is the major direct running cost the weight for this criteria, as for the procurement cost, is set to 5.

4.6.2 Functional criteria

D. Flexibility in handling different product designs
The SCAP project is, as mentioned before, a flexible packaging system. It is therefore important that the handling system is flexible as well in order to be able to handle different SCAP-top designs. The weight for this criterion is set to 3.

E. Protection against external damage
If the SCAP-tops are damaged during the transport to the customer or in storage handling, and arrive in a non-acceptable condition, this will reduce revenue and produce unsatisfied customers. The reason why this criteria gets a weight of 4 and not 5 is the

assumption of FTL-transports, which will reduce damage risks considerably in addition to groupage traffic.

F. Protection against internal damage
By the same reason as the criteria above, reduction of internal damage is important. By internal damage we mean damages caused by internal friction between SCAP-tops and internal construction aids inside the box that in one way or another can damage the SCAP-tops. The weight for this criterion is set to 4.

G. Maintenance and operation
Since the SCAP project's main customers are in the industrialized world, wages for operators and service personnel are relatively high. This, together with the fact that a large need of maintenance of the system will reduce system accessibility, motivates this criteria. The weight for the criterion is set to 3.

H. Probability of system problems
The more activities are included and the more complex the total system is, the more the probability of system problems to occur increase. With system problems we mean events causing down-time, and thereby reduces the availability, for any unit within the system. It is of this reason appropriate to use this criterion in the evaluation process. The weight is set to 4.

I. Ergonomics
From an ethical point of view, as well as for Tetra Pak to keep an ethically sound image, it is important that the manual activities within the system are ergonomically. Not least the economical consequence of operators that are on the sick-list because of ergonomically bad operations, suggests that this criterion is appropriate in the evaluation process. The weight is set to 3.

4.6.3 Environmental criteria

J. Environmental impact
The possibility of reusing the primary package, the possibility of recycling used materials and the filling rate in the primary package as well as in the trailer are all factors that have environmental impact and are therefore all considered in this last criterion. The weight is set to 4.

Below the Kesselring chart with all the different solution alternatives graded against the criteria, is shown. As seen in the right column for the relativity sum, the corrugated board box with 0,5m height have got the highest grades closely followed by the corrugated board "tower" together with the corrugated board frame box. The ordered alternative, the robotized solution got the lowest grades of all, why this type of handling system most likely can be abandoned.

Table 9: *Kesselring evaluation chart with the grades for all solution alternatives.*

Evaluation scale	
g = 4	Excellent
g = 3	Very good
g = 2	Treshold
g = 1	Below treshold
g = 0	Poor

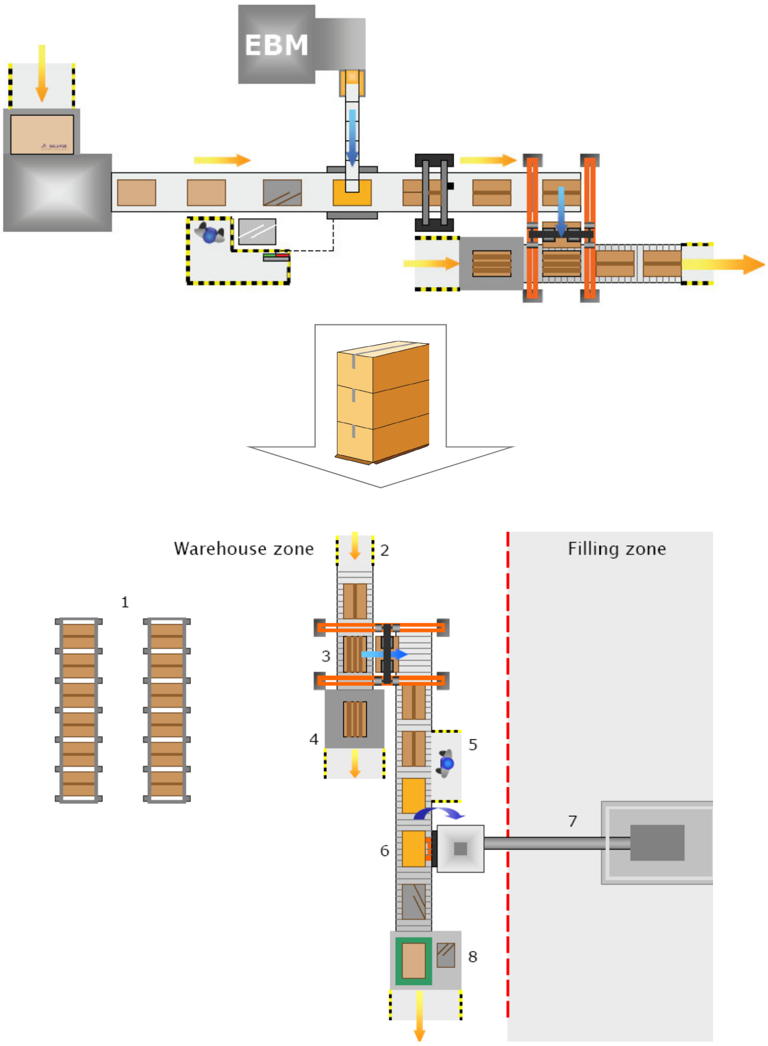
Criteria scale	
n = 5	Absolutely must
n = 4	Very highly desired
n = 3	Highly desired
n = 2	Little desired
n = 1	Very little desired

