

# CHALMERS



## A proactive approach towards developing a customer-oriented package

*Master of Science Thesis*

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## **Abstract**

Today, the strategic role of packaging has been recognized both in theory and practice and its significance is being acknowledged by every organization. Packaging business has become more innovative and serious than it was before. Consumers start to feel that packaging must fit into their world and all products should be packed responsibly. Companies are facing stiff competition and started including packaging in their business strategy to differentiate themselves. The case company also identified packaging as an important area with possible improvements.

The case company has been manufacturing and packing the case product all over the world without any major issues. However, different machines and materials are used and different procedures are followed in the packaging processes across the company locations. The case company is interested in improving their existing packaging processes and the package on a global scale. They think that one way to differentiate themselves from the competitors and be proactive is by developing a customer-oriented package for their case product and by standardizing the packaging processes. Therefore, the aim of this thesis is to propose a systematic approach for developing a customer-oriented package.

The methods used in this thesis are interviews, factory visits, workshops and other industry visits. An important part of the thesis is the development of a systematic approach towards developing a customer-oriented package. The model comprises of four quality tools, namely, QFD, AHP, ECQFD, and a creative problem solving tool called TRIZ. The tools are used to identify and prioritize the customer needs, translate those needs into technical requirements, solve the contradictions between requirements, and generate new options. The validation of the proposed solutions is carried out using Benefit-Cost-Opportunity-Risk (BCOR) analysis.

The recommendation to the company is to use Liquid Packaging Boards with aluminium coating as a new packaging material complemented by end-load cartoner machine and sealing machine. A new approach has been proposed for package improvement and it can help the company to achieve standardization globally. Moreover, this can be applied to improve any package and packaging process across industries.

*Keywords: Package, Customer-oriented, AHP, ECQFD, TRIZ*



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This thesis has provided us with valuable knowledge and insights in the world of packaging and its significance in any industry and we are happy to experience that!

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## **Abbreviations**

AHP – Analytic Hierarchy Process

BCOR – Benefits, Costs, Opportunities, Risks

CC – Component Characteristics

CEPA – Canadian Environmental Protection Act

CN – Customer Needs

CPG – Consumer Packaged Goods

DP – Design Parameters

DQ – Demanded Quality

ECQFD – Environmental Conscious Quality Function Deployment

EUROPEN - European Organization for Packaging and the Environment

HoQ – House of Quality

ISO - International Organization for Standardization

LPB – Liquid Packaging Board

PEFC - Program for the Endorsement of Forest Certification

QFD – Quality Function Deployment

RFID - Radio-Frequency Identification

RQ – Research Question

TRIZ – Theory of Inventive Problem Solving

VOC – Voice of Customer

VOCE - Voices of Customer and Environment



# Chapter 1: Introduction

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This chapter describes the problem background, rationale, purpose, problem formulation, research questions, and delimitations of the thesis.

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## 1.1 Problem Background

Recent trends show an increasingly important role for packaging as a marketing vehicle because a package is a face of the company and therefore maintains the social reputation of an organization (Silayoi and Speece, 2004). Today, the strategic role of packaging has been recognized both in theory and practice and its significance is being acknowledged by every organization. Improving health standards, changing demographics and life styles and increasing rate of e-commerce are forcing the packaging companies to constantly upgrade their products (Yiangkamolsing, 2010). Packaging business has become more innovative and serious than it was before (Azzi et al., 2012). Consumers wanted their product packaging to fit their needs and all products to be packed responsibly. Due to these factors, companies are facing stiff competition and started including packaging in their business strategy.

According to Holdway et al. (2010), a well designed package and a streamlined packaging process can bring various benefits to the businesses ranging from added functionality and effectiveness, environmental impact during usage and disposal, better product differentiation in the market, and greater resource efficiency. Since packaging can be a source of competitive advantage; designing a better quality package from a customer perspective is highly emphasized. Moreover, packaging industry is facing community concerns about the environmental impacts of packaging and being 'green' is no longer an option but a necessity.

In short, including environmental concerns early in strategic planning phase is considered necessary to create positive ecological and social effects. The case company decided to overcome some of these issues and differentiate them from the competitors. A thesis was proposed by the case company to launch a new customer oriented package and standardize the current packaging process.

## 1.2 Rationale - the Company's Perspective

The case company has been doing packaging as a final part of their product manufacturing for many years successfully. They have made innovations in the packages for their products, which made the company a major player for decades. Their products are sold as high quality and very demanded products. They are constantly innovating and developing new products for the customer. They have the best practices in place. However, there is still room for improvement in the area of packaging. This opportunity for improvement has been neglected because they were doing successfully in the market without any major customer complaints and they were able to meet the customer orders. This is dangerous because it is still a problem and it cannot continue in the future due to the constantly changing market. However, the company has realized this situation now and they are interested in developing a proactive approach towards customer focused package. This thesis can be an opportunity for the company to set the ground for further research. The necessity to explore this opportunity is related to company's strong motivation factors.

They want to reduce cost and increase flexibility. They believe that standardization can bring this change. They also realized that standardization is imperative to improve their overall effectiveness and compete globally. Hence, they want to focus on improving the package and the operability and maintainability of the packaging system. They also think that they need a packaging strategy with the goal of conveying their brand impressions and forming customers' perception of their product.

### **1.3 Problem Formulation**

The strategic significance of standardization and the importance of developing a customer oriented product are highly emphasized in the literature. However, only few companies have realized and incorporated these best practices. Many companies are yet to notice the benefits these practices can bring to their organization.

At present, the case company does not have major problems with their packages and the packaging processes. However, they have realized the potential to improve their existing packaging processes and the product package on a global scale. They think that one way to differentiate themselves from the competitors is by developing a customer oriented package for their case product and by standardizing the packaging processes. Currently, the case product is packed in four different packages made of four different materials which create diversity in packaging processes, machines, materials and appearance of the package resulting in non-standardization. Moreover, the package is quite basic.

To address this situation, the research will commence by identifying the customer needs and by investigating various packaging materials used in different industries. Based on literature study, we will propose a framework to develop a customer oriented package. The idea is to propose a framework that will help in developing a new package. We will focus on the customer needs, suitable methods to capture and analyze them and tools to generate and validate new options for recommendation.

### **1.4 Purpose**

The sole purpose of this thesis is to propose a systematic approach for developing a customer oriented package. Having a systematic approach serving as baseline for the company will accelerate the learning and development process. It is well known that organization largely depend on systems and procedures. In the absence of guidelines and procedures, an organization could disintegrate and fail to make profit.

### **1.5 Research Questions**

Based on the problem identification and purpose, two research questions have been formulated and stated below. The answer to the first research question will be an input for answering the next research question.

*RQ1: How to identify and prioritize customer needs for a package?*

*RQ2: How to utilize the customer needs to improve the existing package?*

### **1.6 Delimitations**

The research involves survey of various types of packages, package materials, packaging machines and packaging technologies in the current market. The results will be used to improve the existing situation. This thesis will be carried out only for a specific type of product and it is restricted particularly to primary packaging. Designing the package is not within the scope of this project. Competitor analysis will not be carried out due to non-availability of information. Customer survey will be done but it will only include workers from the company due to time restrictions. With the introduction of new package, it is important to introduce new packaging machines as well. The latest packaging machines available in the market will be investigated and proposed. However, the focus will be only on proposing appropriate machines and not on designing a package line.

## **Chapter 2: Research Methodology**

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This chapter describes the methodology applied throughout the thesis. First, it gives an overview of the approaches for data collection and how they are used. Second, it describes what data has been collected. At the end, the reliability and validity of the thesis are discussed.

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### **2.1 Research Approach**

#### **2.1.1 Deductive Versus Inductive Approach**

- The deductive approach represents examining of hypothesis based on theory and data collected.
- The inductive approach represents a hypothesis which is inferred based on literature and empirical data (Bryman and Bell, 2011).

#### **2.1.2 Qualitative Versus Quantitative Analysis**

Qualitative and quantitative analysis are methodologies using different types of data in the research. According to Bryman and Bell (2011) they are defined in the following way:

- Qualitative analysis is used to generate hypothesis. In the process of data collection and analysis, qualitative methods use words as a tool. These methods emphasize on the inductive approach and the ways the individuals interpret an object and the environment around it, which is constantly changing.
- Quantitative analysis is used for testing hypothesis. The quantitative methods require measurements for the data collection and the analysis processes. Emphasis is put on the deductive approach.

#### **2.1.3 Selection of Research Approach**

Based on the nature of the research and the audience, an approach was selected. The research approach is mainly abductive, combining both inductive and deductive approach to collect the data. The data collected is qualitative and quantitative in nature. The data collected for the research is about the packaging industry, namely, the package for an industrial product.

### **2.2 Data Collection Approach**

In order to get an understanding of packaging process and how it works, data was collected from different sources. The focus was to understand the implications of the package on the product and the customers. Furthermore, data was also collected to understand the packaging process and to identify opportunities for improving packaging equipment. The thesis employs both qualitative and quantitative methods. The research was conducted through interviews, questionnaires, observations and reading company documents.

#### **2.2.1 Overview of Data Collection Methods**

First, data collection included reading company internal documents and manuals related to packaging machines used in the factories. Second, the factory, where the product is produced and packed, was visited. Observing the production and packaging processes improved the level of understanding and helped to identify possible bottlenecks in the packaging process. Third, packaging fairs were attended to explore various options on the current market in terms of materials and machines. It was a platform to draw inspiration from the latest trends in packaging industry. Last, a packaging workshop was attended to learn about packaging technologies, package materials, packaging regulations and most importantly packaging science as a subject.

Familiarity with the topic and available options in the market enabled the authors to proceed with the next step that is, identifying the needs of the customers. A number of semi-structured interviews with management people and workers were conducted. A pilot questionnaire was sent to some workers in the company (internal customers). Based on the feedback from the pilot survey, a revised questionnaire was sent in order to confirm and analyze the results from the first one.

### **2.2.2 Interviews**

Collecting and confirming the data from customers were considered important. To achieve this, the authors conducted interviews with employees and managers from the company. In order to avoid group thinking and to capture individual needs and preferences, managers and employees were interviewed individually. In some occasions, two people were interviewed at the same time. Both interviewers were always present during the interviews. The interviews were carried out in a semi-structured way. It allowed for investigation and exploration of problems and aspects related to package and packaging process that were not taken into consideration previously.

The interviews with the workers followed the questionnaire structure and the questionnaire itself served as a checklist. Issues that arose during the discussions were also included in the interview.

The main idea of these interviews was to identify the problem in the case company and to gather data and contact information of employees and customers. The data collected from managers was both of qualitative and quantitative in nature, including statements and numbers.

### **2.2.3 Questionnaire**

A pilot customer survey was conducted within the case company to identify needs and preferences of the internal customers. The needs and preferences are only related to package of the case product.

The questionnaire sent to internal customers (Appendix 2) consisted of two distinct parts with multiple choice open ended questions. The first part consisted of general questions which aimed at identifying the customer. The second part included questions on how workers interact with the package based on their experience. While conducting the survey, software was used to weight the needs and preferences of internal customers. In-depth interviews were conducted in order to clarify answers from the questionnaire and to expand on the topic.

### **2.2.4 Observations**

First, data about packaging material and packaging equipment was collected through observation of the packaging process at the factory to understand the whole process and the importance of equipment. Second, fairs and exhibitions about packaging equipment and materials were attended to explore the available options existing in the market. Finally, workshop participation also took place to observe how the packaging process for various products works in another country. The workshop had some lectures on packaging technology and company visits. The workshop expanded the knowledge and helped in generating proposals for possible improvements of the package and the packaging process.

## **2.3 Validity and Reliability**

### **2.3.1 Validity**

Bryman and Bell (2011) wrote that validity is concerned with the purity of conclusions drawn from the collected data. Checking the validity of the data is to verify if the collected data can provide the right information

Data was collected through observations, questionnaire and interviews. It covered both qualitative and quantitative data. This data was sufficient to carry out the research and arrive at useful conclusions for the development of package and improvement of packaging process.

The observations provided mostly qualitative and some quantitative data. The validity is based on the authors' perception and level of understanding of the specific topic, which was later confirmed with professionals in the field.

The questionnaire and the software were used as tools to gather quantitative data from the customers. The questionnaire was properly tested by sending a pilot questionnaire to internal customers, thus improving the questionnaire.

The interviews were carried out with workers and managers from the case company. Professionals from industry and academics were also interviewed. The managers had a clear overview of the types of package and the whole process, providing data which guided the research in the right direction. Some of the quantitative data provided by the managers were not confirmed by internal documents. Also, as stated above, the interviews were carried out in a semi-structured way, which sometimes led the conversation in a direction not completely relevant to the problem at hand. However, questions were rephrased and asked again in order to confirm the statements of the interviewees.

The data can be considered valid due to the fact that both interviewers were present at all times, which prevented from misunderstandings and receiving the wrong data. The interviews served the purpose of collecting the voice of the customer (VOC), which was supported by quantitative data (questionnaire and software).

### **2.3.2 Reliability**

Reliability is about repeatability of results from a study, meaning that the measures of the concepts should be consistent (stable). Furthermore, replication is very closely connected to reliability (Bryman and Bell, 2011).

