Evaluating the benefits of product and packaging integration – a multiple case study

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ABSTRACT

The success of a company increasingly depends on the efficiency and effectiveness on its activities along the product life cycle. In the effort of optimizing its activities, companies must integrate themselves. Due to the significance packaging has within many of these activities, it is of utmost importance to integrate product and packaging development activities in order to optimize processes.

It was shown in previous studies the interest that companies have on putting into practice such integration. Nevertheless, it is not clear either the possible benefits resulting from the implementation of product and packaging integration at an operational level or the appropriate manner to carry out such implementation.

Through a multiple case study, several products within mechanical actual industry and which show, at some extent, product and packaging integration, are analyzed. By means of the product cases' analysis, the purpose of this study is to evaluate the advantages that companies gain by changing present activities to the suggested concept. The integration performed by the companies studied will be analyzed and connected to the development procedure model proposed by Bramklev et al (2005).

From the contributing companies' results, this study concludes that integration performance involves noticeable improvements along product life cycle processes. In particular, the distribution costs and the quality of processes in general, are the most benefited aspects by packaging integration. The results emphasize the importance of packaging in logistical activities considering help-in-distribution as maybe the most important characteristic of packaging. It is believed that taking into account earlier in the development process, packaging and other activities requirements, guarantees a more efficient product development reducing the risk of failure and consequent need of redesign.

Development procedure models are declared very important tools for the companies in order to facilitate the work and organize activities. All the product development procedures for every case and company have similar structures to each other because even when things are called different the idea is the same. However, packaging development processes do not match that much to a generic model. Packaging integration has shown to be performed in a wide variety of approaches but always resulting on benefits for the companies.

The results of the study show a clear support to the model proposed by Bramklev et al (2005); the higher the integration is performed, the higher the benefits are obtained.

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INTRODUCTION

1.1 *Background*

When talking about products, there are many things to take into account throughout the product life cycle. The life cycle of a product can be briefly described as a sequence of stages; a product "starts" with an idea and then it can be developed, manufactured, distributed, used and recycled (product life cycle is more extensively treated in next chapters). Thinking about all these diverse activities and in order to create the proper interactions between those, most of the areas within the company (if not all), must be somehow involved in the processes, from the initial idea until the final product reaches the end consumer.

Thus, in an effort to maximize the efficiency and effectiveness of their activities, companies must integrate themselves. There exist relationships, tasks and problems which can be made more efficient, can be rationalised and can be solved using the tools of integration (Andreasen & Hein, 1987). In this way, to control costs and to improve resource utilisation in the development of a product-to-be, it is important to incorporate features of the globally dispersed company activities early in the product development process (Prasad, 1997).

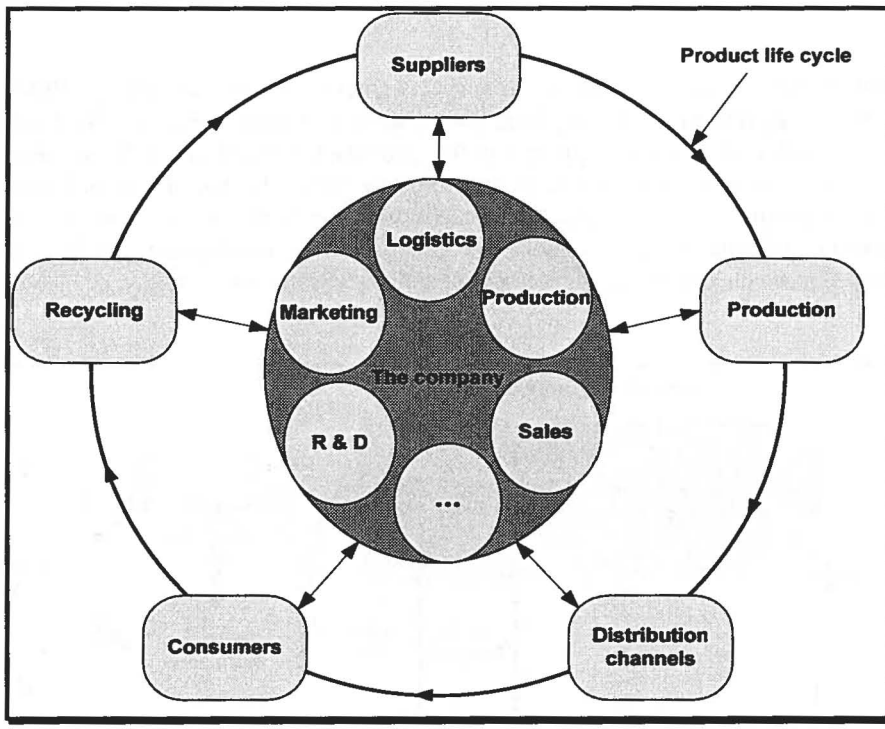


Figure 0-1: Company global activity

The activities realized by the companies do not reduce to internal activities between the diverse areas and departments; the relationships with suppliers, retailers and customers are becoming of utmost importance since the need for considering logistical aspects has increased in importance for the last decade. Nowadays, it is not sufficient to be very efficient and

effective in manufacturing, but a company also needs to be efficient and effective in the logistical activities (transportation, handling and storage) of both intermediary and final products. The logistical activities between global divisions, between company and its suppliers and between company and customers crave for such logistical efficiency and effectiveness.

As part of the importance of logistics, packaging plays a significant role in the support of these logistical activities.

In the paper by Bjärnemo, Jönson & Johnsson (2000) a proposal for integrating product and packaging development was suggested. The objective is to include the concurrent development of packaging into the traditional product development process by integrating product design and packaging. That proposed integration is based on the idea that the package not always fulfils the needs required by the product in some periods of its life cycle, and that a packaging system should provide an extension of the product features to fulfil all the demands from the different periods of the life cycle of the product. Additionally, the authors introduced an extended procedure model based on Integrated Product Development (IPD) (see Andreasen & Hein, 1987; Olsson, Carlqvist & Granbom, 1985). The paper was of a conceptual nature and the industrial support for such integration was not provided in the paper. Therefore, it became important to verify whether the suggested integration concept was supported by the industry or not.

As a result of that concept, a research project was carried out (see Bramklev, 2004), where three product areas (pharmaceuticals, food and mechanical) were surveyed. The results from such surveys reflected a clear support for the proposed integration in those areas. As a secondary objective from those research activities, for industrial and theoretical purposes, a further development of the integration concept was necessary as well as a test of the implementation of this theory in industrial practice. The mechanical product area was recommended to be chosen for the first implementation. (Bramklev, 2004)

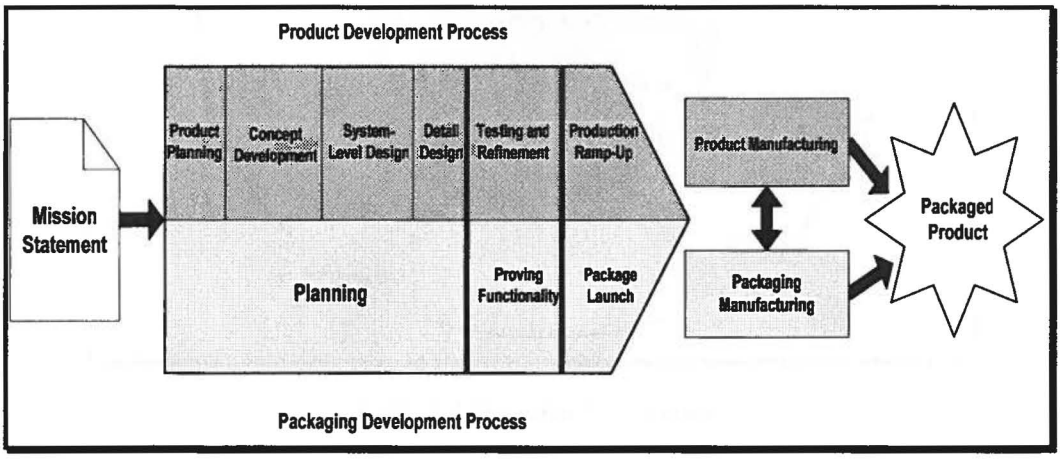


Figure 0-2: An illustration of the integration of product and packaging development (Bramklev, 2004)

1.2 *Problem definition*

The actual situation within the companies shows an interest in putting into practice the integration concept. However, in order to use resources on implementation companies need to know what they gain by changing present activities to the suggested concept. They should be provided as well with a plan on how this concept can be implemented and used operationally.