Formulas
T = Sum (t)
t = n * g
T_{max}= 148

	Criteria	Investment requirements and system development	Procurement of PP	Transportation costs	Flexibility in handling different product designs	Protection aganist external damage	Protection against internal damage	Maintenance and operation	Probabilty of system problems	Ergonomics	Environmental impact	**Sum (T)**	**Relativity sum (T/Tmax)**
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**		
Idea / Concept	n	2	5	5	3	4	4	3	4	3	4		
Frame"tower" (h=2,2m) EUR-pallet Regular Truck	g	1	4	1	2	2	2	3	1	2	4		
	t	2	20	5	6	8	8	9	4	6	16	84	0.568
Corrugated board box (h=1,0m) with devider, Slip Sheet Jumbo Truck	g	2	2	4	2	2	1	1	2	1	3		
	t	4	10	20	6	8	4	3	8	3	12	78	0.527
Corrugated board box (h=1,0m) with devider, EUR-pallet Regular Truck	g	2	2	2	2	2	1	1	3	1	2		
	t	4	10	10	6	8	4	3	12	3	8	68	0.459
Corrugated board box (h=2x0,5m) EUR-pallet Regular Truck	g	4	1	2	3	2	1	2	4	3	0		
	t	8	5	10	9	8	4	6	16	9	0	75	0.507
Corrugated board box (h=3x0,5m) Slip Sheet Jumbo Truck	g	4	1	4	3	2	1	2	3	3	1		
	t	8	5	20	9	8	4	6	12	9	4	85	0.574
Frame box (h=1,0m) with devider, Slip Sheet Jumbo Truck	g	2	4	3	2	2	1	1	2	1	3		
	t	4	20	15	6	8	4	3	8	3	12	83	0.561
Wooden box (h=0,8m) with devider, EUR-pallet Jumbo Truck	g	2	2	0	2	3	1	0	3	0	4		
	t	4	10	0	6	12	4	0	12	0	16	64	0.432
Robot version EUR-pallet Regular Truck	g	0	1	0	1	1	4	4	0	4	1		
	t	0	5	0	3	4	16	12	0	12	4	56	0.378

5. Conclusions

The alternative for the SCAP-top material handling system that got the highest rank with the Kesselring method in the previous chapter is also what we recommend to Tetra Pak. It means in broad outline that a highly automated EBM layout is used, a 0,5m high corrugated board box of model 210BC with an unsealed, plastic inner bag is used as primary package for stochastically placed SCAP-tops, the Slip Sheet is used as load carrier and that transportation is handled by jumbo trailers.



Even though this alternative received the highest points with the Kesselring method, a different choice could be justified because of the small margin to the following two alternatives;

- A 2,2m high frame "tower" containing five sealed plastic bags. The frame is put on a EUR-pallet and is transported by a regular trailer.
- A 1m high slotted box with a divider seperating two sealed plastic bags. The box is put on a Slip Sheet and transported by a Jumbo trailer.

There are however a couple of arguments that settles the choice. First of all, the winning alternative is based on a well-known technique with many standard components. This means that little development work has to be done and therefore it is likely to be a fast system to initiate. The exception to this is the Slip Sheet handling, that Tetra Pak never has been in contact with before. Our guess is though that it would not take too much of an effort to initiate such a handling system. Further more, this system can be constructed with a very high level of automatization. The only manual handling in our system is the placing of a plastic bag in the boxes, but even that could certainly be automated, creating a material handling system only requiring sporadic monitoring and material loading. Finally, this system has a high flexibility for all kinds of adaptations. Changing for example the sizes or the materials of the boxes, the level of automatization or the SCAP-top production rate would mean no greater difficulties.