During the data collection process, customers were asked the same questions in different ways (questionnaire and interviews) to ensure data consistency. Data was also collected through repeated observations during workers' interaction with the package.

The reliability of the questionnaire is related to how successfully the procedure was followed. The response rate of the questionnaire (100%) and the sample size (n=4) have big impact on reliability. The sample consisted of 4 workers specialized at using the case product (expert users). Three of the expert users have experience mainly from working indoors and one has experience mainly from working outdoors. Due to that fact, the input from the worker with experience outdoors is excluded from the calculations. This expert user falls into a different customer category.

Reliability also greatly depends on the clarity of the questions asked.

Furthermore, criteria for choosing the most suitable package were set. These criteria are supported by means of decision software called *Super Decision*, which prioritized the customer

needs. The software also showed the inconsistency values from the answers recorded by respondents. These values were within the acceptable limits.

There were few advantages during the data collection process: the data collection process was closely supervised; interviews with the manager responsible for the project (the process owner) were possible; during all interviews with the managers both the interviewees were physically present which created the possibility to ask additional questions to workers and managers after the interviews.

## Chapter 3: Literature Review

This chapter explains the literature within the packaging field of study. The literature is reviewed to lay a theoretical foundation for our thesis that can be used to analyze the current situation described in the subsequent chapters. This chapter gives the reader a brief overview of packaging science, certain aspects of packaging, packaging trends and methods used in the proposed methodology (Chapter 4).

To help the readers learn and understand about packaging, it is necessary to introduce them to the world of packaging and the trends in packaging. The entire packaging industry revolves around packaging science and their applications which will be explained here.

### 3.1 Literature Review on Packaging

#### 3.1.1 Packaging Science

Packaging science (Figure 1) is a study of packaging sociology, packaging material science and packaging technology (Sasaki, 1994). According to him, it focuses on the application of scientific, technological, design, and business principles to the development of packages and packaging materials into usable forms.

According to Saghir (2002), packaging is “a coordinated system of preparing goods for safe, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal combined with maximizing consumer value, sales and hence profit.” The birth of every package is a combination of science, art and technology (Soroka, 2002).



Figure 1: Constituents of packaging science

##### 3.1.1.1 Packaging Sociology

It comprises of ‘packaging environment’ and ‘marketing’. The environment deals with the background of packaging such as its purpose and function, ethics, environmental problems and laws and regulations. The marketing deals with marketing aspects of packaging such as product planning, marketing strategy, packaging economics and intellectual property.

##### 3.1.1.2 Packaging Material Science

It comprises of ‘materials engineering’ which deals with various materials used to create packages and ‘materials processing’ which deals with technologies that are used for processing different packaging materials. The packaging materials can be classified into two basic types namely, basic materials and composite materials. Based on the individual needs, the material is chosen. It can be either one material or combination of more than one. The materials could be

natural polymers, synthetic polymers, metallic and non-metallic. In real situations, most of the packaging materials are composite. Hence, processing knowledge is very critical. Some basic and important material processing technologies are laminating, coating and printing.

### 3.1.1.3 Packaging Technology

It is a broad area of study under the field of packaging which comprises of product science, packaging design, packaging mechanics, distribution engineering and packaging evaluation. Hence, a brief overview of relevant topics is explained as follows.

- **Product Science**

It deals with the classification of products to be packaged. Based on the product diversity, packages must perform various functions as needed by its contents. Therefore, it is necessary to have a sound knowledge of different products to be packaged.

- **Packaging Design**

It covers design requirements of a package from the functional and aesthetic points of view. The functions could be product protection and safety, product information and fitness for purpose. The aesthetics could be the better appeal and attractive quotient of the package. All these requirements are necessary for creating a new package or improving the existing ones.

- **Packaging Mechanics**

It deals with packaging machinery as a whole. All sorts of packaging machineries from cartoning machine till wrapping machine are covered under packaging mechanics.

- **Packaging Evaluation**

It deals with techniques to evaluate different package materials and products to ensure product and package quality. The techniques are necessary to assess material characteristics and the overall quality.

### 3.1.2 Package

A package is just like any other physical product except that the functions are different. Bramklev (2009) states that, the four main functions of a package are to protect, store, handle and inform. A package can be a simple wrapped or specially designed.

#### 3.1.2.1 Functions of a Package

The functions of a package are straightforward and they are depicted through a package function diagram below (Figure 2). It is very important that all companies that design and manufacture packages ensure that, their packages perform these functions to be successful in the market.

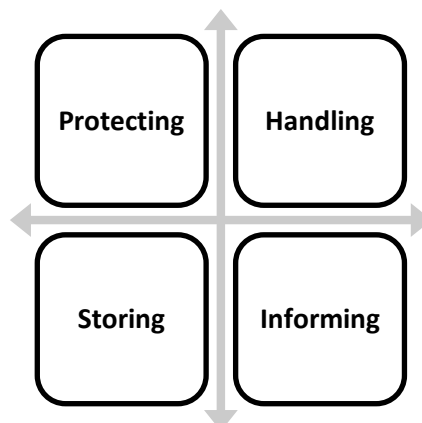


Figure 2: Functions of a package

### 3.1.2.2 Types of Packaging

Saphire (1994) classifies packaging into three major types and describes them. They are:

1. Primary or consumer packaging
2. Secondary packaging
3. Tertiary packaging

The secondary and tertiary packaging can be collectively called as *industrial packaging*.

- **Primary Packaging**

Primary packaging (Figure 3a) refers to a basic package that first envelops the product and holds it until it is consumed by the user. It is in direct contact with the contents. Since, the users access only this package, the primary packaging can also be referred to as consumer packaging. It also has an additional role of marketing the product in itself to the customer and stimulating the product sales through better appeal.



**Figure 3: a) Primary packaging b) Secondary packaging**

- **Secondary Packaging**

Secondary packaging (Figure 3b) is outside the primary packaging used to group all primary packages together.

- **Tertiary Packaging**

Tertiary packaging (Figure 4) is a packaging that facilitates logistical, production and procurement systems. It refers to tertiary and full load packaging unit, intended for use within industrial and distribution system with emphasis on product protection, ergonomics and shipping consideration (Azzi et al., 2012).



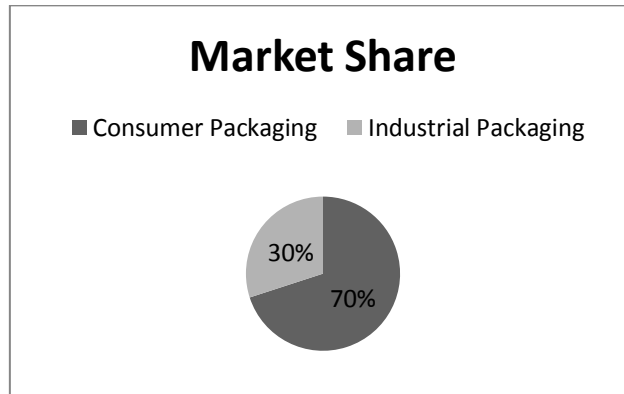
**Figure 4: Tertiary packaging**

### 3.1.2.3 Market Share of Industrial and Consumer Packaging

While consumer packaging represents 70% of the packaging industry, the remaining 30% is industrial packaging (Figure 5). Consumer packaging is more heterogeneous than industrial

packaging. Moreover, the cost involved in collecting and sorting for reuse and recycling is relatively higher than industrial packaging.

Unlike consumer packaging, industrial packaging is more homogenous in nature. It involves mostly corrugated boxes, plastic or metal boxes, plastic bags and film, wooden or plastic crates and woven polypropylene bags. Since industrial packaging is relatively homogenous, it is often regularly recycled, as a matter of business practice to reduce waste disposal costs (Verghese et al., 2007).

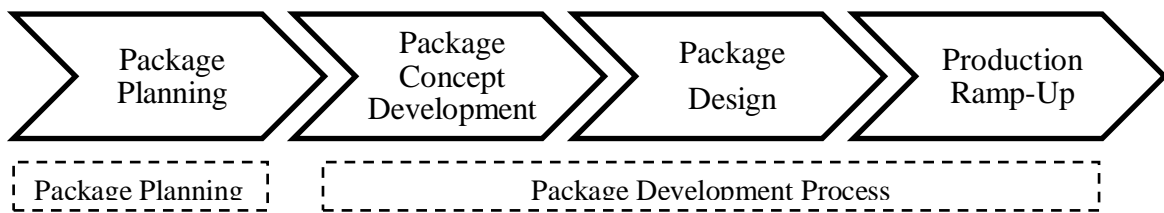


**Figure 5: Market share of consumer and industrial packaging**

### 3.1.3 Package Development Process

In this globalized world, competitive pressure is unavoidable. This has made significant changes in the way companies are organized today. To be successful in packaging, it is not only important to conceptualize an innovative package but it is also important to develop and manufacture them in an effective and efficient way resulting in shorter time to market. To achieve this, an understanding of generic package development process (Figure 6) is necessary. It is crucial because it will facilitate package development and provide a proactive and holistic approach towards creating a new and innovative package for the global market (Bramklev, 2009).

There are different variations of package development process across different industries. Here, a simple package development process is explained briefly as proposed by Bramklev (2009).



**Figure 6: Package planning and package development process**

#### 3.1.3.1 Package Planning

This is a separate process and is done before the actual package development process takes place. It is the decision making phase that will result in which type of package to be used for a given product and who should take care of the package development process. This strategic phase has to be performed by the product developing company either independently or in collaboration with the package developing company. The input to this phase will be market information such as market needs for a particular package, emerging new technologies, materials and production methods. This information will be evaluated and prioritized based on

the goals of the company. Then resources will be allocated depending on the feasibility resulting in a project plan.

### **3.1.3.2 Package Concept Development**

The input to this phase will be information about a single package. The first task is to set the specifications. The concepts will be generated based on the package information and specifications. The generated concepts are then subjected to evaluation to select the most promising concept. The output of this phase is the package concept selected.

### **3.1.3.3 Package Design**

The output from the previous phase will be fed as input to this phase. The architecture of the package is developed in this phase. Then a detailed design is carried out followed by developing the first prototype. Before these activities are carried out, the design specifications are set. The final task is to evaluate and decide on the design outcome. The output is the package design information with drawings and technical information. There are 5 important aspects that should be taken into consideration during package design, namely, safety, ergonomics, sustainability, logistics, and marketing (Azzi et al., 2012).

### **3.1.3.4 Production Ramp-up**

The input to this phase is the package design information. The entire production line is planned, developed and realized in this phase. Additionally, the necessary tooling is done. The filling process also undergoes the planning, development and realization stages. Finally they are subjected to quality assessment.

From a business perspective, a package has become increasingly important. It does reflect the face of a company. For a package to perform all their functions, it is necessary to satisfy a list of criteria for easy evaluation. Yiangkamolsing et al. (2010) mentioned a below list of criteria. However, only few relevant criteria from this list will be used in this thesis:

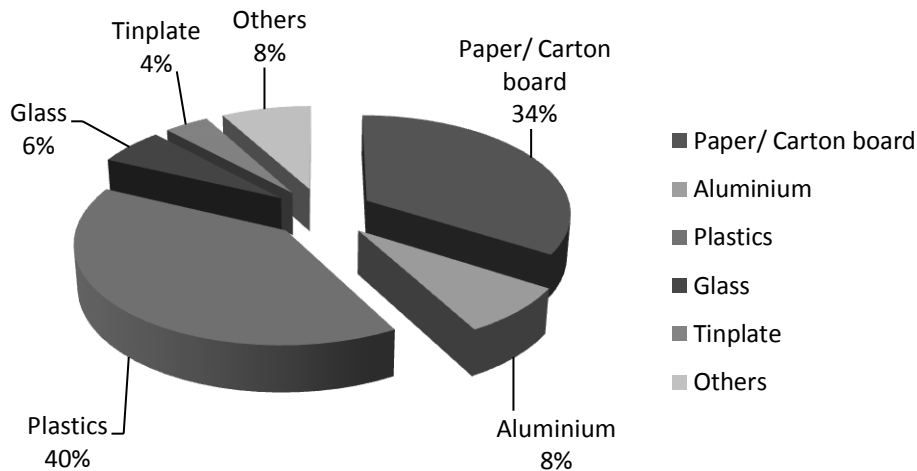
- Machineability
- Product protection
- Flow of information
- Volume and weight efficiency
- Right size
- Hand-ability
- Product information
- Safety
- Reduced use of resources
- Waste minimization

After establishing a standard packaging process and a set of evaluation of criteria, it is important to investigate and choose the appropriate materials for the product.

### **3.1.4 Packaging Materials**

Selection of right packaging material is extremely crucial in the study of packaging science. From the very early days, people have been using different types of materials such as leaves, earthenware, wood, vegetable fibers for domestic storage and local sales. The list of materials gradually increases over time and today there are many different types of materials available for packing different goods.

It is very important to choose materials according to the types of goods to be packed and protected. Material selection depends on few important factors like price, value, weights and strength of the items to be packed. Some goods are vulnerable to air and moisture. Hence, it is important to choose the material that can protect the product from air and moisture. Some of the most commonly and widely used packaging materials are cardboards, plastic, metals, glass, wood and textiles (Practical Action, 2006). Figure 7 gives an overview of how different packaging materials are distributed across industries and their share.