At the time this thesis started, from the several different works regarding integrated product and packaging development (Bjärnemo, Jönson & Johnsson, 2000; Bramklev, 2004) the following advantages were expected:

- Reduction in lead-times of the development project and reduction of development costs.
- Reduction in distribution costs.
- Improved quality of processes in terms of time, money and resources consumption.
- Impacts on productivity in terms of increasingly efficient and effective utilization of resources.
- Lesser impact on environment.
- The possibility of arranging a functional decomposition between product and packaging, thus facilitating a "tailor-made" packaging of the product and a possible simplification of the product.

But the real potential either expected or not, should be presented in the industry through convincing real cases. In order to serve as a base and model for the industry, it is necessary to find cases which illustrate the benefits and possible problems (either caused or solved) when implementing such an integration concept. All these cases exposed in this thesis should be as general as possible to help the different companies of the industry to situate themselves close to one of the cases and motivate these companies to solve their own problems and inefficiencies.

1.3 *Purpose*

As the problem definition has been stated, the actual situation is that the industry is aware and interested in product and packaging integration. However companies need to know about with the benefits resulting from the integration concept as well as the way for implementing such concept.

Considering this, the purpose of this thesis can be established as: *"To examine and evaluate the advantages achieved through concurrent product and packaging development on an operational level in industry"*. Besides, in order to connect the benefits obtained by the companies with the way development process is performed, an analysis of the companies' procedure models for developing products will be also carried out.

1.4 *Research Questions*

As a complement to the purpose of this study, research questions are formulated to help the authors guide their investigation.

The necessity to distinguish between general and specific research questions is emphasised by Punch (1998). General research questions can be considered as a guide during the research process but are not precise enough to be answered. On the other hand, the specific questions are object of answer during the research. These specific questions are generally direct consequence of the general one(s) and lead the empirical procedures. In our particular case, the specific questions developed early in the process were used as starting points for the collection of data when conducting the cases. As it will be referred to afterwards, due to the diversity of the selected cases, the specific questions are adapted to each case. However, while conducting the cases, we were not limited by these questions, using them as the base and central points of interest but always being open to other aspects in order to get relevant information as long as it was possible.

Since this research project pretends to serve as an example for the industry on the benefits achieved by integrating product and packaging, the general questions that will guide the research process are stated as follow:

What are the advantages for the companies to integrate product and packaging development?

And

How integrated product and packaging development is implemented within the studied companies?

The first question as formulated is fairly wide so it can be approached from many standpoints since the benefits that can be considered enclose a wide set of possibilities. As mentioned before, many different advantages are expected when implementing the integration concept. It would be impossible to analyze in depth all the factors, thus, when developing the investigation the focus will be on costs and lead time reduction as the main benefits achieved with this practice. Nevertheless, the research will be open to any other benefits, either expected or not, in order to make the investigation as accurate as possible.

Complementing the general research questions, various specific research questions will be introduced in the methodology chapter. These specific questions are intended to support the researcher in the procedures for studying the assigned cases. The diverse companies that are going to be studied understand the concept of the integration of packaging and product development in their own way, that is, the integration is put into practice with different approaches and to different extents. Therefore the interaction between these two activities is going to differ among the different companies; some could speak about a complete integration while in some others the integration can be performed at a very specific level and to a low degree. In this way, the various cases will need different specific questions when being analyzed.

1.5 *Focus and Demarcations*

The research has been carried out evaluating the integration concept within the specific product area of mechanical engineering. The focus of the research has been limited to Sweden and Spain in the companies studied.

The research has focused on aspects concerning cost and time connected with product and packaging development, production and logistics. There are many features that could be considered, but it would be impossible to reach all of them.

It is believed that the supervisors' participation was necessary for the selection of the cases in Sweden. This situation slowed down several activities, ending with a time and location constraint. The direct collaboration of our supervisors was necessary for finishing the cases in Sweden. In those circumstances, the only way to get direct information from the companies was through e-mails and telephone calls with their related problems. Sometimes, the supervisors' collaboration was also required when the companies wanted them to clear information that would be provided to us for research.

1.6 *Outline of the thesis*

Next, the different chapters of the thesis are presented in order to give a clear structure for the reader.

Chapter 1: Introduction – introduces the background and actual situation of the subject studied as well as the purpose looked for in this research project.

Chapter 2: Methodology – the method followed for the realization of the thesis is described.

Chapter 3: Frame of reference – introduces the theoretical framework that constitutes the basis of the thesis.

Chapter 4: Conducting the case study – presents the description of the cases analyzed during the research process as well as provides with the individual conclusions for the those different cases.

Chapter 5: Cross case conclusions – the conclusions from the individual cases are here merged and combined in order to draw general conclusions for this thesis.

2 METHODOLOGY

After identifying the problem and purpose of the thesis and developing a question for inquiry, it becomes necessary to choose the most appropriate methodology to proceed with the research project. It is important in research that the question be not separated from the method. (Denzin & Lincoln, 2000)

Having done the methodology study intended to be followed during the research process increases the ability of doing better research. In this way the methodology is supposed to detail the path walked as well as to help justify the decisions taken during the research process.

The below depicted flowchart shows the research process followed during this thesis:

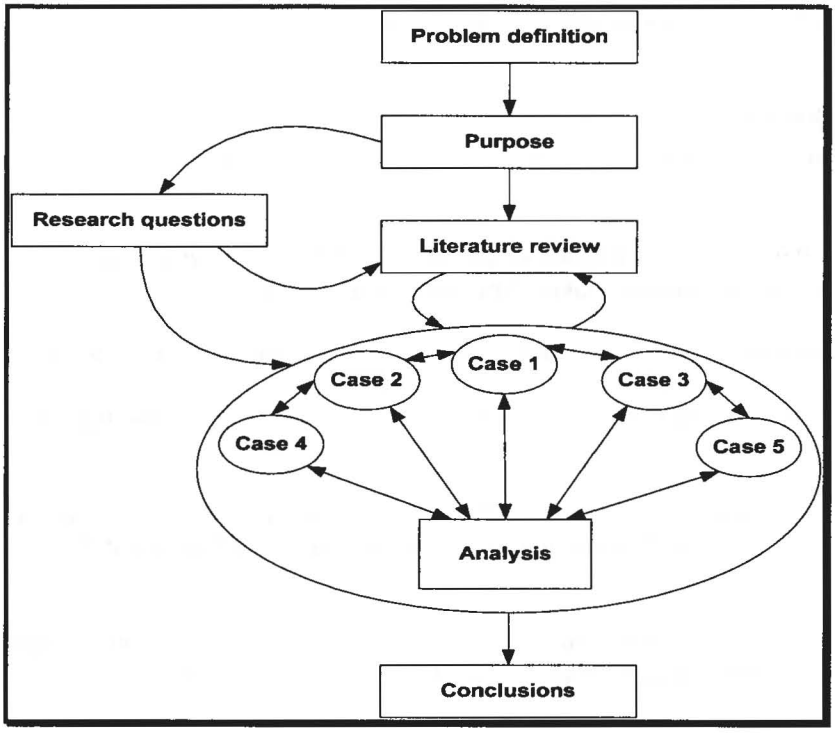


Figure 2-1: Research process

Supported by this figure and throughout this chapter, it is intended to show the reader what has been done during the total process, from the thesis' assignment to the conclusions it draws.

2.1 *Research process*

First thing to do after the assignation of the project was to decide and design a research process. Research design, in a general conception, has to engage the purposes of the study, *"what information most appropriately will answer specific research questions, and which strategies are most effective for obtaining it"* (LeCompte & Preissle, 1993, p. 30) (Denzin & Lincoln, 2000).

After the purpose of the research was clear it was time for deciding how the research was going to be carried out. During the first months, while some literature was read, we developed supportive research questions introduced in the subsequent chapter. The questions were developed always keeping in mind the purpose of this work since they were going to be a supportive tool for getting the necessary data. The research questions constitute the starting point for the collection of data; and as the data sought refers to potentials resulting from product and packaging integration, the mentioned supportive research questions are connected to the expected advantages.

As the research was intended to provide with the potentials already gotten in industry, direct contact with the analyzed companies was important and personal interviews were the most appropriate way for it since the interview is designed for *"improving knowledge going into matters in depth"* (Wengraf, 2001). Besides planning interviews, it was considered the possibility of analyzing companies' documents when they could be gotten, as well as using observation as another tool to find out information when the meetings had place in the own companies' facilities.

Due to problem specifications, the research was proposed to be conducted as several cases analysis. It was agreed that the case study fitted within the aim of the thesis since the study of real and actual cases, as it will be commented, is the best way for getting relevant information to draw conclusions. After a couple of meetings with the supervisors of the thesis, a multiple case study was established as the way for carrying it out. Multiple case studies offer the possibility of getting a more robust support when drawing conclusions. Considering that the contexts of the different cases will differ to some extent, if the findings guide to common conclusions from the several cases the external generalization is likely to be much more expanded (Yin, 2003).