As mentioned above, some work would have to be done before a Slip Sheet handling system could be put into operation. Our recommendation is therefore that someone at Tetra Pak is given the task to do a mapping of suppliers and specifically needed equipment. At the same time, it would be wise to let the transport department at Tetra Pak start discussing or negotiating about jumbo trailers with their carriers.

6. Recommendation of further investigation

Since our calculations show that up to 11% of the total running expenses could be saved by re-usage of the primary packages, an interesting thing to look more deeply into would be if the slotted boxes our system assumes could be re-used or changed to re-usable ones. Today, corrugated, slotted board boxes are not re-used, but maybe the light weighted SCAP-tops that probably will get regular transports can be an exception. Would it then be possible to erect boxes that have been used in an automated way and would they have to be cleaned after each usage? We believe that these issues could be investigated quite easily during the start of the SCAP project, when a material handling system has been introduced.

Something to investigate further at the prospect of the future is definitively the "snack bag" concept, where air-filled, sealed plastic bags are put on top of each other in a 2,2 m high die-cut box. The main reason why this alternative did not get higher points in the Kesselring evaluation is that it results in the lowest filling rate of SCAP-tops of all alternatives and therefore high transportation costs. However, being "worst" at the most important financial item can in this case be positive - if the filling rate could be increased, or in other terms be found to be higher in reality, there is a great potential of reducing the costs. Furthermore, the die-cut cardboard frame is only assumed to be used three times, why there should be a good chance of increasing that figure and thereby lower the second biggest financial item of primary package purchase.

When the filling rate is discussed, also the load carrier plays an important role. Our solution assumes the wooden EUR-pallet, since we believe that the high frame needs a stable base to minimize the risk of tilting. However, if the EUR-pallet could be changed to the Slip Sheet, 15cm of loadable trailer height would be gained in each transport with a substantial increase of the filling rate as a result. This could relatively easy be investigated by practical experiments.

Apart from the filling rate, there are a number of questions that still remain unanswered for this alternative. The most pressing one is whether it is possible make the plastic bags tight enough, which would require a plastic that can keep the air under pressure without diffusing and also a good sealing of the bag. Other important questions are whether the SCAP-tops will receive enough protection against external influence, such as chocks and blows, but also against internal influences, such as pressures and scratches.

References

Published material

Books

Andersen, Heine et al (2000), *Vetenskapsteori och metodlära*, Studentlitteratur, Lund

Andersson, Roland (1990) *QFD – Ett system för effektivare produktframtagning*, Linköping Studies in Science and Technology, Thesis No. 221, Linköping

Arbnor, Ingeman/ Bjerke, Björn (1995) *Företagsekonomisk metodlära*, Studentlitteratur, Lund

Axsäter, Sven (1991), *Lagerstyrning*, Studentlitteratur, Lund

Bergman, Bo / Klefsjö, Bengt (2001), *Kvalitet från behov till användning*, Studentlitteratur, Lund

Darmer, Per / Freytag, Per V. (1995), *Företagsekonomisk undersökningsmetodik*, Studentlitteratur, Lund

Deschamps, J-P (1995), *Product juggernauts*, Harvard Business School press

Holme, Idar / Solvang, Bernt (1997) *Forskningsmetodik*, Studentlitteratur, Lund

Johansson, L-G (1999), *Introduktion till vetenskapsteorin*, Thales, Stockholm

Johnsson, M. (1998) *Packaging Logistics – a value added approach*, Department of Engineering Logistics, Lund Institute of Technology

Jönson, G. (2000), *Packaging Technology for the Logistician*, Department of Engineering Logistics, Lund Institute of Technology

Knudsen, Daniel (2002), *Kompendium I Materialhantering*, Institutionen för Teknisk Ekonomi och Logistik. LTH

Lumsden, K. (1998), *Logistikens grunder*, Studentlitteratur, Lund.

Ottosson, Stefan (1993), *QFD i produktutvecklingsarbetet*, Institutet för Verkstadsteknisk Forskning, Produktion Ateljén IVF, Göteborg

Schönbeck, Olle, *Boxing – The Noble Art of Packaging*, SCA Packaging Sweden AB

Tarkowski, Jerzy / Irståhl, Bo / Lumsten, Kenth (1995), *Transportlogistik*, Studentlitteratur, Lund

Trost, Thomas (1998), *Identification of damage inducing mechanisms*, PackForsk report nr 183

Trost, Thomas (1998), *Varutransporter och godsskadekostnader*, PackForsk report nr 121

Vega, Daniel (2003), *Optimizing scenarios research for Tetra Pak's SCAP project*, LiTH

Wallén, Gunnar (1996) *Vetenskapsteori och forskningsmetodik*, Studentlitteratur, Lund

Wiedersheim, Paul F. / Eriksson, L. T. (2001), *Att utreda forska och rapportera*, Liber ekonomi, Malmö

Fakta om förpackningar och miljö (2001), Packforsk, Kista, Sweden

Fibre Box Handbook (1999), The Fibre box association, USA

Internationell Distributionsteknik (2003), Institutionen för teknisk ekonomi och logistik, LTH.