**Figure 7: Distribution of packaging material**

The above figure gives an overview of how different packaging materials are distributed across industries and their share.

#### **3.1.4.1 Plastics**

One of the most common and popular packaging material is plastics. It is used all over the world because of its functionality and aesthetic appeal. The other important reason is low cost. They can be manufactured according to the user preference. Due to the versatile nature, plastics have gained popularity so quickly ever since it was introduced and it continues to lead in the materials category. There are few important types of plastics that are repeatedly used, those are:

- Polyethylene (PE) - inert and not expensive, low melting temperature
- High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE)
- Polypropylene (PP) - inert, stiff, medium melt temperature
- Polyethylene Terephthalate (PET) - high barrier (oxygen & water vapor)
- Polyamide (PA) - good barrier (oxygen, carbon dioxide)
- Polyvinylidene chloride (PVDC) - heat sealable, high barrier (oxygen & water vapor)

Of these, PP and PVDC can be used as films to protect the package from moisture. PE can be further classified into HDPE and LDPE.

#### **3.1.4.2 Paper/Carton Board**

It is the second most commonly and widely used material for packaging. The term cardboard refers to various paper-like materials such as paper board, card board box, corrugated fiberboard and carton boxes. Most of the time paper boards are coated with materials like wax and aluminium and laminated with some kind of polymers for better protection. Corrugated cartons are used mainly as shipping containers for transportation purposes since it provides cushioning and impact damage.

### **3.1.4.3 Glass**

Glass bottles are mainly used for making vials, ampoules to pack juices, alcohol, medicine and jams. The glass bottles have certain advantages over other materials where it can be heat processed, recycled and reused. They are transparent and they do not react with any food products. They can be made into any shape and size. The main disadvantages are they are heavy and fragile.

### **3.1.4.4 Aluminium**

It is a highly effective and visually attractive packaging material. It is used in various forms in packaging such as cans, aerosols, tubes and wraps. It can be used in rigid, semi-rigid, laminated and flexible forms. It has a high level of corrosion resistance. It acts as a metal barrier to light, UV rays and water vapor.

Sometimes these materials are used as a standalone packaging material and most of the times they are used in combination with other materials creating laminates and composites for various purposes. Materials like bio-plastics, bio-polymers made from renewable bio-mass sources are relatively new and they are still in their nascent stage. The demand is expected to rise in the future and hence quite a lot of research is going on all over the world to reduce the cost and make it available commercially for large scale consumption.

### **3.1.5 Packaging Machines**

It is the primary role of the packaging machine to perform the packaging process and at the same time interact with packaging material and the product to be packed by:

- providing the packaging material
- forming the packaging container
- filling the product into the container and
- closing the package

A wide variety of packaging machines are available to choose from the market. Different machines are used for different purposes. Hence, the machines should be carefully investigated, analyzed and selected according to individual needs. The packaging machines can be purchased or customized based on the requirement and this decision influences directly the cost. It is practically not possible to list all the available packaging machines. However, some general types of machines are listed below from authors' experiences through packaging fairs and workshops. They are:

- Feeding machines
- Filling machines
- Wrapping machines
- Labeling machine
- Cartoning machines
- Labeling machines
- Sealing machines
- Conveyor belts

These cover most widely used types of packaging machines in the world.

### **3.1.6 Packaging Trends**

In this competitive market each and every element in a product packaging counts. Hence, it is important to understand the external factors that may influence the customers' buying decision. Packaging trends evolve with changing customer needs and they can decide if your product packaging will succeed or not. Although it is practically impossible to look into every trend across the world, it is wise to have an overall idea on the packaging trends.

The future packaging must be able to enhance its functions due to demanding customers and strict regulatory requirements. To meet these challenges and tackle customer demands several innovative packaging concepts are being proposed and implemented across the world. Several promising and successful concepts explained by Ahmed & Alam (2012) are summarized as follows.

- Active packaging
- Edible packaging
- Intelligent packaging
- Nano-packaging

From these concepts it is possible to develop a hybrid form of packaging to serve the customer needs. A brief look at these concepts and their benefits are described below.

#### **3.1.6.1 Active Packaging**

This innovative concept is a mode of packaging which creates an interaction effect between package, product and environment to prolong the shelf life or enhance safety, while maintaining the quality of the product. It is used in USA, Japan, Europe and Australia. Some examples of active packaging systems are oxygen scavengers, humidity absorbers, aroma emitters and antimicrobial systems.

#### **3.1.6.2 Edible Packaging**

Edible packaging is defined as a thin layer of edible material formed on the food as a coating or placed on or between food components. These materials give the possibility to prolong shelf-life. A very good example is application of polysaccharides as edible films in agricultural products for prolonging the shelf life of fruits and vegetables.

#### **3.1.6.3 Intelligent Packaging**

It is well known that package creates expectation. People identify and associate quality of the product with packaging most of the times. Hence, high emphasis is placed on the way packages are designed and presented. A package can be made smart by adding functional attributes to it thereby bringing benefits to the product and customer. The usability and effectiveness of the product can be enhanced through mechanical, chemical, electrical and electronically driven functions. Few good examples of such smart way of packaging include using of time-temperature indicators (TTIs), RFID, biosensors, and ripeness indicators.

#### **3.1.6.4 Nano-Packaging**

Nano-packaging with its nano-scale innovation could potentially address some of the most common issues by improving the barrier and mechanical properties and also introduce smart and active packaging with safety and quality benefits. Nanotechnology alters the structure of materials on a molecular scale in order to give the material the desired properties. However, the technology is still in its nascent stage and there are several issues to be addressed. Furthermore,

there are speculations that the technology might create strange new substances that could not be commercialized until further research has been completed. Hence it should be cautiously handled and all the information about this technology cannot be completely relied upon.

## **3.2 Literature Review on Methodology**

### **3.2.1 Analytic Hierarchy Process (AHP)**

In this thesis, the authors decided to record the needs of workers and quantify them. It is very important for any package to meet these customer (workers) needs. However, it is very difficult to identify and prioritize the needs when they are subjective in nature. To overcome this challenge, a tool called AHP will be used. The internal mechanism of AHP allows the subjective judgments to be systematically quantified. It helps to evaluate a set of customer needs against each other through a set of pairwise comparisons and ranks them. AHP is a structured decision making tool that has widespread applications in numerous fields and the authors believe that the application of AHP is suitable in this context.

AHP is an effective and flexible multi criteria decision making tool for prioritizing alternatives when multiple needs have to be evaluated. In this approach, the problems are structured in the form of hierarchy, starting from goal, needs and alternatives (Bevilacqua and Braglia, 2000). The major advantage of AHP is the use of pairwise comparisons to obtain a ratio scale of measurement. By reducing complex decisions into a series of simple comparisons and rankings and then synthesizing the results, it helps the decision makers to arrive at a decision that is rational. Ratio scales are a natural means of comparing the alternatives, enabling measurement of both tangible and intangible factors (Bevilacqua and Braglia, 2000).

### **3.2.2 Environmental Conscious Quality Function Deployment (ECQFD)**

QFD is a proven methodology for translation of customer requirements into specifications and actions during any new product or service development process (Kogure and Akao, 1983). QFD facilitates product design process by reducing the product development duration and enhancing the competitiveness of the product. It is a customer driven product design tool that is essential in product planning (Luangjinda et al., 2011). With all the advantages, no other tool could be most appropriate in this context other than QFD.

There are always some problems that exist between customers and engineers/designers. Either the customers do not understand the technical jargons of engineers/designers or the engineers have problem translating client's requirements into technical terminology. To overcome these misunderstandings, QFD is being used to improve the communication process between customers and company to enable mutual satisfaction. QFD is customer oriented and therefore the first step in QFD is always to determine the needs of customers. Along with customers' requirements, one can also use ecological requirements in the context of environmental management (Wolniak and Sedek, 2009).

In order to carry out QFD successfully, there are some prerequisites as mentioned below. According to Carnevalli and Miguel (2011) the prerequisites are:

- Have support from top management
- Define the objectives
- Define the target market
- Provide the resources necessary to apply QFD
- Carryout training in QFD
- Have time to apply QFD
- Have resources for market research
- Have infrastructure

- Train teams both qualified and committed

It is quite flexible and versatile that the environmental and the traditional quality aspects of a package can also be incorporated together into QFD, making it Environmental conscious Quality Function Deployment ECQFD (Masui et al., 2003). The combination of TRIZ and ECQFD has been proven effective previously in a paper published by (Sakao, 2007) wherein he confirms that the combination of QFDE and TRIZ along with LCA effectively supports concept designing and product planning phase of a new product development. The authors believe that this thesis can verify Sakao's statements about QFD centered design methodology for environmentally conscious product design through application of the proposed framework to a real industrial product. It is an effective way to transform voices of customer and environment (VOCE) into engineering practices from a green design perspective.

### **3.2.3 Theory for Inventive Problem Solving (TRIZ)**

In the context of packaging, organizations must be able to innovate and position themselves in the face of packaging technology. A sustainable product quality is imperative for survival and growth due to new, intensive and constant demand from all over the world. To satisfy this, there should be constant efforts to improve the quality of packaging. TRIZ (Altshuller, 1999) can be supportive for facilitating and encouraging innovation.

TRIZ is a problem solving method based on logic and data that helps in solving problems in a creative manner. Due to its structure and algorithmic approach, it is repeatable, predictable and reliable in nature. TRIZ is mainly composed of 39 TRIZ engineering parameters and 40 inventive principles. They are found to repeat across many fields and its fundamental concept is that contradictions should be eliminated (CTQ Media, 2012).

## Chapter 4: Proposed Methodology

This chapter describes the proposed methodology which will be used for improving the package of the case product. It consists of four main tools, namely, the Analytic Hierarchy Process (AHP), modified Environmentally Conscious Quality Function Deployment (ECQFD), Theory for Inventive Problem Solving (TRIZ), and Benefits, Costs, Opportunities, Risks (BCOR).

### 4.1 The Methodology

A set of methods is proposed for improving or generating new options for the package of the case product. The step-by-step methodology is shown in Figure 8 and described as follows.

*Step 1:* Understand the product, process and packages. The data collection and the literature review help for understanding the problem and developing a framework that will guide us throughout the thesis. The VOC will be collected from internal customers and will be used as input for the methods.

*Step 2:* Collect, identify and prioritize customer needs using the AHP method. *Super Decision* software will be used to execute this step.

*Step 3:* Translate the needs to technical requirements using ECQFD (Masui et al., 2003).

*Step 4:* Identify contradictions between technical requirements using ECQFD and then resolve them using a problem solving method TRIZ. *Step 5:* Evaluate the new options together with an existing option. The options will be evaluated using ECQFD and BCOR.

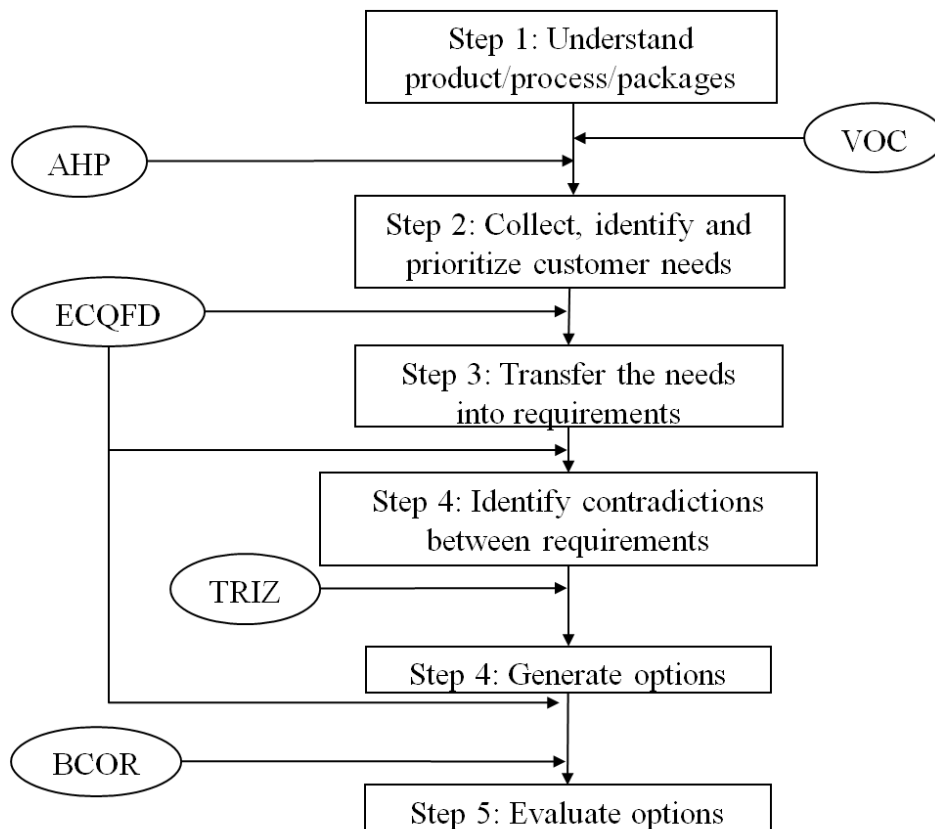


Figure 8: Proposed Framework

## **4.2 Analytic Hierarchy Process (AHP)**

AHP can be executed by means of computer software *Super Decision* to quantify customers' perception. AHP is done in four steps. Of the four steps, only the first three will be performed. They are:

- Step 1: Structuring – hierarchy
- Step 2: Measuring – pair wise comparison
- Step 3: Synthesizing – prioritization

The decision criteria are defined in the form of hierarchy of objectives. The goal is on the top level with criteria and sub-criteria in the subsequent levels below it. The defined criteria are weighed using simple pairwise comparison and their weights and ratings are determined.