Every case has to contribute to the overall purpose of the research taking into account that *"each case is a complex historical and contextual entity"* (Denzin & Lincoln, 2000). In this way, the analysis of each one of the cases is intended to be a support to confirm the potential benefits achieved by integrating product and packaging. According to Yin (2003), each individual case study consists of a total study where convergent evidence is sought regarding the facts and conclusions for the case, so the individual case's conclusions are used as replication to each other.

Our supervisors were in charge of the selection of the cases in Sweden. In Spain, we ourselves chose the companies to study. The cases were intended to be studied one by one, but they have been conducted combined in most of the situations; while the data gathered in one case was being analyzed and interpreted we could (for example) be preparing for an encounter with a different company for a different individual case. Hence, interviews, case descriptions, analysis... have being carried out with no specific order, as the course of the work required it. Anyway, the experience acquired in the first cases was used for conducting the following ones trying not to commit the same mistakes regarding planning and unexpected answers.

For both researchers, it was the first time carrying out this kind of investigation with all it entails. After the first interviews, we deeply prepared the following ones learning to improvise and react when the course was unexpected. For conducting the cases, literature was consulted and the information gathered with the different cases was compared. Doing so, it was possible to use findings from one case for improving another one. The decision of the relevance of some information is likely to change as the study progresses (Richardson, Dohrenwend & Klein, 1965).

However, the real course of the research differs widely from the initial action plan which is depicted at the end of this section (figure 2-2). The design of the plan to follow was made assuming that the course of the research could probably affect the action plan so it was flexible enough to adjust it during the development of the investigation.

In this way, the research design is intended to describe a flexible guide that connects theoretical paradigms to methods for collecting empirical data (Denzin & Lincoln, 2000). This idea is supported by many authors. Yin (2003) describes the research design as *"the logic that links the data to be collected (and the conclusions to be drawn) to the initial questions of study"*. Sierra Bravo (1986), goes further stating that the research design *"sets up the guideline to follow when gathering and processing data, establishing which data is necessary, the collection procedure and the way for further analysis"*.

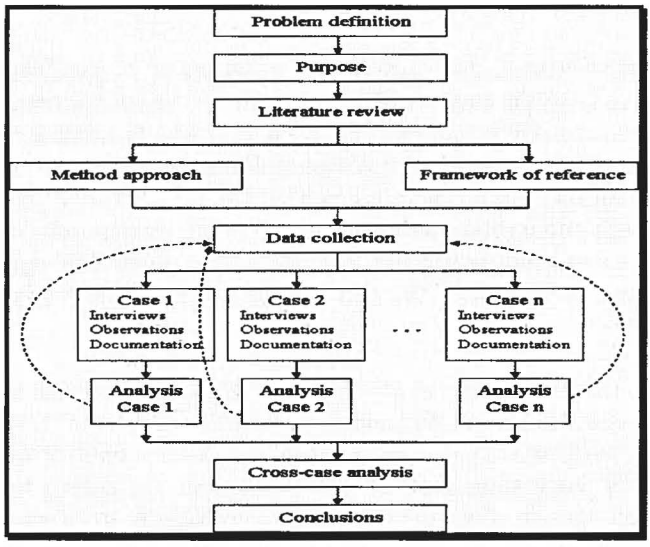


Figure 2-2: ***Initial action plan for the research process***

2.2 *Research strategy*

The five major research strategies are experiments, surveys, archival analyses, histories and case studies. Each of them has its advantages and disadvantages and different ways of collecting and analyzing data. (Yin, 2003)

In order to decide which one better adjust to the research, three aspects must be considered (Yin, 2003):

- the type of research question posed,
- the extent of control the investigator has over actual behaviour events and,
- the degree of focus on contemporary events as opposed to historical ones

2.2.1 Case study as research strategy

The project will be carried out as a case study. *"Case study is not a methodological choice but a choice of what is to be studied"* and it is identified not by the methodology employed but by of the importance of individual cases (Denzin & Lincoln, 2000). We want to know what is really going on within the actual mechanical industry regarding the integration of product and packaging; therefore, the best way for getting it must be to analyze and study real cases.

Regarding the three above stated aspects for selecting a research strategy, case study is the most appropriate strategy to carry out according to the characteristics of the situation, because according to Yin (2003):

- Case studies are, in general, the preferred strategy for dealing with "how" or "why" questions. The mean of this research is to evaluate the benefits that the integration concept provides, and the research questions intended to lead to that purpose have been expressed:

  What are the advantages for the companies to integrate product and packaging development? Which is a clearer manner to ask why it is beneficial,

  And

  How integrated product and packaging development should be implemented?

- The case study researcher poses no control or little control on what is being studied; and studying different cases in specific companies does not offer the possibility of manipulation.

- The case studies are focused on actual events; the current situation within the mechanical industrial area is a fairly contemporary event.

According to Eisenhardt (1989), the three different purposes for using case studies are: to provide description, test theory or generate theory. As expressed before, the purpose of this research is:

"To examine and evaluate the advantages achieved through concurrent product and packaging development on an operational level in industry".

Hence, it can be said that the case study carried out in this research will evaluate the potentials of implementing a previous theory generation (the integration concept between packaging and

product) while providing descriptions of several procedures in different companies within the mechanical industry.

2.2.2 Supportive research questions

In order to better manage the research strategy it becomes necessary in the "warm-up" period, or the period of making decisions at the beginning of the study, to find out some specific questions that may direct the investigation in every singular case. Although the questions are established at the beginning of the research in order to guide the study, those questions must be target of constant revision with the possibility of acquiring new shapes during the course of the process. (Denzin & Lincoln, 2000)

Since the study of the profitability achieved with concurrent development is going to be analyzed by examining several cases, different situations will be faced; therefore, different specific questions will be needed in the different cases.

On the one hand, the situation in which the existing development procedure within a company do not show concurrent product and packaging development but sequential activities (or at least not a structured integration procedure) and where some kind of redesign has been made to solve production or distribution problems, the following will be the questions to guide the analysis:

- *Why is not the process done in a concurrent way? Is it not necessary? Is it not possible?*
- *Can the entire process be considered successful?*
- *Why was redesign necessary?*
- *Which were the failures or origin of the redesign?*
- *Why was not packaging considered from the beginning and in all the aspects of the process? Was not it possible?*
- *How is the redesign process? What is the difference between the redesign and the original process?*
- *Has the redesign solved the problems and the best solution has been reached?*
- *Which problems have been faced when redesigning?*
- *What costs and lead times are involved in the process? How do they differ?*
- *Would it be possible to avoid these costs and to reduce these lead times by acting in a concurrent way?*
- *How does the redesign process affect the different activities along the supply chain?*
- *What kind of indirect effects have been derived from the redesign process?*

On the other hand, there can be cases where the integration of product and packaging development is performed from the beginning with all the product and packaging activities done concurrently. In this way, the "contact points" between product and packaging development are well defined before starting the project. The questions to be answered should be:

- *Why is the concurrent development implemented?*
- *How is the concurrent development process? Why is it that way?*
- *What activities are considered concurrently?*
- *Which are the contact points?*
- *Which benefits, in terms of costs and lead times, are achieved?*
- *Which problems have been faced when concurrently developing?*
- *How does the concurrent development affect the different activities along the supply chain?*
- *Are all the problems solved with this concurrent development or some problems are unavoidable even with this method?*
- *What kind of indirect effects have been derived from the concurrent process?*

Of course these two particular situations are not normal inside the industry and the companies are usually situated somewhere in the middle of these. Consequently in this thesis, the questions leading the different interviews with the companies were adapted to the particular situation and organization of the company studied, using a mix of both extreme situations.

Answering the stated questions will lead to a better understanding of the actual situation within the industry and the potentials offered by the integration of both product and packaging development.

2.3 *Literature review*

The first thing to do after a research project is defined is to find out what has already been done on it (Russell, 2000). With that intention, literature was gathered as a starting point. Some literature was recommended by our supervisors with the intention of getting familiarised with the integration concept and the different areas that could be interested in the research. Methodology literature was also necessary to start with the thesis looking for the appropriate manner to approach the research.