Tillverkningssystem (2000), Avdelningen för mekanisk teknologi och verktygsmaskiner, LTH.

Articles

Akao, Yoji / Mazur, Glenn H. (2003), "The elading edge in QFD: past, present and future", *International Journal of Quality & Reliability Management*, Vol. 20, No.1

Bjöörn, U. (1990), *Conference about supply chain management at Volvo*, Göteborg

Johnson, Corinne N. (2003), "QFD Explained", *Quality Progress*, Mar 2003

Electronic sources

www.cascorp.com/dowloads/links

www.crafoord.se

www.eleiko.com/html/industri

www.exaktvagteknik.se/spider

www.masetllc.com/products, The MASET, LLC website

www.nefab.se

www.tetrapak.com>TheCompany>History

www.vv.se/yrkestraf/regler/gods, the website of Vägverket, Sweden

www.wasabrod.se

www.qfdi.org, the Quality Function Deployment Institute's website

Oral sources

Persson, Åke, Project manager, Converting technologies, Tetra Pak R&D

Duckert, Anders, SCA Packaging Sweden, Malmö

Edström, Johan, Project manager, Cardboard & Pallet Systems, Tetra Pak Carton Ambient AB.

Palm, Sandra, SCA Packaging Sweden AB, Malmö.

Lehto, Jari, Boxon Bags AB

Mårtensson, Lars, Project manager, Aseptic technology, Tetra Pak R&D

Fällström, Arne, Trioplast Landskrona AB

Spjuth, Lena, Development Engineer, Polymer Technology, Tetra Pak.

Jäderberg, Magnus, Tetra Pak Group Travel and Transport, Lund

Sivertsson, Håkan, DHL, Malmö

Lindberg, Mats, DFDS Dahlqvist AB

Ericsson, Mikael, warehouse manager at The Absolut Company, Åhus

Appendix A – Definitions

Customer A dairy or juice manufacturer. This company is next after the EBM-production in the physical flow of the supply chain.

Consumer The end-user of the finished SCAP-product. The consumers in most cases obtain the product from a retail store.

Central plant production The logistical layout of the plant in which the SCAP-tops are to be produced. A central plant production means that only one production unit exist for one region, in our case, Europe.

SCAP-top A part of a consumer packaging. The fact that, when the SCAP-product is assembled, this unit will represent a primary packaging for another product, i.e. juice, is not considered. In this thesis the SCAP-top is treated as a product and not as a primary packaging.

Primary packaging The packaging being used closest to the product, the SCAP-tops. In our case this can i.e. be a box with a belonging plastic bag.

Load carrier The unit on which the primary packaging is placed in order to be able to be moved with an industrial. A load carrier is also often referred to as a transport packaging. The most common example is a pallet.

B2B distribution "Business to business distribution". Distribution between two different companies or organisations without interactions with end-users.

JNSD The Tetra Pak abbreviation of the product segment including juice and nectar still drinks.

LDP The Tetra Pak abbreviation of the product segment including liquid dairy product.

Appendix B – example of specification of requirements

Filling of SCAP-tops

1. Function

Capacity

- Flexible speed of production
- Never Bottle neck
  - Must be able to exceed capacity of all earlier steps in the production line
  - Possible buffer > …, to enable reloading process
- Number of operations < …

Effect on product

- No permanent damages of SCAP-tops (buffer included)
- Aseptic environment

Flexibility/set-up-time

- Must be able to handle all SCAP-top models
- No set-up time (same for all SCAP-tops)

2. Operation

Operator requirements

- No special requirements of operator qualification

Efficiency

- Availability (A) = 100 %
  A = MTBF / (MTBF + MDT)
- Quality efficiency (Q) = 99.99 % (SCAP-tops)
  Q = number of approved units out / number of approved units in

3. Service

Service interval/service friendliness

- Service shall be handled continuously without causing down time

Preventive maintenance

- Preventive daily maintenance must be possible

4. Environment/surroundings

Environment

- Materials used shall comply with the Environmental Policy of the company

Temperature

- The operation must work in an ambient temperature interval between + 5 °C to + 50 °C.
- In transit, the equipment must be capable of being subjected to temperatures between – 20 degrees and + 70 degrees without being damaged.