### **4.2.1 Structuring**

The first task is to create the analytical hierarchical model. A goal cluster containing the goal element, a criteria cluster containing the criteria elements and an alternatives cluster containing the alternatives elements should be created to form the hierarchy.

### **4.2.2 Measuring and Synthesizing**

A pairwise comparison should be done for each criterion to derive accurate ratio scale priorities. The importance of one criterion over another is judged by respondents as 'equally important' or 'more important'. The verbal responses are quantified and translated into score using 9 point scales. Using the software, the synthesized priorities of all the criteria can be obtained.

After carrying out all the three steps, the final weights of each criterion are obtained. The criteria defined in the *Super Decision* software represent the needs.

## **4.3 Environmental Conscious Quality Function Deployment (ECQFD)**

Brody et al. (1999) argue that, although QFD is used for product development, it can also be used as a package design/development tool. There are tools and techniques for packaging design and development. However, they are relatively few and none of those methods offer an easy way to capture the voice of the customer and prioritize their needs in a way QFD does. With the help of QFD, both the internal and external customer needs can be accommodated in the package design process and also the package design problems can be reduced.

The QFD will be an Environmental Conscious QFD as it incorporates the environmental aspects of a package. The phases of ECQFD are described in the next chapter. The identification of environmental VOC and design parameters explains the different requirements and attributes from environmental perspective. The workers inside the organization are considered as customers.

The deployment of VOC to design parameters is done in Phase 1 of the ECQFD. The relation between VOC and design parameters is indicated by numbers to show the relational strength between them. Phase 2 elaborates the deployment of design parameters to component characteristics. The relative importance of each component of a package is calculated in the same way as in Phase 1. Phase 3 is estimating the improvement rate for environmental design parameters and Phase 4 is translating the improvement rate for these parameters into environmental quality requirements.

## 4.4 Theory for Inventive Problem Solving (TRIZ)

TRIZ is of big importance for the proposed methodology because it fills a research gap between Phase 2 and 3 of the ECQFD. There is no explanation of how the options are generated. According to Sakao (2007), the combined effects of ECQFD, LCA and TRIZ are very effective in terms of product planning and conceptual design. By using these methods together, most of the aspects of product development can be covered. Sakao (2007) has already verified the effectiveness of QFD based methods for eco-design and application of TRIZ in eco-design in his publication. TRIZ allows for a structured way of generating options for the final phases of the ECQFD. The options generated with the help of this tool are supportive for solving contradictions identified between the design parameters. The creative generation of options focuses on the component characteristics with the highest rank.

### 4.4.1 Engineering Parameters

The relevant engineering parameters are:

- *Volume (8)* – The cubic measure of space occupied by the object
- *Shape (12)* – The external contours, appearance of a system
- *Strength (14)* – The extent to which the object is able to resist changing in response to force; resistance to breaking
- *Amount of substance (26)* – The number or amount of a system's materials, substances parts or subsystems that can be changed fully or partially, permanently or temporarily
- *Harmful factors acting on object (30)* – Susceptibility of a system to externally generated effects

### 4.4.2 Inventive Principles

The relevant inventive principles are:

- *Prior Counteraction (9)* - Perform a counter-action in advance.
- *Cheap short living objects (27)* - Replace an expensive object by a collection of inexpensive ones, forgoing properties.
- *Flexible shells and thin films (30)* - Replace traditional constructions with those made from flexible membranes or thin film. Isolate an object from its environment using flexible membranes or thin film.
- *Parameter changes (35)* - Change an object's aggregate state, density distribution, degree of flexibility, temperature.
- *Inert atmosphere (39)* - Replace the normal environment with an inert one. Carry out the process in vacuum.
- *Composite materials (40)* - Replace a homogeneous material with a composite one.

## Chapter 5: Application of Proposed Methodology for the Case Product

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This chapter explains in detail the application of the proposed methodology for improving the package of the case product. The methodology is explained in seven steps.

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### 5.1 Step 1: Understand Product/Process/Packages

The first step is to observe and learn the products, types of packages used in the company, the packaging process and the market environment. This is done to get an overview of package function as a whole and understand the current process. It contains company and market information. Furthermore, it is important to study the market for the case products and take into consideration the upcoming standards for better understanding.

#### 5.1.1 The Product and its Packaging

The products, for which the packages are designed, are relatively insensitive to moisture or other impurities. The products come in various sizes and lengths, complicating the packaging process. The company uses 3 types of packages for the products, namely cardboard box, plastic box and vacuum package. Each type of package has its variants which differ in relation to the size and length of the products.

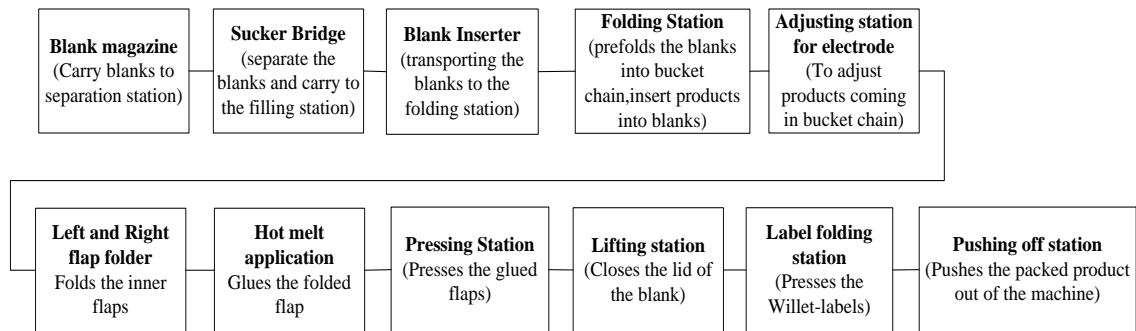
#### 5.1.2 Existing Packaging Types

There are more than 30 package variants currently used by the company and these are variations of the 3 types of packages that the company offers.

- **Cardboard box**  
Cardboard box is the most used package type in the company and it is mainly made of paperboard. The products are filled in a pre-folded cardboard sheet, which is later folded on all ends and glued together to seal the box. The cardboard box is also covered with a plastic sheet and shrink-wrapped to protect the package from moisture.
- **Plastic box**  
The plastic box is the physically strongest package among the package types at the company. It consists of a plastic box and a plastic lid to cover it. A tape is also wound around the box and the lid to prevent it from opening and to enhance the seal.
- **Vacuum package**  
This type of package consists of laminated multi-layer film that is vacuum-sealed around a corrugated plastic inner box. According to the company, it is considered to be the most exclusive and most convenient package with optimal security of the product.

#### 5.1.3 Packaging Process

The packaging process is preceded by manufacturing process. After the case products are manufactured, they are collected and stored at a certain place in the factory. In order to perform the packaging process special machines are required. Figure 9 shows the packaging process for the most used package type, including the machines required for the process.



**Figure 9: Packaging process**

In the beginning of the packaging process, the products are picked from a pile at a certain speed and then elevated to a certain height. Once the required number of products to be filled inside the package is collected, the machine pauses and drops the products into the package. Sometimes while picking the products, one or two products are missed due to the speed at which the machine operates. This machine is also used as a counter for products. It was found that occasionally the machine skips inserting the package material in the slot and drops the products in the empty slot, leading to line stoppages.

Further in the process, the products are collected in the pre-folded package and then passed through a series of folders, where the package is closed. Heated glue is then applied to finish the folding process. The labels are printed and glued to the folded box with the help of a labeling machine which is supplied with the continuous roll of paper from outside the line. At the end of the process, a machine places a plastic film around the package. The package is then fed to another machine which heats the plastic film around the package to tighten the package and protect it from moisture.

#### 5.1.4 Product Market

The research for the thesis required information gathering about the market environment, for this reason competitors supplying similar products to the market were identified. General information about their products and the performance of the respective packages was collected. It was found that all major competitors, with few exceptions, have similar packages to the company. Those exceptions were found irrelevant to the thesis and hence they were not considered.

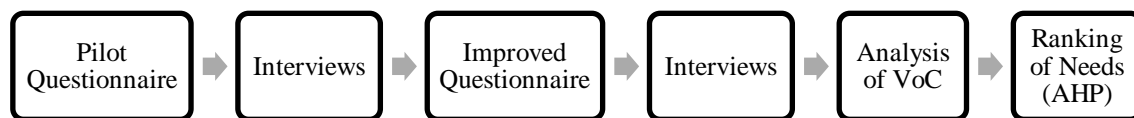
Despite the competitors, there are other factors, such as international standards and legislations, influencing the market environment. According to the US Department of Commerce (2010) and the International Organization for Standardization (ISO, 2012), ISO began developing new international packaging standards in 2009 and are expected to be published in 2012. The standards were based on the six European EN standards and on guidelines proposed by some Asian countries (US Department of Commerce, 2010). The US Department of Commerce (2010) also states that “the effort follows calls from major Consumer Packaging Goods (CPG) manufacturers and packaging industry organizations, such as the European Organization for Packaging and the Environment (EUROPEN), for consistent international packaging definitions, metrics, and standards”. The main motive is to make the packages more environmental friendly and reduce the amount of material in the package.

## 5.2 Step 2: Collect, Identify and Prioritize Customer Needs

### 5.2.1 Customer Needs

In this step, the VOC is collected, identified and then prioritized. It is very important because all customer needs required for further research are collected and prioritized here. An internal customer survey was carried out, as well as interviews with workers (internal customer), to find out what their needs are. The workers were asked to point out at different aspects of a package to know what they want and how much they want, through a visual tool called *Super Decision* software, which converts their perception into numbers.

Figure 10 shows the process of collecting and prioritizing the VOC. First, to understand what expectations and requirements the customers have, a pilot questionnaire was sent to the workers in the case company. The questionnaire included questions identifying the customer and questions related to the interaction between the workers and the package of the case product. Second, interviews were conducted with the workers to confirm and expand the data from the questionnaire. Third, the data collected was analyzed and the questionnaire was improved to obtain data which represents the customer needs. Fourth, interviews with workers were conducted again to confirm the collected data. The second round of interviews concludes the collection of the VOC. The VOC is then analyzed and the customer needs are clearly defined from it. From the data, 14 customer needs were identified and grouped as needs related to the functionality, handling and carrying, and the environmental impact of the package. Finally, the customer needs were ranked using AHP. The sample size is 4, out of which 4 are expert users of the product. Due to the fact that 3 out of 4 expert users have experience in using the product indoors, only their answers were taken into consideration.



**Figure 10: Process for collecting and prioritizing the VOC**

The identified customer needs were:

#### *Functional*

- Package conveys high quality and brand identity
- Package allows easy counting of products
- Information on the package is easy to read
- Package protects the products from moisture
- Package protects the products from physical damage

#### *Handling and Carrying*

- Package is easy to carry
- Package is easy to open
- Package is easy to stack
- Packages allows to take products out easily
- Package is safe to open

#### *Environmental*

- Package allows maximum products usage with minimum wastage
- Package is easy to use
- Package is easy to smash
- Package is harmless for living environment

## 5.2.2 Analytic Hierarchy Process (AHP)

AHP was executed by means of computer software *Super Decision* to quantify customers' perception. Of the four important tasks of AHP, first three were performed. They are

- Structuring – hierarchy
- Measuring – pairwise comparison
- Synthesizing – prioritization

### 5.2.2.1 Structuring

The first task was to create the hierarchical model. A goal cluster containing the goal element, a criteria cluster containing the criteria elements and an alternatives cluster containing the alternatives elements were created thus forming the hierarchy. Figure 11 shows a screenshot of the model from the software.

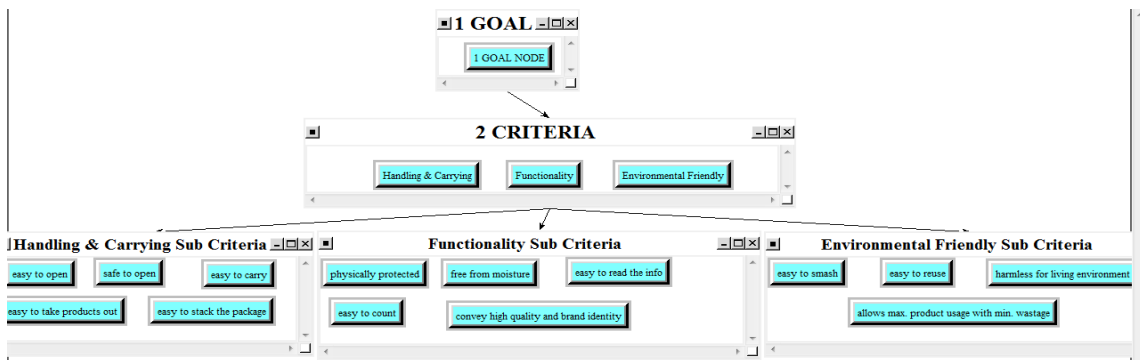


Figure 11: Analytical hierarchy model (Hierarchy)

### 5.2.2.2 Measuring and Synthesizing

For the next two tasks, a pairwise comparison was done for each criterion to derive accurate ratio scale priorities. Using the software, the synthesized priorities of all the criteria were obtained. Figure 12 shows an example of pairwise comparison of sub-criteria from the *Super Decision* software.