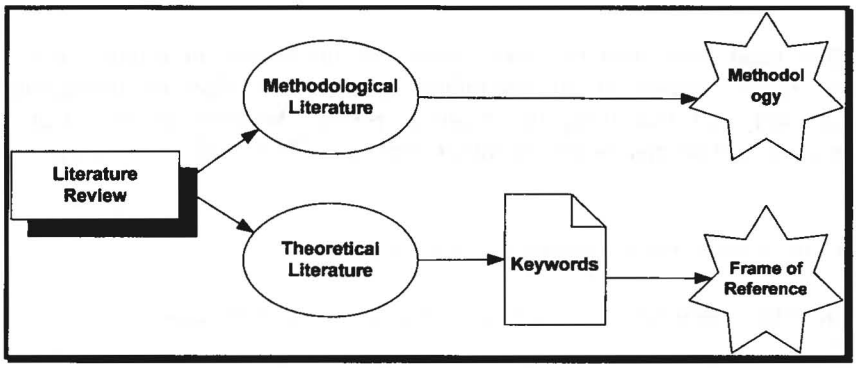


Figure 2-3: Literature review

Reading literature was the first step in the thesis but can be considered as an activity that has been carried out along the whole research. As the research was ongoing many other titles were included in the literature collection. Some subject references were easy to find but other references were needed to be found on the internet. It was always borne in mind the need for having a really strong quality on the literature review so this action has been developed intensely all the way through.

The literature study was crucial for developing a frame of reference to understand in a suitable way what was going to be studied. The development of an appropriate theoretical framework must be considered as an essential part of the design phase. This step in the research is prior to the collection of any data provided with a guide with which to analyze the empirical results of the case study. (Yin, 2003)

The theoretical frame of reference was thought early in the study to serve as a base for further research. A deeper knowledge and understanding of the problem can force a review and updating of the frame of reference and that is why it was partially modified and completed during the course of the research.

2.4 *Collection of data*

After deciding the method approach and developing the theoretical frame of reference, the focus was on preparing for gathering information. Data collection is an important phase when doing research. It becomes decisive for the quality of the research and the conclusions to be drawn to have access to relevant data.

As mentioned before, interviews, document analysis and observations are the tools used for that information collection. There are many helpful sources to be used for collecting data and the decision of which ones to use depends on what is pretended to be gathered and the accessibility of the different sources. The six sources presented by Yin (2003) are: documentation, archival records, interviews, direct observations, participant observations and physical artefacts. The case study's strength is its ability to deal with a full variety of evidence and it relies on interviewing, observation and document analysis (Eisenhardt, 1989; Denzin & Lincoln, 2000). This is supported by Wengraf (2001) who considers these three methods as the basic ones for gathering information and *"often used in the same study, either concurrently or in sequence, to verify or to supplement the information gathered by any one*

of them or for the peculiar advantages of each at various stages" (Wengraf, 2001). It is clear that the use of different kinds of sources makes the conclusions of the case study much more likely to be accurate and reliable.

The data was gathered during the whole research process, and while at the beginning the objectives of information collecting are general, time makes the boundaries well defined (Richardson, Dohrenwend & Klein, 1965). The disposition for collecting the data was to first get a description of the product, its production and the logistical processes as complete as possible in each individual case. Based on the descriptions provided by the first encounter with the companies it was tried to find aspects in each case that would be worthwhile to investigate. Focusing and going deeper on those aspects we try to find supporting data to argue for the implementation of product and packaging integration.

2.4.1 Primary and secondary data

Secondary data refers to data that has been already collected, information that can be found in books, articles... previously written. This kind of data was gathered early in the research and it was the base for the development of the thesis' frame of reference. Literature review is considered somehow secondary data. Primary data is the data collected purposely by the author of a research. Primary data in this study consists mainly of the interviews carried out in the different case analyses and it will be distinguished between qualitative and quantitative data. The qualitative primary data is turned out into the case's descriptions while the quantitative data is used to provide numerical figures to support the conclusions. When the companies were selected, their internet web pages were consulted before and after the interviews in order to check and look for information.

According to Eisenhardt (1989) *"one key to useful field notes is to write down whatever impressions occur, that is, to react rather than to sift out what may seem important, because it is often difficult to know what will and will not be useful in the future"*. The disposition of this thesis was based on collecting as much information as possible, and in this way, although it was clear what we were looking for, almost everything listened to or saw during the interviews and visits to the companies was written down. These notes, constituting the basic data collection of the research, were analyzed selecting the relevant information. In most of the cases, tours along the production and storage facilities were carried out to gain a better understanding of the case. Sometimes it was possible to take pictures of several processes.

2.4.2 Interviews, observations and document analysis

There is a huge literature concerning interviewing but it is not possible to learn how to interview by reading it (Russell, 2000). There was no previous information about the cases that were going to be studied. That circumstance made it rather difficult to prepare the interviews intended to carry out in the companies. For preparing them it is important to consider an interview as a verbal exchange (Mishler, 1986).

In the development of this thesis one of the most important parts was the personal interviews carried out in the companies. In the different companies different people were interviewed depending on the organizational structure of each company and also on the particular case studied. For Nederman, the interviewees were the Technical Manager (media supply) and the R & D Manager for low vacuum, but the last one just for punctual information. In the Istobal cases three employees were interviewed: R & D Director, a Design Engineer (selected by the

Director) and a Production Engineer (also selected by the Director). The initial contacts in this company were with the Director, but some technical aspects of the products were provided by the Engineers. In Dresser Wayne the contact with the company was by e-mail with a Design Engineer. The first contact with this company was through the thesis supervisors. For the company A the contact was first settled with the Technical Director Manager and once in the company also a Technical Engineer was interviewed for the technical details of the product.

Because of lack of information about the cases, the first interviews within each company were planned to be mainly open-ended questions trying to get relevant information about the product and processes. It is important to feel confident about the development of the interview, as it is expressed by Mishler (1986), through *"mutual reformulation and specification of questions and responses, so interviewer and respondent strive to arrive together at meanings that both can understand"*. Therefore, the interviews were partially prepared in advanced and largely improvised during the own interview. In this way, the interviews are based on a clear plan, but there is a minimum control over the interviewed responses (Russell, 2000). A great advantage the interview has in contrast to with observational and documentary information is that the own interpretation of the interviewer can be checked with the respondent (Richardson, Dohrenwend & Klein, 1965).

The intention in all of the individual cases was to first establish a case description and afterwards to concentrate on the areas interesting for the thesis where there was a lack of information. The findings of the first interviews were used as the basis for further inquiries. That is, the unstructured open-ended interviews turned on more focused and structured ones as the knowledge got wider.

Sometimes, observations become essential when other tools do not provide accurate information or when the interviewees, even if they are not unwilling to reveal information, they can be strongly moved to distort it (Wengraf, 2001). Because of this, observations and document analysis were performed when possible looking for different tools to supplement one another (Richardson, Dohrenwend & Klein, 1965)

The companies' documents analyzed were supplied by the own companies' personnel, either when the interviews were performed or by internet mail. These documents contained procedure models, product descriptions, companies' processes... In one of the cases, we had no direct contact with the company for the first encounter, and the collaboration of our assistant supervisor was necessary for obtaining the first information. Her notes and the material supplied by the company through the supervisor were the documents analyzed, constituting the base for the case description. However after this first "indirect" approach we contacted this company in order to go deeper into the matters considered relevant for the purpose of the research.

2.5 *Analysis of data collected*

The analysis can be considered as the most difficult phase in case study research. The analysis and interpretation of the data have been performed all through the course of the investigation. In fact, analysis usually starts before data is collected, when some ideas are in your head about what is going to be studied and it goes on throughout the research effort (Russell, 2000).

When the collection of data was ongoing, we held numerous meetings in order to discuss and analyze the results from the visits. We complemented to each other in information, ideas, interpretations; it was a first contact for the analysis of what had been obtained. It is proclaimed that in the interpretation process the "data speak for themselves" so the researcher is unbiased and neutral (Denzin & Lincoln, 2000). Sometimes, our assistant supervisor joined during those discussions. The collection of all the information in each individual case was not done at once but several contacts with the companies were required in all the cases. In every case the data obtained from the first encounter was analyzed looking for relevant aspects to go in depth. With that focus, more data was gathered and afterwards interpreted and analyzed, and so on if it was necessary.

The information gathered from the different cases was compared looking for appropriate conclusions. With this multiple case study we pretended to find out the potentials or advantages resulting from the integration of product and packaging development. Hence, it was important to merge and combine the findings from all the cases. Examining the common potentials would lead to relevant conclusions as well as to the isolated benefits. The relevant factors influenced by product and packaging integration, either expected or not, are used as "parameters" to establish conclusions.

In order to offer a clearer exposition of the results, they are laid out in matrix form in the cross case analysis. As for all kind of analysis the production of visual displays is an important part helping to understand what it has been done (Russell, 2000).

2.6 *Research approach*

Because of the purpose of this case study, both qualitative and quantitative data are required to provide with good case descriptions and supportive numerical figures as well. A brief description of both methodologies is introduced afterwards in order to make easier to understand the reasons for using one and another. An introduction of different study approaches is also provided to express the perception used in the product-packaging situation has been treated with.

2.6.1 Qualitative vs. Quantitative study

It is common when researching to distinguish between qualitative and quantitative methods. The selection of one of these methods depends on the problem statement and the chosen method must support the purpose of the project.