User friendliness

- Noise level < 75 dB
- Easy to handle

Relative humidity

- The operation must be capable of operating in the humidity interval 10 - 95% RH.

Cleaning/washing

- The operation shall be designed to prevent dirt to enter the system
- The equipment shall be easy to clean

5. Mechanical design

Service life

- The technical service life must be at least x hours

Design

- Floor area < …
- Height < …
- Weight < …
- Electric applications must be convertible to all kinds of electricity supply networks

6. Costs

Average

- The average total cost/1000 packages must not exceed X EUR
- The purchase cost of the parts used in the operation should not exceed x EUR.

Operation

- The required operator time should together with operations reloading and closure not exceed x min/8h
- The cost for required maintenance time and spare parts should not exceed x EUR/1000 SCAP-tops in average

7. Level of automatization

- The level of automatization shall be flexible to fit standards/possibilities of different countries

Appendix C – activity analysis at EBM site

Activities	**Frame "tower"** (h=2,2m) EUR-pallet Regular Truck	**Corrugated board box** (h=1,0m) with devider Slip Sheet Jumbo Truck	**Corrugated board box** (h=1,0m) with devider EUR-pallet Regular Truck	**Corrugated board box** (h=2x0,5m) EUR-pallet Regular Truck	**Corrugated board box** (h=3x0,5m) Slip Sheet Jumbo Truck	**Frame box** (h=1,0m) with devider Slip Sheet Jumbo Truck	**Wooden box** (h=0,8m) with devider EUR-pallet Jumbo Truck	**Robot**
Handling of delivered PP								
Recieving and transp. of incoming PP	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0
Transp. of PP from pre-storage to prod	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0
Σ (seconds/package)	240,0	240,0	240,0	240,0	240,0	240,0	240,0	240,0
Nr of pallets with unfilled packages/year	481	1 037	1 037	1 456	1 456	1 037	8 128	2 307
Hours needed for act./year	32,09	69,14	69,14	97,10	97,10	69,14	541,84	153,81
Number of operaters required / shift	0,01	0,01		0,02	0,02	0,01	0,10	0,03
Activity cost [SEK] /year	**5 760**	**12 412**	**12 412**	**17 430**	**17 430**	**12 412**	**97 266**	**27 610**
SCAP-top handling								
Erection and placing of PP	60	40	40			40	50	
Placing of plastic bag				20	20			
Inserting devider		30	30			30	30	
Placing of filled plastic bag		30	30			30	30	
Preparing package for closing				15	15			
Closing box	40					20	20	
Σ (seconds/package)	100	100	100	35	35	120	130	0
Σ (seconds) for complete factory	200	200	200	70	70	240	260	0
Nr of boxes/year	49 916	90 374	90 374	178 865	178 865	90 374	114 473	100 309
Hours needed for act./year	2 773	5 021	5 021	3 478	3 478	6 025	8 268	0
Number of operaters required / shift	0,49	0,89	0,89	0,62	0,62	1,07	1,47	0
Activity cost [SEK] /year	**497 801**	**901 282**	**901 282**	**624 326**	**624 326**	**1 081 538**	**1 484 111**	**0**
Warehouse handling								
Transp. of SCAP-tops to warehouse	193,8	169,8	169,8	169,4	169,4	169,8	179,5	173,8
Transp. from warehouse to trailer	154,8	130,8	130,8	130,4	130,4	130,8	140,5	134,8
Σ (seconds/package)	348,6	300,5	300,5	299,7	299,7	300,5	320,0	308,5
Nr of pallets for shipping / year	49 916	90 374	90 374	89 432	59 622	90 374	114 473	100 309
Hours needed for act./year	4 833	7 544	7 544	7 446	4 964	7 544	10 176	8 597
Number of operaters required / shift	0,86	1,34	1,34	1,32	0,88	1,34	1,80	1,52
Activity cost [SEK] /year	**867 554**	**1 354 189**	**1 354 189**	**1 336 685**	**891 123**	**1 354 189**	**1 826 638**	**1 543 274**
Σ Activity cost [SEK] / year	**1 371 116**	**2 267 883**	**2 267 883**	**1 978 441**	**1 532 879**	**2 448 139**	**3 408 016**	**1 570 884**
Activity cost [EUR] / 1000 single SCAP-tops	0,328	0,542	0,542	0,473	0,366	0,585	0,814	0,375
Nr of operators:	1,35	2,24	2,24	1,95	1,51	2,42	3,37	1,55