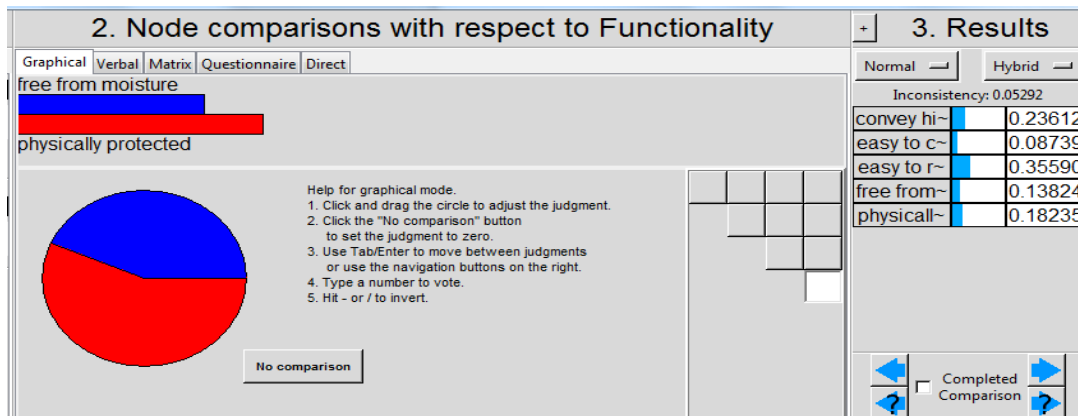
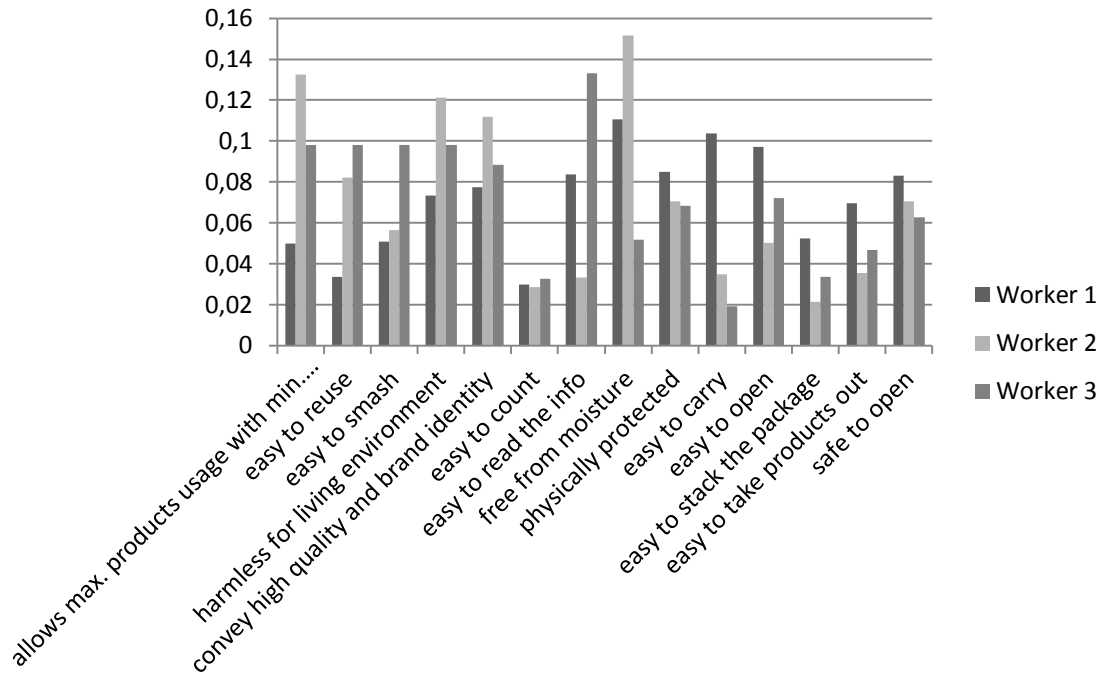


Figure 12: Pairwise comparison of criteria with Super Decision software

Figure 13 shows the variation in workers' perceptions on which attributes are more important than others. Each worker assessed the needs with different importance levels and rankings were obtained from their answers using the *Super Decision* software, which also has a built-in feature

to check the inconsistency. The variation of workers' perception about the attributes depends on their knowledge about the product and the package, as well as on their experience.



**Figure 13: Importance of customer needs**

After carrying out all three steps, the final weights of each criterion were obtained. The criteria defined in the *Super Decision* software represent the customer needs. Table 1 shows the ranking of the groups of customer needs (criteria) and Table 2 shows the ranking of the customer needs (sub-criteria). From the values in the table, it is evident that customers prefer the package to satisfy, first of all, the needs related to the functionality of the package and then needs related to environment and to handling and carrying.

**Table 1: Priorities of the groups of customer needs**

Group of Needs	Weight	Rank
Environment	0.317	2
Functionality	0.385	1
Handling and Carrying	0.272	3

**Table 2: Ranking of Customer Needs**

<b>№</b>	<b>Customer Needs</b>	<b>Weight</b>
<b>1</b>	Free from moisture	0,086
<b>2</b>	Physically protected	0,065
<b>3</b>	Allows max. product usage with min. wastage	0,065
<b>4</b>	Harmless for living environment	0,095
<b>5</b>	Convey high quality and brand identity	0,091
<b>6</b>	Safe to open	0,030
<b>7</b>	Easy to open	0,072
<b>8</b>	Easy to take the product out	0,095
<b>9</b>	Easy to read the info	0,074
<b>10</b>	Easy to smash	0,041
<b>11</b>	Easy to reuse	0,071
<b>12</b>	Easy to carry	0,033
<b>13</b>	Easy to stack the package	0,049
<b>14</b>	Easy to count	0,072

### **5.3 Step 3: Transfer Needs Into Requirements**

#### **5.3.1 ECQFD – Phase 1**

In this step, the customer needs are translated into technical requirements. The final weights obtained from the AHP are used as inputs in this step, where ECQFD is applied. The final weights of the customer needs are used in Phase 1 of the ECQFD.

In Phase 1 (Figure 14), the design parameters (DP) were generated after a series of brainstorming sessions. The DPs reflect the properties of the package. The strength of relationships was assigned between customer needs (CN) and DP. A common approach of 3-level weights was used (“1”=weak, “3”=moderate, “9”=strong). If there is no relationship, the cell is left blank. The raw scores and relative weights of all DPs were calculated and then normalized. This procedure gives the most critical DP which will have a great impact on the customer satisfaction level. The relationships among DPs were analyzed and were indicated in the roof with a plus and minus sign. The roof was used for identifying the contradictions between each DP. These contradictions can be resolved or treated with the help of Theory of Inventive Problem Solving (TRIZ).



**Table 2: Ranking of design parameters**

<b>Design Parameters</b>	<b>In terms of environment</b>	<b>In terms of functionality</b>	<b>In terms of handling and carrying</b>	<b>Overall Rank</b>	<b>Overall Weight</b>
Thickness of material	5	1	3	1	0,123
Shape of the package	8	5	1	2	0,114
Strength of the package material	7	3	2	3	0,110
Size of the package	2	6	2	4	0,106
WVTR of material	4	4	n/a	5	0,074
Water absorption of material	4	4	n/a	5	0,074
Physical lifetime of material	1	7	n/a	6	0,060
Oxygen permeability of material	9	4	n/a	7	0,055
Weight of the package	10	8	4	8	0,052
Font size	n/a	2	n/a	9	0,051
High resolution of pictures	n/a	2	n/a	9	0,051
Toxicity of package material	3	9	n/a	10	0,046
Biodegradability of package material	6	9	n/a	11	0,042
Recyclability of package	6	9	n/a	11	0,042

### 5.3.2 ECQFD – Phase 2

For Phase 2 of the ECQFD (Figure 15), the component characteristics (CC) of the package were identified and listed in order to find out the interrelationships between DPs and component characteristics. The relationship strengths between DPs and component characteristics were weighted in the same manner as in Phase 1.

DP \ CC	Phase 1 relative weights	Component Characteristics					
		Container (solid body)	Protective film	Lid/Cap	Tape	Label	Glue
Size of the package	0,106	3	3	3	1	1	
Shape of the package	0,114	3	3	3		1	3
Weight of the package	0,052	9	1	1			
Thickness	0,123	9	9	9			
Strength of the package material	0,110	9	9	9			1
Water vapor transmission rate	0,074	9	9	9	3		
Water absorption	0,074	9	9	9	3		
Oxygen permeability	0,055	9	9	9	3		
Toxicity of package material	0,046	9	9	9			1
Biodegradability of package material	0,042	9	9	9	1	1	1
Physical lifetime	0,060	9	9	9	1	1	3
Recyclability of package	0,042	9	9	9	1		
Font size	0,051					9	
High resolution of pictures	0,051	3	3			9	
Raw Score		7,29	6,50	6,34	0,86	1,25	0,72
Relative weights		0,32	0,28	0,28	0,04	0,05	0,03

Figure 15: ECQFD - Phase 2

The second phase of ECQFD was finalized with the calculation of the raw scores for the component characteristics. The weights of the component characteristics proved that the container (solid body) was the most important component of a package. For this reason, it was considered that improving the DPs for the container will provide the desired result to satisfy the customers' needs. This consideration was used as basis for the development of a new package for the case product. Table 3 shows the ranking of the component characteristics after Phase 2.

Table 3: Ranking of component characteristics

№	Component Characteristics	Weight
1	Container (solid body)	0,32
2	Protective film	0,28
3	Lid/Cap	0,28
4	Label	0,05
5	Tape	0,04
6	Glue	0,03

## 5.4 Step 4: Identify Contradictions between Requirements and Generate Options

### 5.4.1 Theory for Inventive Problem Solving (TRIZ)

In this step, the contradictions between technical requirements are identified and highlighted. Then, the contradictions are resolved using TRIZ. It will help to generate new options. The

input for TRIZ depends on the DPs and the CCs. According to the ranking of DPs, the main DPs are: thickness of material, strength of material, shape of package, size of package, water vapor transmission rate of material, water absorption of material, oxygen permeability of material. Furthermore, according to the ranking of CCs, the main components are the container, the protective film and the lid/cap. It is considered that improvements of the design parameters of these components would improve the quality of the package. Thus fulfilling the customer needs and increasing the customer satisfaction. Based on these considerations, it was assumed that the most important points for improvements of the package are the packaging material and the dimensions of the package.

All the 39 TRIZ engineering parameters were studied and related to the most important DPs. The identified TRIZ parameters, with the biggest relevance to the DPs, are Volume of Nonmoving object, Shape, Strength, Amount of substance, and Harmful factors acting on object.

- Volume (8) represents the cubic measure of space occupied by the package.
- Shape (12) represents the external contours, appearance of a package.
- Strength (14) represents the extent to which the package is able to resist changing in response to force.
- Amount of substance (26) represents the amount of a system’s materials, substances parts or subsystems that can be changed fully or partially, permanently or temporarily.
- Harmful factors acting on object (30) represents susceptibility of a system to externally generated effects.

### 5.4.2 Contradictions

The values of the selected TRIZ parameters should be modified in order to propose a better package. Variations in the TRIZ parameters will change the quality of the package and lead to contradictions among the parameters. The identified contradictions were:

- C1 – Less substance, less strength (26 and 14);
- C2 – Less substance, more harmful factors on the object (26 and 30);
- C3 – Different shape, less strength (12 and 14);
- C4 – Less strength, more harmful factors on the object (14 and 30);
- C5 – The more volume, the more harmful factors on the object (30 and 8);

These contradictions are also shown in Figure 16.