This study will have mainly a qualitative focus. The aim of this research is to draw conclusions from the relationships between product and packaging development; hence, it will be important to focus on the relevant features among these areas, rather than the common ones or the frequency on which those features occur. Complex relations become possible to understand when using the qualitative method. A number of cases within Swedish and Spanish companies will be analyzed in order to point out the benefits resulting from the integration concept. Due to the complexity of what is going to be studied, a deeper understanding will be necessary through qualitative study looking for appropriate conclusions. However, since it is expected to provide potential benefits resulting from the integration, it is important to support the results with numerical figures, which usually make clearer the conclusions. Because of the need of this numerical support, quantitative methodology will be required as well.

Qualitative
The research is going to employ qualitative methodology because in these studies, it is important to focus on what is relevant with the aim of describing and understanding a situation. Qualitative researchers set up a wide range of interconnected practices hoping always to get a better understanding of the subject matter on hand. That is why the collection of a great amount of data becomes essential to get a better understanding of what is being studied. In this way, the qualitative design looks at the larger picture, the whole picture, and then begins with a search for understanding the whole. (Denzin & Lincoln, 2000) The purpose of this method is to give an understanding with a low level of formalisation. This type of study is characterised by a high level of flexibility (Sierra Bravo, 1986).

Quantitative
In contrast, in the quantitative study what is central is to focus on the common and representative features that are repeated. This method is characterized by the application of more statistical, formalised and structured methods providing a higher level of control and reliability. The questions asked in quantitative methods are quite different from those asked in qualitative ones. (Denzin & Lincoln, 2000)

2.6.2 Systems approach

Since the purpose of this thesis is to try to find out the potentials of developing product and packaging concurrently, among the three different competitive research approaches presented by Abnor & Bjerke (1994), the systems approach will best support this work. The idea is to consider the set product-packaging as the whole that is affected by the different processes and activities that are carried out during the product life cycle. The other approaches are analytical approach and actors approach, and the main differences between all these are:

- **Analytical approach** assumes that the whole can be considered as the sum of its parts. Another characteristic of the analytical approach is that the knowledge acquired is objective and can be replicated.

- **Systems approach** assumes that the whole is not just the sum of its parts but the relationships between them as well. The knowledge depends on the system. A system can be either closed or open. In a closed system all the parts affecting the system are taken into consideration. On the other hand, in an open system there are components surrounding it, which can affect the entirety, that are not taken into account.

- **Actors approach** assumes that reality is identified as a social construction. The knowledge depends on the different actors involved.

With the systems approach the disposition of this work is based on collecting as much information as possible in each case in order to search for important relationships among the activities. In contrast, the analytical-oriented studies use mainly statistical analyses and forecasts, while the actors-oriented studies have its own unique techniques and way of interpreting the reality.

Through the analysis of the relationships between all the processes which are linked and affecting each other, the total product-packaging system can be described and the benefits resulting from the integration concept will be easier to find out. It would not be realistic to think that all the "components" in this research can be analyzed properly in order to get the

influence over the whole, so it is assumed that the system is an open system where there will possibly be features not taken into account.

2.7 *Quality of data*

For the multiple-case study carried out in this thesis three quality tests are relevant: *Construct Validity*, *External Validity* and *Reliability,* which will be treated in depth, while another one, *Internal Validity,* will not be considered here because it is used for explanatory studies only (Yin, 2003).

The quality of the data is something that has to be planned for the whole research process. It is important to minimize errors. When these errors can not be avoided by good planning, it is important to keep always in mind the quality of the data during the course of the investigation.

In some of the cases, different people within the companies were consulted in order to give more objectivity to the information. It is normal when interviewing that there is a trend by the respondents to answer all the questions, even if they do not remember, do not want to tell you or do not understand, because sometimes they are willing to mislead you to create a good impression (Russell, 2000). After the cases' reports were written down, they were sent to the companies for them to verify the data. Doing so, the quality of the data was strengthened.

To measure thesis credibility it is necessary to use certain logical tests. According to Yin (2003) four tests have been commonly used to establish the quality of any empirical social research, and therefore they are also valid for the case study. Table 2-1 (Yin 2003, pp.34) registers the four tests and the recommended case study tactics as well as a cross-reference to the phase of research when the tactic is to be used.

Tests	Case Study Tactic	Phase of research in which tactic occurs
Construct validity	• Use multiple source of evidence • Establish chain of evidence • Have key informants review draft case study report	Data collection Data collection Composition
Internal validity	• Do pattern matching • Do explanation-building • Address rival explanations • Use logic models	Data analysis Data analysis Data analysis Data analysis
External validity	• Use theory in single-case studies • Use replication logic in multiple-case studies	Research design Research design
Reliability	• Use case study protocol • Develop case study database	Data collection Data collection

Table 2-1: Case Study Tactics for Four Design Tests. Source: Cosmos Corporation

Construct validity

This first test is always problematic in case study research and is all about *objectivity*. According to Cambridge dictionary (http://dictionary.cambridge.org/), objective is defined as: *"based on real facts and not influenced by personal beliefs or feelings"*. This objectivity has been taken into consideration along the interviews and while writing, but in some extent the researcher will always "manipulates" the outcome of the research by his personal point of view. As Yin (2003) expresses a multiple source of evidence is important. In this thesis all the interviews have been presented as appendices and the treatment of the information collected has been carried out carefully and trying, as long as possible not to influence on it. It is important to notice as well that in Dresser-Wayne, the information was collected with the help of our supervisor: she interviewed the companies with the questions we provided to her.

External Validity

It is always said that single cases offer a poor basis for generalizing. This thinking is based on the idea that survey research relies on statistical generalization while case studies rely on analytical generalization. In the cases, the researcher tries to generalise a particular result to a broader theory, but this generalization is not automatic, the findings should be replicated several times. Once such direct replications have been made, the results might be accepted as providing strong support for the theory. In this thesis a multiple case study has been carried out, so the generalisation into a broader theory relies on a stronger base, as several replications have been taken into account.

Reliability

Reliability refers to *"whether or not you get the same answer by using an instrument to measure something more than once"* (Russell, 2000). The objective is to be sure that if a later investigator followed the same procedure as described by an earlier investigator and conducted the same case study all over again, the later investigator should arrive at the same findings and conclusions (Yin, 2003).The goal of this test is to minimize errors and biases in a study. For this case study, another group of investigators will probably present similar case descriptions as the ones presented here, although when trying to obtain conclusions some subjectivity will appear, therefore the conclusions could have certain discrepancy. However, this thesis has been carried out trying to describe every step in an operational way with the intention of giving the possibility to conduct a similar case study in a similar way.

The use of several methods for collecting data and the fact that we were two researchers working together, made lower the risk of misinterpretation; as expressed by Denzin & Lincoln (2000) using multiple methods, also called triangulation, provides an attempt to secure a deep understanding on what is being studied.

3 FRAME OF REFERENCE

3.1 *The product life cycle*

Product development in a mature, continually operating business is an interminable, cyclic activity (http://www2.uiah.fi/projects/metodi/130.htm). One important tool in the development of industrial products is a description of the product life cycle. The idea of a product life cycle admits the fact that designing and selling a product is only part of the story. In fact, every product goes through a series of steps between the time it is first imagined and the time the manufactured product is retired or discarded.

Considering Olsson (1976) the life cycle of a product is referred to as the technical product life cycle and it is formed by different phases: product origination, production, distribution, sales, use, re-use and disposal. In the definition proposed by Roozenburg & Eekels (1995), it is considered that the industrial innovation starts with the origination of the product (all activities included in the product development) runs through different stages and ends with the disposal of the product. These two descriptions of the product life cycle were followed by Bramklev (2005) to create figure 3-1.

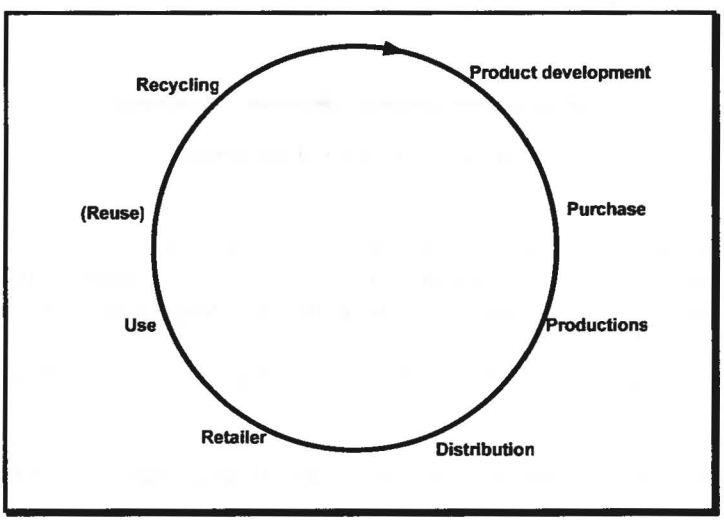


Figure 3-1: Product life cycle. Bramklev (2005)

These different parts of the product life cycle have to be considered in the phase of the product development. It is important to notice the sequence followed in this process and that all the activities are in some way subordinate to the future activities (or more precise to the specifications of these activities) but also to the past activities and the way they were done. That is the reason why product development should be considered as a milestone. The design for product life cycle will be treated later on in this frame of reference.