Appendix C – assumptions for activity analysis at EBM site

Industrial truck activities								
Movement into/from pre-storage [movem./h]	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0
Movement into storage [movem./h]	18,6	21,2	21,2	21,3	21,3	21,2	20,1	20,7
Movement from storage [movem./h]	23,3	27,5	27,5	27,6	27,6	27,5	25,6	26,7
Cycle time for movem. into/from pre-storage	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0
Cycle time for movem. into storage [s/cycle]	193,8	169,8	169,8	169,4	169,4	169,8	179,5	173,8
Cycle time for movem. from storage [s/cycle]	154,8	130,8	130,8	130,4	130,4	130,8	140,5	134,8
Truck operator cost [SEK] / hour	179,5	179,5	179,5	179,5	179,5	179,5	179,5	179,5

Number of shifts	3

Appendix D – transportation costs

SCAP-top transport

Pallet type		EUR-pall					Slip Sheet	
Trailer type		Regular	Regular	Regular	Jumbo	Regular	Jumbo	Jumbo
Packaging height (m)		1 (devider)	1 (ordered)	2x0,5	0,8 (devider)	2,2	1 (devider)	3x0,5
Requested nr of packages		90 374	100 309	178 865	114 473	49 916	90 374	178 865
Nr of packages/trailer		66	66	132	99	33	99	198
Nr of trailers		1 370	1 520	1 356	1 157	1 513	913	904
Cost of transportation to		(the distribution between the different customer locations is assumed to be even)						
	Berlin	331 736	368 057	328 346	322 183	366 362	254 238	251 732
	Düsseldorf	251 493	279 029	248 923	244 251	277 744	192 741	190 841
	Munic	270 673	300 309	267 907	262 879	298 926	207 440	205 395
	Paris	78 286	86 857	77 486	79 337	86 457	62 606	61 989
	Pamplona	370 879	411 486	367 089	360 199	409 591	284 236	281 435
	Malaga	370 879	411 486	367 089	360 199	409 591	284 236	281 435
	Rome	370 879	411 486	367 089	360 199	409 591	284 236	281 435
Σ		**2 044 823**	**2 268 709**	**2 023 927**	**1 989 247**	**2 258 261**	**1 569 734**	**1 554 260**

Return transport

		Frame box	Position trays		Wooden box with devider	Frame "tower"	Frame box	
Nr of packages/trailer		66	66		99	33	99	
Nr of packages/year		90 374	100 309		114 473	49 916	90 374	
Nr of return packages/trailer		1680	1467		594	840	1680	
Nr of return deviders/trailer		2100			2100		2100	
Nr of return trailers/year		97	68		247	59	97	
Cost of return transport from								
	Berlin	23 446	16 561		68 844	59 864	26 963	
	Düsseldorf	17 775	12 555		52 191	45 384	20 441	
	Munic	19 131	13 512		56 172	48 845	22 000	
	Paris	5 533	3 908		16 953	14 127	6 640	
	Pamplona	26 213	18 515		76 967	66 928	30 145	
	Malaga	26 213	18 515		76 967	66 928	30 145	
	Rome	26 213	18 515		76 967	66 928	30 145	
Σ		**144 524**	**102 080**		**425 061**	**369 004**	**166 479**	

Transport fares [EUR] per trailer from Dijon, France, to the cities below:

	Standardtrailer	Mega trailer	
Berlin	1 695	15%+	1 949
Düsseldorf	1 285	15%+	1 478
Munic	1 383	15%+	1 590
Paris	400	20%+	480
Pamplona	1 895	15%+	2 179
Malaga	1 895	15%+	2 179
Rome	1 895	15%+	2 179

For all return transports a return-ratio of 1:8 is assumed.

Appendix E – costs of primary packages

Cardboard box

Packaging material:	h 1,0 m	0,85 m	0,5 m
Box	53	50	42
Plastic bag	7	6	5
Staples	0,23	0,23	0,23
Strapping tape	0,46	0,46	0,46
ID Label white	0,46	0,46	0,46
ID Label colour	0,23	0,23	0,23
Σ [SEK]	**61,4**	**57,38**	**48,38**

Return data:

Nr of boxes/pallet	70

Frame box; h=0,85m

Packaging material:	[SEK]
Frame, top & bottom	42,1
Plastic bag	18
Strapping tape	1,38
ID Label white	1,38
ID Label colour	0,69
Σ [SEK]	**63,55**

Purchase incl. material for 3 return transports.