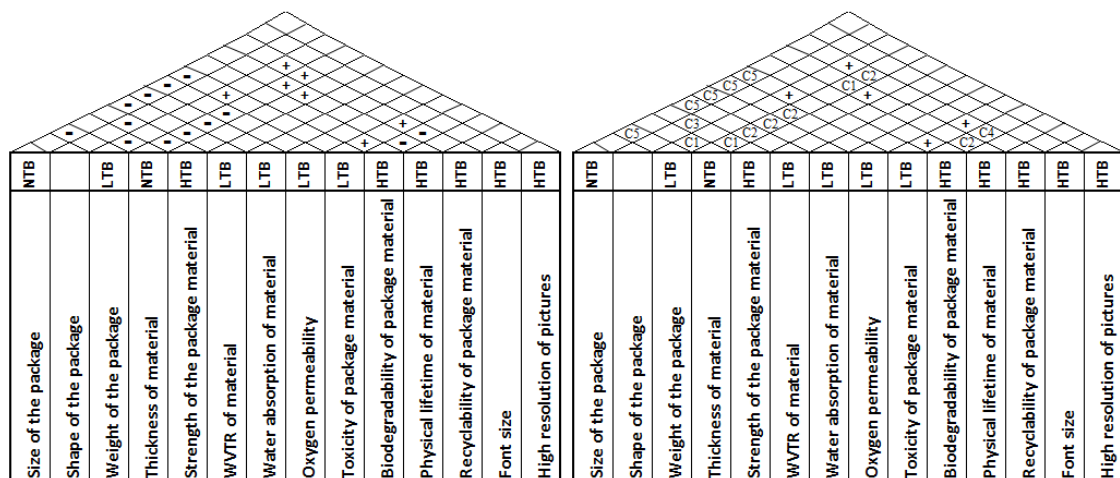


Figure 16: Contradictions between parameters

To resolve these contradictions, 40 inventive principles were studied. After a careful study, the relevant principles were listed. The principles, with their respective numbers, are explained below, as well as the conflict matrix (Table 4).

*P9* - Perform a counter-action in advance.

*P27* - Replace an expensive object by a collection of inexpensive ones, forgoing properties.

*P30* - Replace traditional constructions with those made from flexible membranes or thin film. Isolate an object from its environment using flexible membranes or thin film.

*P35* - Change an object's aggregate state, density distribution, degree of flexibility, temperature.

*P39* - Replace the normal environment with an inert one. Carry out the process in vacuum.

*P40* - Replace a homogeneous material with a composite one.

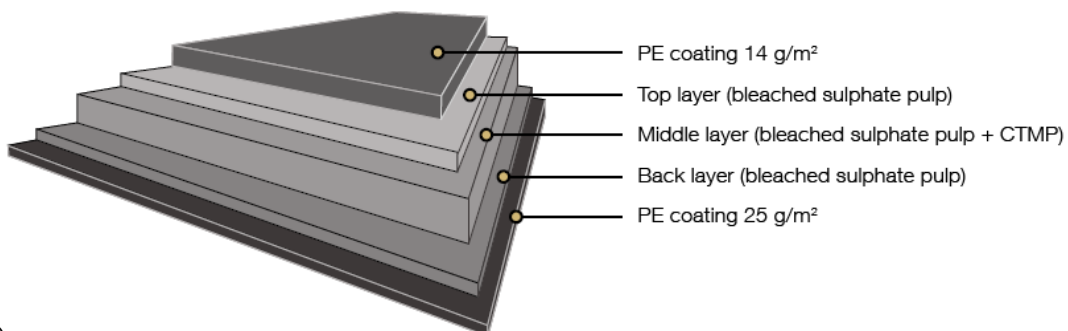
**Table 4: TRIZ conflict matrix**

Parameters	8	12	14	26	30
8	-				P35, P39, P40
12		-	P9, P40		
14		P9, P40	-	P40, P35, P39	P9, P35, P39, P40
26			P40, P35, P39	-	P40, P30, P35
30	P35, P39, P40		P9, P35, P39, P40	P40, P30, P35	-

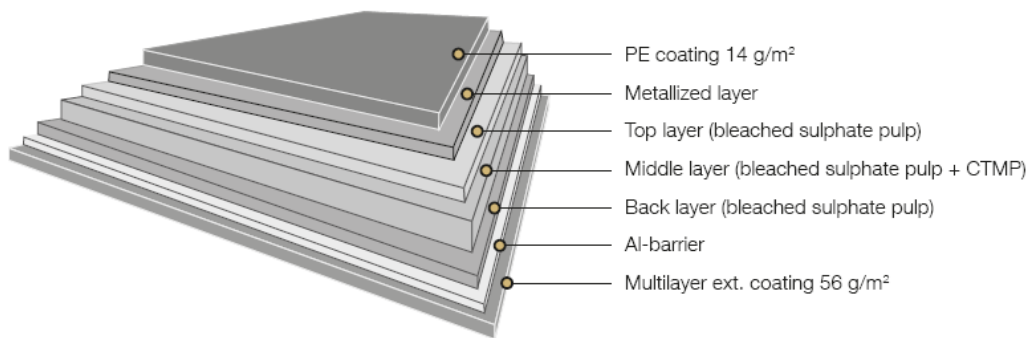
The conflict matrix shows the principles that can be supportive for solving the contradictions and improving the package.

### 5.4.3 New Options

To generate new option, all data from literature, observations, interviews, and questionnaires and results from methods were combined. The result was a proposal for package material following TRIZ principle number 40. Of all the principles, principle 40 was the suitable choice that helped solve the contradiction because having less material and having low water absorption, low oxygen permeability and low WVTR and better strength is quite difficult to achieve. It was identified that having composite layers with materials (principle 40) could help solve this contradiction. Hence, two variants (Figure 17) of package material were proposed and they were also assumed to be processed by the same machines.



a)



b)

**Figure 17: Liquid packaging board a) without aluminium b) with aluminium**

The new proposed material was Liquid Packaging Board (LPB). It consists of 70-75% paper, 20% Low-Density Polyethylene (LDPE) film and 4% aluminium film, which are fused together. This composition was assumed to resolve the contradictions stated above and to bring advantages, such as excellent barrier properties, improved strength, longer shelf life, reduced weight of the package. The properties of this composite material with multiple layers act as a barrier protecting the case product from external factors.

**Table 5: Contradictions and inventive principle**

Parameters	Contradiction	8	12	14	26	30
8	C5-8,30	-				P40
12	C3-12,14		-	P40		
14	C1-14,26			-	P40	P40
26	C2-26,30				-	P40
30	C4-30,14					-

It is important to understand and ensure if the contradictions will be resolved by the proposed new option.

C1 - Having less substance and more strength is difficult to achieve with the existing material. Composite material with layers can still have less substance but provide more reinforcement. This is solved by the new material which has 3 different layers that provide better strength than the cardboard.

C2 - Having less substance can be a reason for more harmful factors on the products. But with the suggested material, this can be eliminated because it provides more coating and hence can prevent the harmful factors from affecting the products.

C3 – The strength of an object is strongly influenced by its shape. The packages can be made out of LPB in the shape of existing cardboard box and it can still have higher strength.

C4 – If the strength of the material is not good enough to protect the product from harmful factors then the package will failure. With the introduction of new material, this problem can be solved because of the composite material’s layers, which provide better strength than the cardboard.

C5 – If the volume of the package is larger, there is a possibility for greater exposure to the environment which can harm the product. The new material can be made to a package in desired volume which can reduce the exposure.

Two variations of liquid packaging boards were proposed. The first variant consists of paper and polyethylene and the second variant consists of paper, polyethylene and aluminium. These variants have their advantages and disadvantages, which will be evaluated in the later steps.

## 5.5 Step 5: Evaluate Options

### 5.5.1 ECQFD – Phase 3 and Phase 4

In this step, the generated options are evaluated for further recommendations. The authors provided two new options, namely, LPB with aluminium layer and LPB without aluminium layer, based on the results from the first two phases of the ECQFD and TRIZ.

In Phase 3, the effect of changes on the design parameters was estimated. According to Masui et al. (2003), there are two approaches to decide on what should be focused on. The first approach is related to a target VOC where components should be suppressed in terms of customer need. The second approach examines the critical components identified in Phase 2. For the case company, the second approach was used assuming that the proposed new material will improve the features of the package for the case product. The relational strength between DP and CC from Phase 2 remained as shown in Tables 5 and 6. The proposed new materials were assumed to add the following improvements to the package for the case product.

#### *Option 1 – LPB without aluminium layer:*

- Reduced size of the package should reduce the environmental impact of the package.
- Reduced size of the package should reduce the weight of the package.
- The proposed material is thicker and should provide better protection for the case products.
- The proposed material is stronger and should provide better protection of the case products.
- The proposed material consists of layers of different materials and should provide better moisture protection.
- The proposed material has longer physical lifetime.

#### *Option 2 – LPB with aluminium layer:*

- Reduced size of the package should reduce the environmental impact of the package.
- Reduced size of the package should reduce the weight of the package.
- The proposed material is thicker and should provide better protection for the case products.
- The proposed material is stronger and should provide better protection of the case products.
- The proposed material consists of layers of different materials and should provide better moisture protection.
- The proposed material consists of layers of different materials and should provide better protection from gas.
- The proposed material has longer physical lifetime.

**Table 6: Phase 3 - Option 1**

DP \ CC	Phase 1 relative weights	Characteristics						Score	Improvement rate of design parameters
		Container (solid body)	Protective film	Lid/Cap	Tape	Label	Glue		
<b>Size of the package</b>	0,106	3	3					6	0,545
<b>Shape of the package</b>	0,114							0	0,000
<b>Weight of the package</b>	0,052	9	1					10	0,909
<b>Thickness</b>	0,123	9	9					18	0,667
<b>Strength of the package material</b>	0,110	9	9					18	0,643
<b>Water vapor transmission rate</b>	0,074	9	9					18	0,600
<b>Water absorption</b>	0,074	9	9					18	0,600
<b>Oxygen permeability</b>	0,055							0	0,000
<b>Toxicity of package material</b>	0,046							0	0,000
<b>Biodegradability of package material</b>	0,042							0	0,000
<b>Physical life time</b>	0,060	9	9					18	0,563
<b>Recyclability of package</b>	0,042							0	0
<b>Font size</b>	0,051							0	0
<b>High resolution of pictures</b>	0,051							0	0

The improvement rate for each DP was obtained from the equation:

$$mr_j = \frac{\sum_{k=1}^K b_{j,k} \cdot c_{j,k}}{\sum_{k=1}^K b_{j,k}} \quad (j = 1, \dots, J) \quad (1)$$

Where  $K$  is the index number of component,  $J$  is the index number of DP,  $b_{j,k}$  is the relational strength between DP item  $j$  to component  $k$ ,  $c_{j,k}$  is the improvement rate of DP item  $j$  to component  $k$  and originally allowed to take the real number from 0.0 to 1.0. In this thesis,  $c_{j,k}$  is assumed to take the binary numbers:

$c_{j,k} = 1$  (improvement possible),  $c_{j,k} = 0$  (improvement impossible) (Masui et al., 2003).

**Table 7: Phase 3 - Option 2**

DP \ CC	Phase 1 relative weights	Component Characteristics						Score	Improvement rate of design parameters
		Container (solid body)	Protective film	Lid/Cap	Tape	Label	Glue		
<b>Size of the package</b>	0,106	3	3					6	0,545
<b>Shape of the package</b>	0,114							0	0,000
<b>Weight of the package</b>	0,052	9	1					10	0,909
<b>Thickness</b>	0,123	9	9					18	0,667
<b>Strength of the package material</b>	0,110	9	9					18	0,643
<b>Water vapor transmission rate</b>	0,074	9	9					18	0,600
<b>Water absorption</b>	0,074	9	9					18	0,600
<b>Oxygen permeability</b>	0,055	9	9					18	0,600
<b>Toxicity of package material</b>	0,046							0	0,000
<b>Biodegradability of package material</b>	0,042							0	0,000
<b>Physical lifetime</b>	0,060	9	9					18	0,563
<b>Recyclability of package</b>	0,042							0	0,000
<b>Font size</b>	0,051							0	0,000
<b>High resolution of pictures</b>	0,051							0	0,000

In Phase 4, the effects of the changes on DP were translated into quality requirements. Tables 7 and 8 show the results for the two options. The relational strength between DP and CC remained the same as in Phase 1. The improvement rate for each CC  $vr_i$  was obtained from the equation:

$$vr_j = \frac{\sum_{j=1}^J mr_{j,a_{i,j}}}{\sum_{j=1}^J a_{i,j}} \quad (i = 1, \dots, I) \quad (2)$$

Where  $J$  is the index number of a DP and  $I$  is the index number of a CC,  $a_{ij}$  is the relational strength between CC item  $I$  and DP item  $j$  in Phase 1. The improvement effect for the CC, taking into consideration the relative weights, was obtained by multiplying  $vr_i$  and relative weight  $i$  together.