It is also important to mention that other concept of product life cycle is considered by other authors. For example, Armstrong & Kotler (2005) describe a product life cycle divided into the stages of product development, introduction, growth, maturity and decline. Armstrong &

Kotler (2005) refer to a process describing benefits and sales over the duration of a product's life cycle, in contradiction with the model proposed by Roozenburg & Eekels (1995) and Olsson (1976). In this thesis, the life cycle of a product described by Armstrong & Kotler (2005) is not going to be considered.

3.1.1 Supply Chain

The supply chain can be defined as the entire set of activities involving the organization to produce and deliver a product to a final customer (Schary & Skjott-Larsen, 2003). But there are other authors that suggest substituting the word "supply" by "demand" to reflect the fact that the chain should be driven by the market. Equally there is suggested to change the word "chain" by "network" since there will be multiple suppliers and as well multiple customers (see figure 3-2). (Christopher, 2005).

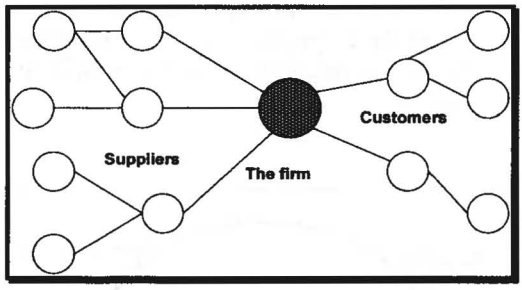


Figure 3-2: The supply chain network

Considering these ideas Christopher (2005) defines supply chain as: *"a network of connected and interdependent organisations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users".*

According to Schary & Skjott-Larsen (2003) there are six essential attributes of the supply chain:

- The supply chain is a complete process for providing goods and services to final users.
- Membership includes all parties, including logistics operations from initial material supplier to final user.
- The scope of supply chain operations includes procurement, production and distribution.
- Management extends across organizational boundaries to include planning and control over operations of other organizational units,
- A common information system accessible to all members makes coordination possible between organizations.

Member organizations achieve their own individual objectives through the performance of the supply chain as a whole.

3.2 *Product*

A definition of product is given by Armstrong & Kotler (2005): *"Anything that can be offered to a market for attention, acquisition, use, or consumption that might satisfy a want or need"*. But there are other definitions that can be found in the literature, for example, Ulrich & Eppinger (2003) defines it as: *"something sold by an enterprise to its customers"*. If we look into the Cambridge dictionary (http://dictionary.cambridge.org) it is said: *"something that is made to be sold, usually something that is produced by an industrial process or, less commonly, something that is grown or obtained through farming"*. All these definitions express the different products that can be found, from services or ideas to physical products.

3.2.1 Product classifications

There are different classifications of products in literature. The first group of classifications is made by the marketers and they are produced on the basis of consumer preferences and consumption behaviour. In this group of classifications is enclosed the one realised by Armstrong & Kotler (2005).

- **Consumer products**. These are products and services bought by final consumers for personal consumption. Consumer products include convenience products, shopping products, specialty products and unsought products (this further classification is based on how consumers go about buying them).

- **Industrial products**. These are those products purchased for further processing or for use in conducting a business. Thus, the distinction between a consumer product and an industrial product is based on the purpose for which the product is bought.

But there is other group of classifications that is more interesting for this thesis. There is a classification realised by Ulrich & Eppinger (2003) under the point of view of the product development that considers these different products:

- **Generic (market-pull) products**. The firm begins the process with a market opportunity and then uses whatever available technologies are required to satisfy that need. Process generally includes distinct planning, concept development, system-level design, testing and refinement, and production ramp-up phases (these phases will be described later on in this thesis). Examples of these products are sporting goods, furniture, tools…

- **Technology-push products**. Here the sequence is completely different; the team begins with a new technology and then finds an appropriate market for it. In this kind of product the technology "pushes" development. Here planning phase involves matching technology and market. Examples of these products are Gore-Tex rainwear and Tyvek envelopes.

- **Platform products**. These products will be built around a pre-existing technological subsystem, a technology platform. This platform has already demonstrated its

usefulness in meeting customers' needs; this utility is assumed by the concept development. Examples of these products are computers, printers, electronics...

- **Process intensive products**. Properties of these products are highly constrained by the production process, so that the product design cannot be separated, even at the concept phase, from the production process design. Product and process must be developed together from the start. The examples here include semiconductors, snack foods, breakfast cereals, chemicals...

- **Customized products**. These kinds of products are slight variations of standard configurations and are typically developed in response to a specific order by a customer. For these products, the generic process is augmented with a detailed description of the information-processing activities required within each of the phases. Typical customized products include switches, motors, batteries...

- **High-risk products**. Are those that involve unusually large uncertainties related to the technology or market so that there is substantial technical or market risk. Analysis and testing activities are placed as early as possible. Pharmaceutical or space systems products are good examples here.

- **Quick-build products**. Rapid modelling and prototyping enables many design-build-test cycles. Detail design and testing phases are repeated a number of times until the product is completed or time/budget runs out. The examples here include software and cellular phones.

- **Complex systems**. System must be decomposed into several subsystems and many components. Subsystems and components are developed by many teams working in parallel, followed by system integration and validation. Typical examples here are airplanes, jet engines, automobile...

3.3 *Packaging*

There are a lot of different definitions available in the literature for describing what is packaging but first of all the main functions of packaging gave by Jönson and Johnsson (2001) and expressed in figure 3-3 have to be shown.

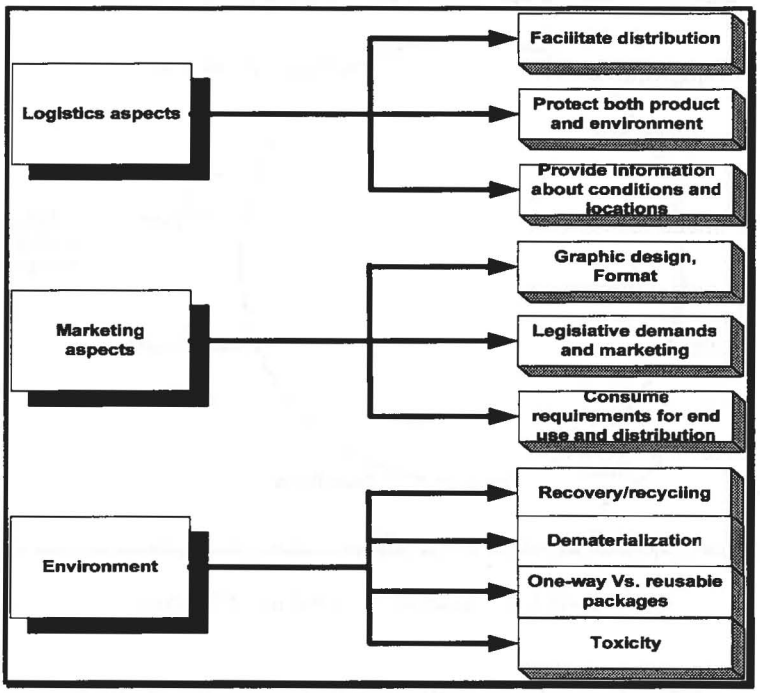


Figure 3-3: Overview of different packaging functions. Jönson and Johnsson (2001), page 25.

These three aspects will be treated somehow in all the cases. Even though depending on the particular cases there are some aspects more important than others. For example, the marketing aspects will be very important when the product is going to be used directly by the final consumer, but will not be as important in the other cases:

For covering all these aspects with a wide overview, several definitions have been explored and taken in consideration for each of it. Below are expressed some of them for better understanding every purpose.