Return data:

Nr of boxes/pallet	70

Wooden box; h=0,80m

Packaging material:	[SEK]
Box	850
Plastic bag	300
ID Label white	23
ID Label colour	11,5
Σ [SEK]	**1184,5**

Purchase incl. material for 50 return transports

Return data:

Nr of boxes/pallet	15
Nr of boxes/pallet (return)	9

Cardboard box with devider; h=1,0m

Packaging material:	[SEK]
Box & devider	71,4
Plastic bag	10
Staples	0,23
Strapping tape	0,46
ID Label white	0,46
ID Label colour	0,23
Σ [SEK]	**82,78**

Return data:

Nr of boxes/pallet	70
Nr of deviders/pallet	##

Frame box with devider; h=1,0m

Packaging material:	[SEK]
Frame	33,89
Top & bottom	33,89
Devider	24,43
Plastic bag	30
Strapping tape	1,38
ID Label white	1,38
ID Label colour	0,69
Σ [SEK]	**125,67**

Purchase incl. material for 3 return transports.

Return data:

Nr of boxes/pallet	70
Nr of deviders/pallet	150

Wooden box with devider; h=0,80m

Packaging material:	[SEK]
Box	850
Devider	407,17
Plastic bag	500
ID Label white	23
ID Label colour	11,5
Σ [SEK]	**1791,7**

Purchase incl. material for 50 return transports

Return data:

Nr of boxes/pallet	15
Nr of boxes/pallet (return)	9

Position tray @ h=1,0m

Packaging material:	[SEK]
Tray (57mm top => 9 layers)	86,4
Corner protecters	3,76
Wrapping film	3
ID Label white	0,46
ID Label colour	0,23
Σ [SEK]	**93,85**

Return data:

Nr of corner protectors/pallet	4
(1) Nr of trays/pallet	400
(2) Nr of trays/package	9
(1)/(2)	44,44

Frame "tower"; h=2,2m

Packaging material:	[SEK]
Frame	66,60
Top & bottom	45,00
Plastic bags	79,80
Strapping tape	1,38
ID Label white	1,38
ID Label colour	0,69
Σ [SEK]	**194,85**

Purchase incl. material for 3 return transports.

Return data:

Nr of boxes/pallet	70

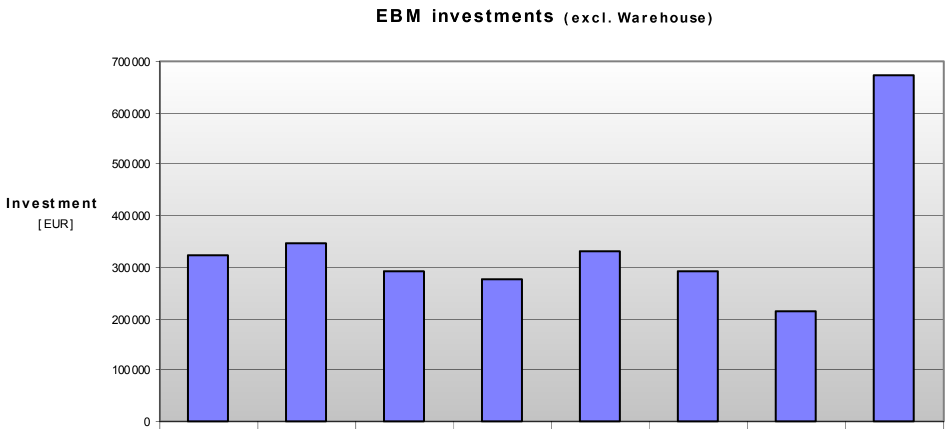
Plastic bag

Packaging material:	[SEK]
Plastic bag	6
Σ [SEK]	**6**

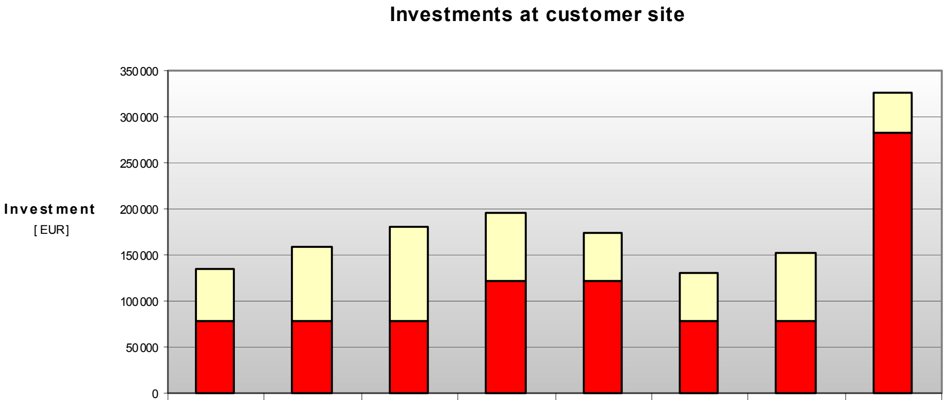
Transport data:

Ant påsar / pall	1000
Ant påsar / rulle	2000

Appendix F – diagrams

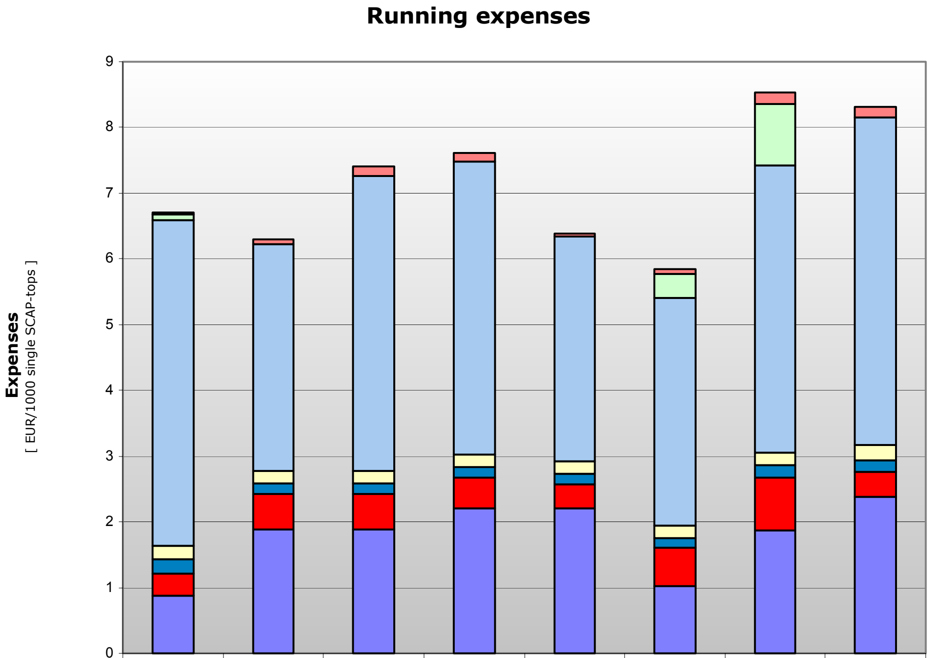


	Frame"tower" (h=2,2m) EUR-pallet	Cardboard box (h=1,0m) with devider	Cardboard box (h=1,0m) with devider	Cardboard box (h=2x0,5m) EUR-pallet	Cardboard box (h=3x0,5m) Slip Sheet	Frame box (h=1,0m) with devider	Wooden box (h=0,8m) with devider	Robot version (h=1,0m) EUR-pallet
Equipment at production site	323 304	344 348	290 696	276 565	330 217	290 000	214 609	673 674



	Frame"tower" (h=2,2m) EUR-pallet	Cardboard box (h=1,0m) with devider	Cardboard box (h=1,0m) with devider	Cardboard box (h=2x0,5m) EUR-pallet	Cardboard box (h=3x0,5m) Slip Sheet	Frame box (h=1,0m) with devider	Wooden box (h=0,8m) with devider	Robot version (h=1,0m) EUR-pallet
Customer optional equipment	58 543	81 370	103 109	75 935	54 196	54 196	75 935	43 326
Customer mandatory equipment	77 174	77 174	77 174	120 652	120 652	77 174	77 174	282 609

Appendix F – diagrams



	Frame"tower" (h=2,2m) EUR-pallet	Cardboard box (h=1,0m) with devider	Cardboard box (h=1,0m) with devider	Cardboard box (h=2x0,5m) EUR-pallet	Cardboard box (h=3x0,5m) Slip Sheet	Frame box (h=1,0m) with devider	Wooden box (h=0,8m) with devider	Robot version (h=1,0m) EUR-pallet
Pallet purchase	0.027	0.072	0.144	0.142	0.047	0.072	0.182	0.160
Return transport	0.088	0	0	0	0	0.366	0.934	0
Transport of SCAP-tops	4.963	3.450	4.494	4.448	3.416	3.450	4.372	4.986
Maintainance	0.195	0.198	0.192	0.191	0.197	0.192	0.184	0.235
Warehouse	0.230	0.157	0.157	0.155	0.155	0.157	0.187	0.169
Personnel	0.328	0.542	0.542	0.473	0.366	0.585	0.814	0.375
Purchase of PP	0.878	1.881	1.881	2.206	2.206	1.016	1.864	2.388