**Table 8: Phase 4 - Option 1**

	CN	DP	Importance Rating	Size of the package	Shape of the package	Weight of the package	Thickness of material	Strength of the package material	WVTR of material	Water absorption of material	Oxygen permeability	Toxicity of package material	Biodegradability of package material	Physical lifetime of material	Recyclability of package material	Font size	High resolution of pictures	Improvement rate of customer requirement	Improvement effect of customer requirement
Environmenta I	Allows max. products usage with min. wastage	0,086	9	1	1	1	1	9	9	3				1				0,5282	0,0457
	Easy to reuse	0,065	1	3	1	3	3	3	3	3	3	1	3	1				0,3812	0,0247
	Easy to smash	0,065	3	3	1	9	9						1					0,573	0,0375
	Harmless for living	0,095	1		1	1						9	9	9	9			0,1843	0,0176
Functional	Convey high quality and	0,091	3	9	1	1	3	3	3	3	3	3	3	3	3	9	9	0,1862	0,017
	Easy to count	0,030	9	3														0,4088	0,0124
	Easy to read the info	0,072	1	1												9	9	0,0273	0,002
	Free from moisture	0,095				9	3	9	9	9								0,4803	0,0458
	Physically protected	0,074	3	1	3	9	9						3					0,6372	0,0473
Handling & Carrying	Easy to carry	0,041	9	3	9	3	1											0,6292	0,0258
	Easy to open	0,071	1	3	1	9	9											0,5758	0,0407
	Easy to stack the package	0,033	3	9	9	3	9											0,5335	0,0178
	Easy to take products out	0,049	9	9	1													0,306	0,0149
	Safe to open	0,072	1	9	1	1	1											0,2126	0,0152
	Improvement rate of DP		0,55	0	0,91	0,67	0,64	0,6	0,6			0	0	0,56	0	0	0		
<b>Amount</b>																		5,6635	0,3643

**Table 9: Phase 4 - Option 2**

	CN	DP	Importance Rating	Size of the package	Shape of the package	Weight of the package	Thickness of material	Strength of the package material	WVTR of material	Water absorption of material	Oxygen permeability	Toxicity of package material	Biodegradability of package material	Physical lifetime of material	Recyclability of package material	Font size	High resolution of pictures	Improvement rate of customer requirement	Improvement effect of customer requirement
Environmenta I	Allows max. products usage with min. wastage	0,086	9	1	1	1	1	9	9	3				1				0,5796	0,0501
	Easy to reuse	0,065	1	3	1	3	3	3	3	3	3	1	3	1				0,725	0,0469
	Easy to smash	0,065	3	3	1	9	9						1					0,573	0,0375
	Harmless for living	0,095	1		1	1						9	9	9	9			0,184	0,0176
Functional	Convey high quality and	0,091	3	9	1	1	3	3	3	3	3	3	3	3	3	9	9	0,218	0,02
	Easy to count	0,030	9	3														0,409	0,0124
	Easy to read the info	0,072	1	1												9	9	0,027	0,002
	Free from moisture	0,095				9	3	9	9	9								0,619	0,059
	Physically protected	0,074	3	1	3	9	9						3					0,637	0,0473
Handling & Carrying	Easy to carry	0,041	9	3	9	3	1											0,629	0,0258
	Easy to open	0,071	1	3	1	9	9											0,576	0,0407
	Easy to stack the package	0,033	3	9	9	3	9											0,533	0,0178
	Easy to take products out	0,049	9	9	1													0,306	0,0149
	Safe to open	0,072	1	9	1	1	1											0,213	0,0152
	Improvement rate of DP		0,55	0	0,91	0,67	0,64	0,6	0,6	0,6		0	0	0,56	0	0	0		
<b>Amount</b>																		6,2289	0,4071

The total score for the improvement effect for the CC of option 2 (0,4071) is higher than the total score of option 1 (0,3643), making option 2 the better one.

This new option 1 cannot be processed with the existing machine in the factory because the existing machines are not flexible enough to process different materials and are old. Therefore, it is important to identify, evaluate and chose the suitable machines for the newly recommended material.

### 5.5.2 Benefits, Costs, Opportunities, Risks (BCOR)

The material options were evaluated using BCOR analysis. This was mainly performed to dig deeper into the benefits, costs, opportunities and risks involved in the proposed options. LPB was compared to an existing option, cardboard box, which is widely used by the case company. Table 10 shows the BCOR for the proposed material.

**Table 10: BCOR for material**

	<b>Liquid packaging board</b>	<b>Cardboard box</b>
<b>Benefits</b>	<ul style="list-style-type: none"> <li>- Very good moisture and gas barrier</li> <li>- Recyclable (limited)</li> <li>- Lightweight</li> <li>- Easy to stack</li> <li>- Very good strength to weight characteristics</li> <li>- Easily decorated</li> <li>- Made from renewable resources</li> </ul>	<ul style="list-style-type: none"> <li>- Cheap material</li> <li>- Recyclable</li> <li>- Biodegradable</li> <li>- Lightweight</li> <li>- Easy to stack</li> <li>- Very good strength to weight characteristics</li> <li>- Easily decorated</li> <li>- Made from renewable resources</li> </ul>
<b>Costs</b>	<ul style="list-style-type: none"> <li>- Does not retain its shape</li> <li>- Average protection from physical damage</li> <li>- Relatively expensive but cost effective for purpose</li> <li>- Economic intensive to recycle</li> <li>- Separation difficulty</li> </ul>	<ul style="list-style-type: none"> <li>- Does not retain its shape</li> <li>- Poor barrier to moisture, gas and light</li> <li>- Loses strength with increasing humidity</li> <li>- Tears easily</li> <li>- Customer complaints due to damage of products (indirect cost)</li> </ul>
<b>Opportunities</b>	<ul style="list-style-type: none"> <li>- Flexibility in design and characteristics</li> <li>- Allows for reduced usage of resources</li> <li>- High energy source for incineration</li> <li>- Brand representation (unique)</li> <li>- Improved product protection compared to other alternatives</li> <li>- Standardization of the packaging design on a global scale</li> </ul>	<ul style="list-style-type: none"> <li>- Cost reduction</li> <li>- Energy source for incineration</li> </ul>
<b>Risks</b>	<ul style="list-style-type: none"> <li>- Using knife to open the package may cause injury</li> <li>- Layers separation required after usage</li> </ul>	<ul style="list-style-type: none"> <li>- Using knife to open the package may cause injury</li> </ul>

## Chapter 6: Discussion

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In this chapter the results and findings are discussed briefly from both theoretical and practical perspective. It discusses the economic considerations, package development and the chosen methods and tools.

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### 6.1 Package Development

Compared to product development not many quantitative, decision making and problem solving tools were used in package development. This thesis was an exception. Tools such as AHP, QFD and TRIZ were used to develop a customer oriented package. Developing a customer specific package with better quality, sustainability and brand identity representation, requires input from different customers. The customers should be from a wide array of industries who can voice in different opinions and requirements. One of the challenges in identifying and prioritizing the VOC was in getting a representative sample because the customers were internal workers whose needs can be different from needs of customers working in other industries and in different work environments. Due to certain limitations the other customers voice were not captured.

However, the interviewed workers are experts and have previously worked in different industries in different environments which helped us to mitigate this challenge to some extent and proceed further with translating the customer needs to the technical requirements. Some conflicts that arose between technical requirements were resolved with the help of TRIZ which led us to a final idea. However, we believe that the tool could have been exploited in a better way leading to more than one idea if there was a vast array of customer data. This was another challenge in terms of using the customer need to improve the package.

The proposed methodology in this thesis can be applied not only for improving the package for industrial products but also for consumer products. The results can help the firm redefine their packaging strategy to improve their operational flexibility, resulting in better delivery.

The authors believe that the advantages of LPB will result in less complaints and higher customer satisfaction, leading to increased sales and loyalty of the customers. However, it is important to note that this will be achieved at the expense of this new material and recyclability issues. Due to wide use of this material in the food industry and emerging technologies to combat the recycling issues, it is believed that these issues will be solved in the future.

The proposed material, which is an outcome of the methodology, is complemented by suitable machines. However, the machines are not an outcome of TRIZ. The machines were selected and proposed based only on the authors' knowledge from literature review, workshop and fairs visits.

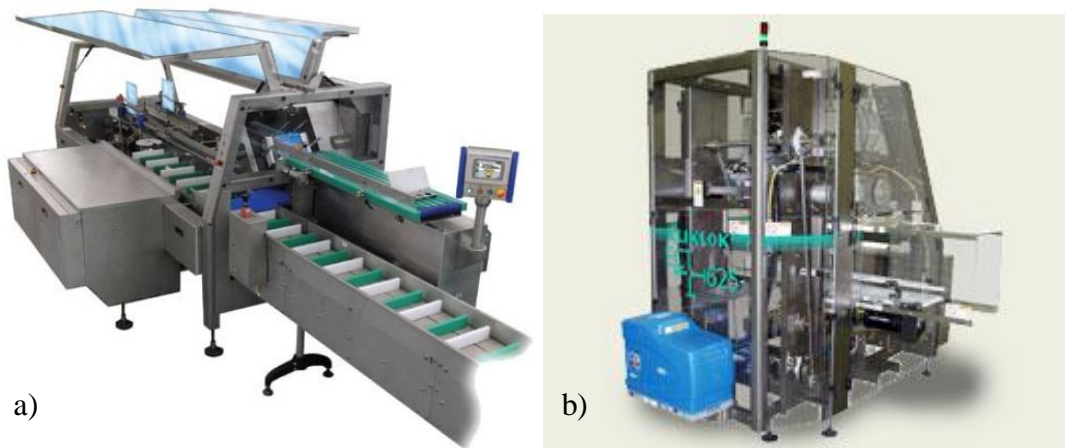
### 6.2 Proposed Machines

This proposed option is different from the existing types of packages in the case company, which makes it necessary to purchase new machines in order to perform the packaging operations. The new machines are proposed to process the recommended package material and they are also capable of processing other materials. The proposal for new equipment includes 2 different machines.

- *End-load or Top-load Cartoner*

The carton machines (Figure 18) were assumed to replace bottleneck machines in the current packaging line. It has an ergonomic and modular design for the operator process and

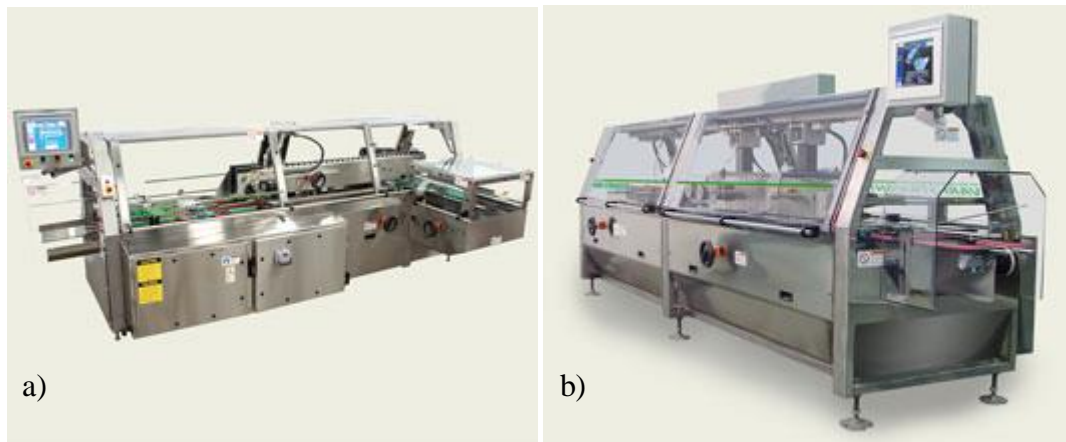
for easy custom configuration. The machine is capable of handling different combinations of products with quick product changeovers and digital counting technology.



**Figure 18: a) End-load cartoner b) Top-load cartoner**

- **Sealing Machine**

Hot air guns were proposed for heat sealing operation of LPB material. The LPB should be sealed on the long side to create a sleeve-like structure for the products to be fed in. After feeding the products into an empty package, the ends of the package are to be sealed. The proposed machines are shown in Figure 19.



**Figure 19: a) Right Angle Tri-Seal Top load Carton Closing Machine b) Straight-Line Tri-Seal Top load Carton Closing Machine**

The BCOR for machines (Table 11) is applied for these new machines and for the existing machines used for packing cardboard box. The proposed machines for the new option are end-load cartoner and heat sealing machine.

**Table 11: BCOR for machines**

	<b>Machines for Liquid Packaging Board</b>	<b>Machines for Cardboard container</b>
<b>Benefits</b>	<ul style="list-style-type: none"> <li>- Short sealing time</li> <li>- Good sealing</li> <li>- Higher capacity of the line</li> </ul>	<ul style="list-style-type: none"> <li>- Low cost</li> <li>- Simple process</li> </ul>
<b>Costs</b>	<ul style="list-style-type: none"> <li>- Investment in new machines</li> <li>- Installation and training cost</li> <li>- Heat-sealing machine requires more energy</li> <li>- Customization</li> </ul>	<ul style="list-style-type: none"> <li>- High maintenance cost due to old machinery</li> <li>- Shrink-wrapping machine requires more energy</li> <li>- Low capacity</li> <li>- Extra materials (glue, labels ink)</li> </ul>
<b>Opportunities</b>	<ul style="list-style-type: none"> <li>- Allows modularity of machines</li> <li>- Possibility for fully automatic machine</li> <li>- Less maintenance of equipment</li> <li>- Eliminates labeling and shrink-wrapping</li> <li>- Standardization of the packaging process on a global scale</li> </ul>	<ul style="list-style-type: none"> <li>- Change machines</li> <li>- Possibility for fully automatic machines</li> <li>- Cost reduction</li> </ul>
<b>Risks</b>	<ul style="list-style-type: none"> <li>- Adaptability with existing production line</li> </ul>	<ul style="list-style-type: none"> <li>- Higher risk of breakdown due to age of machines</li> <li>- Compatibility of machines and material</li> </ul>

The BCOR shows that the proposed machines will be able to operate faster than the existing machines. This will reduce the lead time and the time-to-market. The machines will also provide better sealing for the package which will provide better protection for the products. Having the same machines in each factory will provide basis for standardized and more efficient process on a global scale. Standardization of the process will improve the quality of products and operations, leading again to higher customer satisfaction. Since the case product is of a special size and shape, machines will be customized. This will reduce the risk of having adaptability problems with the existing production line.