Paine (1983) defines the packaging as *"a coordinated system of preparing goods for transport, distribution, storage, retailing and end-use, and a means of ensuring safe delivery to the ultimate consumer in sound condition at the minimum cost".*

The definition establishes the idea that the product has to be "prepared", that is, to do something to the product that facilitates the future manipulations. Here the packaging is considered as an extension of the product in the sense it provides additional features to the actual product to cover all the demands on "product performance" during parts of the product life cycle (Bramklev et al., 2005). Figure 3-4 illustrates it:

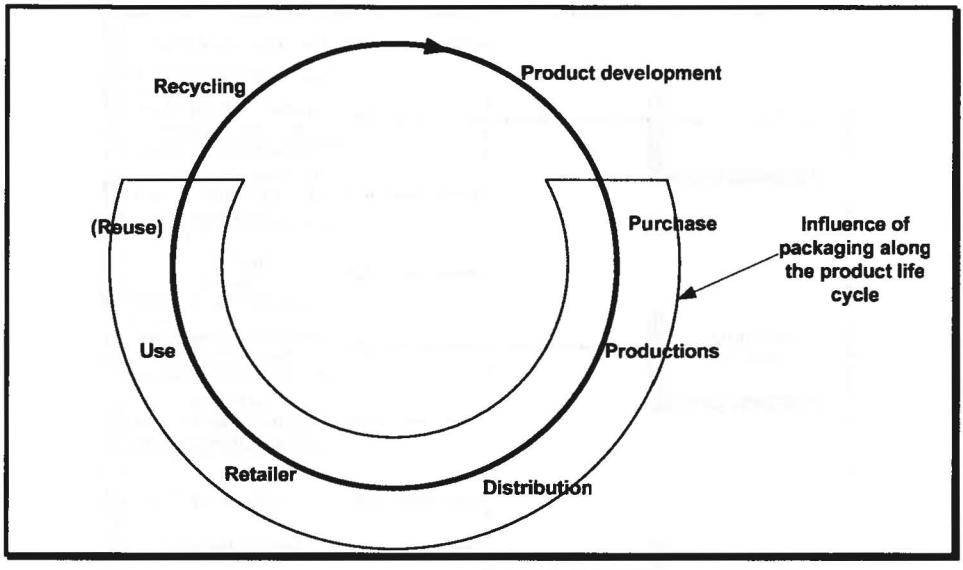


Figure 3-4: Packaging and the product life cycle

In this specific definition, the future manipulations concern the whole process of the supply chain, aspect that is of a great importance in this work. As well it is important to remark the cost of the packaging process. This process sometimes is seen as an inconvenient that just have to be done instead of a process of providing added value to the product; so the main goal should be the compromise of maximizing the added value and minimising the cost.

Other definitions give some different ideas of the concept of packaging and see it under an environmental point of view, such as the one gave by Bjärnemo, Jönson and Johnsson (2000) in which it is added the importance of the *"efficient reuse of the packaging or recovery and/or disposal of the packaging material at minimum cost"*.

Finally, there is another group of definitions of packaging that emphasize its importance in the marketing, as it is expressed by Armstrong & Kotler (2005), where they consider the packaging as the fifth P. As the packaging is considered as another part of the product, it will affect a lot of phases along the product life cycle and its importance on each part will depend on the different products that we will consider.

It is important as well to have crystal clear the difference between package and packaging. These two words are sometimes confused because they are strongly related. Bramklev et al. (2005) has defined the package as the physical object realising the packaging system objectives.

3.3.1 Packaging system

To talk about the packaging system is important to explain briefly the three different types of packaging as are expressed by Jönson and Johnsson (2001, pp. 19):

- **Primary or consumer packaging**. It is the package that holds the basic product and is in contact with it. It is the packaging that the consumer most often brings home.

- **Secondary or transport packaging**. Designed to facilitate handling, transport and storage of a number of primary packages in order to provide efficient production and distribution as well as prevent physical handling and transport damages. It can be taken home or used as a help for loading the shelves in the store. Opening of the transport package should be able without damaging the consumer package.

- **Tertiary packaging**. Designed to enclose several primary and secondary packages. It is not always necessary.

Once defined the packaging hierarchy, it is important for the explanation of what a packaging system is, to remark that, depending on which part of the supply chain is considered, the system can contain more or less levels of the hierarchy and also that sometimes is difficult to place a package in just one of the levels. These different levels and the interactions among them, make the packaging to be considered as a system. Thus, the performance of a packaging system depends on the way that each level of packaging acts and also the influences caused by the possible interactions between the levels.

The packaging system has a major impact on the efficiency of logistical activities as manufacturing, distribution and handling throughout supply chains (Johnsson 1998; Twede 1992). The use of packaging just utilized by a restricted number of companies, could add extra activities at other companies decreasing the final efficiency of the supply chain (Johnsson, 1998).

3.3.2 Packaging logistics

The traditional approach for the packaging was fairly different for the currently existing. It was considered on it that the main purpose of the package is to protect the product, and the package is not analyzed with a system approach but with just a technical one (Johnsson, 1998).

Nowadays there is a modern approach to package that differs in several things with the traditional approach. Nevertheless, it is an extension of the traditional approach rather than a completely new idea of what should be done on packaging.

With this modern approach the package is seen as an integrated part of the entire organization. The main idea is to see packaging in terms of the value that it provides in logistics rather than in terms of materials. The goal of the logistics process is to weave together and coordinate all activities involved in acquiring, converting, and distributing goods from raw material source to final consumer in order to accomplish the customer service objectives (Byrne & Markham, 1991). The packaging is a part of a total logistics system, and the goal is to minimize costs (packaging material, waste, delivery…) and maximize the possible benefits of it (handling, storage, branding…).

Once reached this point, it is important to define what it is understood by logistics. Logistics management is defined by the CSCMP (Council of Supply Chain Management Professionals, 2005) as:

"Logistics Management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and

related information between the point of origin and the point of consumption in order to meet customers' requirements." (http://cscmp.org/AboutCSCMP/Definitions/Definitions.asp)

Knowing what packaging and logistics are it is possible to provide an intuitive definition of what is meant with packaging logistics. In that definition should appear the idea of logistics, which is to *plan, implement and control* something between the point of origin and the point of consumption. In that definition should appear as well the main goal and concepts of packaging, which is to *prepare goods for transport, distribution, storage, retailing and end-use*. With this idea in mind Saghir (2002) defined packaging logistics as:

"The process of planning, implementing and controlling the coordinated packaging system of preparing goods for safe, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal and related information combined with maximizing consumer value, sales and hence profit".

But something else can be added to this definition, that is, to consider the packaging system a little bit before this. In this definition it is not considered the use of the package before the end of the production process, so the package is used for all the activities that follow this end of production. But there is another possibility that will be studied in this thesis, which is the inclusion of the package during the production or assembly activities.

Hence the definition will be modified to:

"...efficient and effective, **production or assembly**, *handling, transportation..."*

3.3.3 Packaging costs

It is not easy to determine the packaging costs, as it is very difficult to distinguish the costs regarding packaging from the other costs. The packaging generates costs (as well as saves!) along the whole logistical process, from the product/package development to the final use.

In the frame of this thesis the system for assessing costs that is going to be used is the Activity-based costing (ABC). This system receives its name because of the focus on the activities performed in the realization of a product. Costs are traced from activities to products, based on each product's consumption of such activities. It differs from conventional costing system in the fact that conventional systems assume that each unit of a product consumes resources while in ABC the products or services does not consume resources, but activities. Another difference is that conventional systems are based on unit-level cost drivers of the product that are directly proportional to the number of units produced. While an ABC system uses cost drivers that can be at the unit-level, batch-level and/or product-level. (Cooper, 1990; Huang, 1996; Turney, 1991). Figure 3-5 describes the sequence to follow for the use of an ABC model in design:

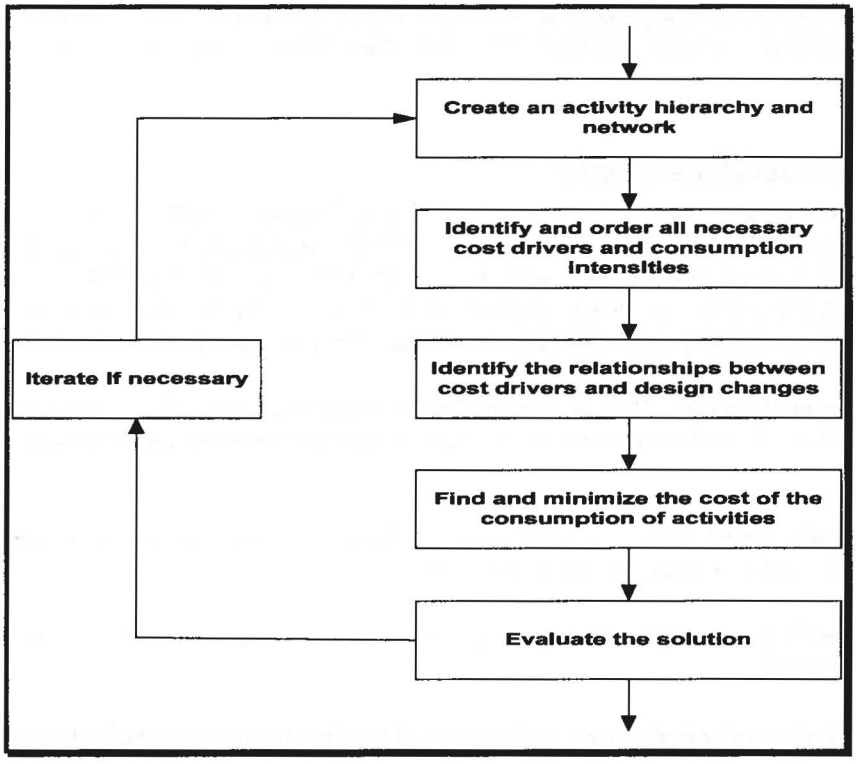


Figure 3-5: Flowchart for development of ABC models for usage in design. Huang, 1996, page 403.