### **6.3 Environmental Considerations**

The environmental considerations for LPB will only cover the main issues related to its specifications, raw material extraction, manufacturing and end-of-life, excluding the environmental assessment of the package when it is on the customer side.

LPB option and the existing cardboard option have two constituents in common, namely paper and polyethylene. In relation to this, the environmental impact of the proposed material is considered to be similar to the impact of the cardboard option. The existing option comprises of paper and polyethylene (shrink-wrap). According to GreenBlue (2011), the liquid packaging board consists of 75% paper, 20% polyethylene and 5% aluminium, which are fused together. The only difference is the 5% aluminium. This leads to the conclusion that the presence of aluminium layer in LPB makes the material less eco-friendly.

Since paper is the main constituent in both options, it is important to know the environmental implications of paper. According to the Canadian Environmental Protection Act (CEPA, 1991), there is waste after the manufacturing process of paper. The process includes bleaching with chemicals. Bleaching is required due to the dark color of material after pulping, because it brightens the pulp for printing and improves its quality. As a result of bleaching, effluents are discharged in the sea, causing chronic effects on the aquatic species. Moreover, paper can be recycled only limited number of times which decreases its quality and characteristics but on the

other hand it can be used to produce energy by incineration. However, there are materials that produce much more energy when burned, such as polymers.

Another issue related to this material is the abuse of forest land. Companies collect raw material for the pulp and paper industry by cutting down trees and sometimes destroying the whole forests. In order to avoid deforestation, it is important for the company to have a supplier who uses wood only from well managed production forests. This would encourage the suppliers to follow the environmental policies.

The main problem with the end-of-life recovery of LPB with aluminium stems from the complexity in the separation of paper, polymer and aluminium layers from each other. The composite material has environmental impact due to the complicated recycling and reuse of the raw materials. However, this impact can be significantly reduced by emerging technologies for separation of polyethylene and aluminium, resulting in efficient reuse and recycling of materials and reduced raw material consumption (Xie et al., 2011).

One high-value solution is, to again extract the paper portion by pulping machine and then separate the aluminium from the polymer by means of *plasma pyrolysis* technology (Pedroso and Bastos, 2006). The result of using this technology is having separated 99% pure aluminium and polymer in the form of paraffin. Another low-value solution is, to separate the paper by means of a conventional pulping machine and then use the remaining as fuel for waste-to-energy, low-grade plastic products, roofing sheets, and plastic lumber (GreenBlue, 2011). The incinerated waste contains material, which when burned provides big amount of energy. This energy can, for example, be used for heating in the urban areas. However, incineration plants have different level of emissions in the atmosphere due to the variation in the systems used. A third option is land-filling but it is the least sustainable of all and for that reason not recommended.

The difference between having LPB with aluminium layer and without aluminium layer is that the absence of such film would make the packaging more environmentally friendly by increasing the recyclability of the package. Furthermore, the price of the package is considered to be lower compared to the LPB with aluminium layer. On the other hand, the case product would not be well protected from oxygen and heat if there was no aluminium.

The energy consumption of the proposed machines is considered to be similar to the consumption of the existing machines due to the age and type of the existing machines. However, it includes heat sealing machine, which consumes more energy and it cannot be ignored.

## **6.4 Economic Considerations**

The discussion about the future cost for machines and material are based on the educated assumptions of the authors and interviews with industry professionals and they should be confirmed with the production manager and technical people.

The price of LPB with aluminium cannot be specified at this point because the price of the material depends on the properties that the material provides. Usually the better the protective barriers are, the more expensive the packaging material is. Specific numbers can be provided only after negotiations and exchange of technical information between the company and the supplier.

Because of the new option, shrink wrapping, labeling and folding units will be eliminated increasing the packaging efficiency and reducing the lead time drastically enabling the packaging line pack more products per hour. It will give the company competitive edge over others by packing high number of products, assuming that the cost for the packaging line will be around 600 000 euro, due to the investment for customized end-load cartoner and heat sealing

machine. It will also facilitate the company to change their pricing strategy for this type of product in the long run generating higher revenue and more profit due to the improved package, adding value to the product. Furthermore, instead of buying a pre-printed package material, there is an option to purchase a better quality printer and print on blank package material as and when required. This can reduce the inventory carrying cost of the packages.

Due to uncertainty in forecasting, the demand cannot be predicted exactly. This leads to overstock or understock, thus increasing the inventory carrying cost or having backlogs. Taking into consideration the supply chain and the product-process design, the production and the package can be made-to-order, thus reducing the demand uncertainty. The labor cost is assumed to be reduced due to making the packaging line fully automatic. However, there will be cost for training the line operators.

## **6.5 Reflection on Chosen Methods and Tools**

The strategies used to collect voice of the customer to answer the research questions were the factory visit of the case company, packaging fair visits, company interviews, process mapping and attending a workshop.

The factory visit gave a clear picture of the way in which packaging is currently carried out in the company. In addition, it helped to map the packaging process, to identify bottlenecks, to assess the overall effectiveness of the process. However, the challenge was getting technical information about the process and machines from the factory.

Two packaging fairs were attended to grasp the current scenario in the packaging market. They gave a deep insight into the world of packaging with the display of latest packages, package machines and technologies.

However, getting the price quote for the machines was difficult because, the suppliers need all technical information from the factory to give us the price quote. Because, there might be some need to customize the machines if required, it was not possible for us to get all such information beforehand. The contact between supplier and the case company had to be established first to discuss in detail the requirements for the supplier to know if they can provide that service.

The interviews were initially planned for customers within the company across different geographical locations. However, the questionnaires were developed and interviews were conducted within the case company in only one location. This is due to the fact that, it was challenging to get a reply, make people speak and interview them from other location. The reason for this challenge is not known.

The workshop in Dresden gave an academic perspective of packaging with few interesting industrial visits. The industry visits helped to carry out an external benchmarking to understand the market and the case company situation better. The challenge was the impossibility to record any form of data from the visited companies. The data collected were observational.

## Chapter 7: Conclusion

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This chapter concludes upon the results of the thesis and future study.

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The package is equally important as a product and it has great influence on the perception of customers about the product. Taking into consideration the importance of the package and the problems that arise from inefficient package design, a proactive approach towards developing a customer oriented package was necessary. It is also important to constantly improve the package because the package should comply with upcoming ISO standards on packaging and also follow the latest trends. It is believed that the proposal would help the company to act in a proactive manner by developing and launching a new customer oriented package in their market.

The result from the thesis shows that the first two steps of the systematic approach helped the authors in identifying and prioritizing the needs of the customer and the remaining steps helped in utilizing those needs to give a proposal to develop a customer oriented package. In the first two steps, the VOC and AHP helped the authors to identify the problems and classify the customer needs in the order of importance. In the remaining steps, ECQFD and TRIZ helped the authors to prioritize the most important needs and generate new ideas which helped in recommending new material for the package. However, the relevant machines to process the new material were proposed based on authors' knowledge and experience on the subject.

The academic contribution of this thesis is the development and application of a customer oriented methodology for package improvement. Little research was found on the topic of package improvement using similar methodologies. Most of the academic work focuses on product development, while the proposed methodology is focused on the package improvement, which is important and sometimes a neglected element. However, the validity and reliability of the methodology should be confirmed with external customers to make the approach practically feasible.

The case company can benefit from this approach by implementing in their pilot project. The implications are a new package material for the case product, elimination of old and outdated machines, addition of new machines for packing, newly improved packaging process and standard operating procedures. This thesis can mark the beginning of the global standardization process with the focus on developing a customer oriented package.

One possibility for future research would be improving the methodology in itself to cover other aspects of package by involving different customers and stakeholders. A larger representative sample of customers will help to achieve better results. The methodology can be developed further to accommodate tools that can aid in generating designs and concepts for the package. There is also a possibility to implement LEAN and Six Sigma methodologies for process improvement, materials improvement and development of machines and test equipment.

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## Appendix 1

### Appendix 1.1: Ranking of design parameters in terms of environment

<b>№</b>	<b>Design Parameters</b>	<b>Weight</b>
1	Physical lifetime of material	0,117441
2	Size of the package	0,110563
3	Toxicity of package material	0,10264
4	Water vapor transmission rate of material	0,094744
4	Water absorption of material	0,094744
5	Thickness of material	0,094022
6	Biodegradability of package material	0,09003
6	Recyclability of package material	0,09003
7	Strength of the package material	0,08472
8	Shape of the package	0,046467
9	Oxygen permeability of material	0,044191
10	Weight of the package	0,030409
11	Font size	n/a
11	High resolution of pictures	n/a

### Appendix 1.2: Ranking of design parameters in terms of functionality

<b>№</b>	<b>Design Parameters</b>	<b>Weight</b>
1	Thickness of material	0,127191
2	Font size	0,11548
2	High resolution of pictures	0,11548
3	Strength of the package material	0,09658
4	Water vapor transmission rate of material	0,089074
4	Water absorption of material	0,089074
4	Oxygen permeability of material	0,089074
5	Shape of the package	0,083361
6	Size of the package	0,06618
7	Physical lifetime of material	0,039079
8	Weight of the package	0,024694
9	Recyclability of package material	0,021578
9	Toxicity of package material	0,021578
9	Biodegradability of package material	0,021578

### Appendix 1.3: Ranking of design parameters in terms of handling and carrying

<b>№</b>	<b>Design Parameters</b>	<b>Weight</b>
1	Shape of the package	0,3064
2	Size of the package	0,1871
2	Strength of the package material	0,1871
3	Thickness of material	0,166
4	Weight of the package	0,1534
5	Water vapor transmission rate of material	n/a
5	Water absorption of material	n/a
5	Oxygen permeability of material	n/a
5	Toxicity of package material	n/a
5	Biodegradability of package material	n/a
5	Physical lifetime of material	n/a
5	Recyclability of package material	n/a
5	Font size	n/a
5	High resolution of pictures	n/a

## Appendix 2

### Questionnaire

- I. Where do you work?
- a. In Energy segment
  - b. In Automotive segment
  - c. In Transport segment
  - d. In Ship building segment
  - e. In Pulp and paper/chemistry segment
  - f. In Construction segment
  - g. In Off-shore segment
  - h. Other (please specify): \_\_\_\_\_
- II. What type of project are you involved in?
- \_\_\_\_\_
- III. How long have you been working on your position?
- a. Less than 1 year
  - b. 1-2 years
  - c. 2 -5 years
  - d. > 5 years
- IV. Where do you work?
- Inside the factory (indoor)
  - Outside - open space (outdoor)
  - Both indoors and outdoors
- V. Which are the different types of product packaging that you have encountered? (You can mark more than one option)
- Cardboard box
  - Metal tube/box
  - Plastic box
  - Vacuum packaging
  - Other: \_\_\_\_\_
1. Once the package is open, how do you carry the products?
- In your pocket/belt
  - Leave them on a shelf or on the ground
  - Place the products in a drying machine
  - Transport them using special equipment
  - Other \_\_\_\_\_

2. How do you prefer carrying the products?
- In your pocket/belt
  - With special equipment for material transportation
  - Other: \_\_\_\_\_
3. On an average, how many products do you use per shift:
- < 20
  - 20 - 40
  - 40 - 60
  - 60 - 80
  - > 80
4. Is the product information on the package easily readable?
- Yes
  - No
5. What would you rank as the most convenient packaging types to handle with a grade from 1 to 5, where 1 is the rank for the most preferred package and 5 being the least?
- Cardboard box: \_\_\_\_
  - Metal tube/box: \_\_\_\_
  - Plastic box: \_\_\_\_
  - Vacuum packaging: \_\_\_\_
  - Other: \_\_\_\_\_
6. We have grouped the following Questions (7, 8 & 9) in 3 categories. If you have 100 points how would you distribute these points to the following 3 categories of questions based on what is most important to you?
- Category 1** - Handling and carrying the package \_\_\_\_\_
  - Category 2** – Functionality of the package \_\_\_\_\_
  - Category 3** – Environmentally friendly package \_\_\_\_\_
7. For **Category 1**(Handling and carrying), if you have 100 points how would you distribute these points to the following choices based on what is most important to you?
- Easy to carry the package \_\_\_\_\_
  - Safe to open the package \_\_\_\_\_
  - Easy to open the package \_\_\_\_\_
  - Easy to take the products out of the package \_\_\_\_\_
  - Easy to stack the packages over one another \_\_\_\_\_
8. For **Category 2**(Functionality), if you have 100 points how would you distribute these points to the following choices based on what is most important to you?
- The products should be physically protected from damage \_\_\_\_\_
  - The products should be free from moisture \_\_\_\_\_
  - Easy to count the products in a package \_\_\_\_\_
  - Easy to read the information on the package \_\_\_\_\_
  - Package should convey high quality of the product and the brand identity \_\_\_\_\_

9. For **Category 3**(Environmentally friendly package), if you have 100 points how would you distribute these points to the following choices based on what is most important to you?

- Easy to reuse the package \_\_\_\_\_
- Easy to smash for recycling \_\_\_\_\_
- Harmless for the living environment \_\_\_\_\_
- Package allows welders to use max number of products with min wastage \_\_\_\_\_