If the packaging logistics concepts are considered, the indirect costs are as important as the direct ones, because a simple variation in the package will affect the costs along the whole supply chain.

The final product can be considered as a combination of a core product and additional services that support it. With this view, the packaging is considered as an external service that adds value to the product or that increases its costs. But there is another perspective in which the packaging system is considered as an integrated part of the product, that is, as another component of it or as another product itself.

Whichever perspective is considered is of great relevance the design of the packaging system when is intended to save money in the different processes. If the package is slightly larger or heavier than necessary, costs appearing during distribution activities will be higher than necessary (Bakker, 1997); i.e. small reduction in package weight or size will increase the number of packages on a lorry that implies a less amount of lorries needed and therefore a less environmental impact.

There is something important that always have to be on mind when a packaging system is designed: *"packaging shall save more than it cost"*, this statement was often quoted by Ruben Rausing, the founder of Tetra Pak. Jönson (1982) showed in her study that packaging cost for a food product can range from 2% to 25%. These kinds of statements have made some people draw the conclusion that elimination of packaging will reduce costs and subsequently lower product prices. However, then the risk of total or partial loss of the

product is not recognised (Jönson & Johnsson, 2001). Losses may occur because of transport damages (54%), humidity damages (21%) and other failures during distribution (25%) (Lox, 1992).

3.4 *Product development*

Product development has been defined by Ulrich & Eppinger (2003) as *"the set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product"*. As expressed as well by Ulrich & Eppinger (2003), *"the goal of product development is to create products that can be produced and sold profitably"*. Five dimensions are used by them to evaluate a product development effort:

- **Product quality**. Here is judged if the product is reliable, if it satisfies the customer needs... It will be reflected in the market share and the price customers are disposed to pay.

- **Product cost**. This cost determines the benefit acquired by the firm for a particular sales volume and a particular sales price.

- **Development time**. Here it is considered how quickly the product development is completed.

- **Development cost**. How much was spent by the company to develop the product.

- **Development capability**. Here is evaluated if the experience acquired by a company along the product development process will help them to develop future products. The company will be able to develop products more effectively and economically in the future.

These five dimensions are going to be used as the principal parameters to find and evaluate the attainment of the purpose in this thesis that is to find and evaluate the potentials achieved by the concurrent development. These variables will be discussed and treated in depth in the conclusions of the cases and the cross-case conclusions

Alternatively, Roozenburg & Eekels (1995) enclosed the product development inside a bigger process, the industrial innovation process (see figure 3-6). This process covers all the activities considered before the adoption of a new product: basic and applied research, design and development, market research, marketing planning, production, distribution, sales and after sales service. In this theory it is considered that marketing department has to define the properties of the new product and designers just have to make that "dreams" became true.

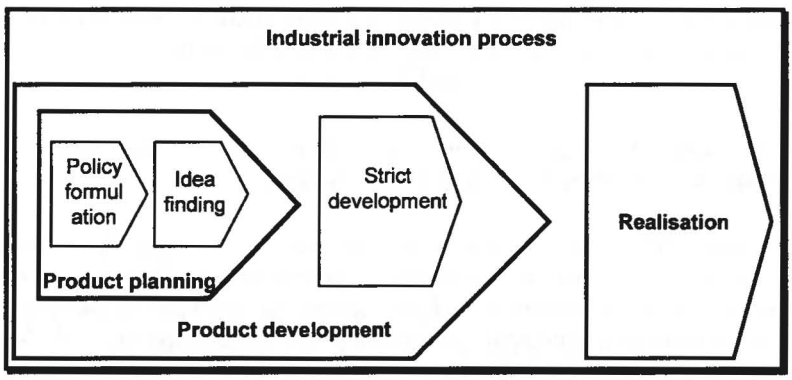


Figure 3-6: The industrial innovation process according to Roozenburg & Eekels (1995)

In the book by Andreasen & Hein (1987), some influential factors during product development are commented. When companies grow there are some departments became more specialized to increase their level of competence, but at the same time it means that a development project will move round from one department to another. When the designer determines the product's function, is badly exploited. This lack of communication is also remarked by Barba (2005) when talking about the problems in a concurrent development of a product. As well it is important to notice that the first phases of a product development have to be very careful and analysed because the bigger amount of money spent is usually in that initial phases.

3.4.1 Product development process for mechanical products

A generic product development process as expressed by Ulrich & Eppinger (2003) can be considered as: *"the sequence of steps or activities which an enterprise employs to conceive, design, and commercialize a product. Many of these activities are intellectual and organizational rather than physical. Some organizations define and follow a precise and detailed development process, while others may not even be able to describe their processes."*

There are some reasons gave by Ulrich & Eppinger that express the usefulness of having a well-defined development process:

- **Quality assurance.** A development process specifies the phases a development project will pass through and the check points along the way. When these phases are chosen wisely, following the development process is one way of assuring the quality of the resulting product.

- **Coordination.** A clearly articulated development process acts as a master plan which defines the roles of each of the players on the development team.

- **Planning.** A development process contains natural milestones corresponding to the completion of each phase. The timing of these milestones anchors the schedule of the overall development project.

- **Management.** A development process is a benchmark for assessing the performance of an ongoing development effort. By comparing the actual events to the established process, a manager can identify possible problem areas.

- **Improvement.** The careful documentation of an organization's development process often helps to identify opportunities for improvement.

Ulrich & Eppinger (2003) also expressed another way of thinking about the development process as: *"the initial creation of a wide set of alternative product concepts and then the subsequent narrowing of alternatives and increasing specification of the product until the product can be reliably and repeatedly produced by the production system*". This process is formed by six phases that are shown in figure 3-7:

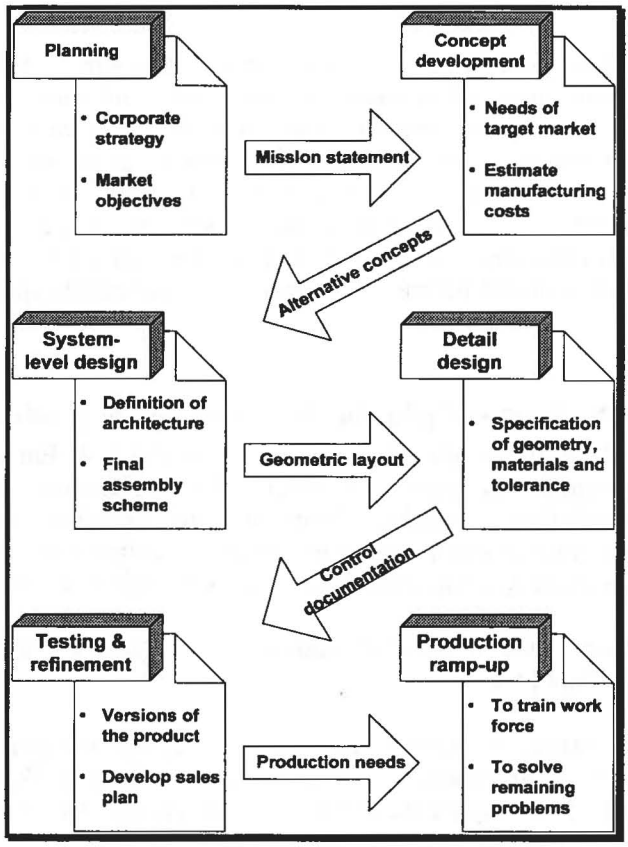


Figure 3-7: The generic product development process modified from the one by Ulrich & Eppinger (2003)

- **Planning**. This phase begins with corporate strategy and includes assessment of technology developments and market objectives. The output of this phase is the project mission statement, which specifies the target market for the product, business goals, key assumptions and constraints.

- **Concept development**. The needs of the target market are identified, alternative concepts are generated and evaluated and one or more concepts are selected for further development and testing. A concept is a description of the form, functions and features of a product and usually goes together with some specifications. Some costs are estimated and production feasibility is evaluated.

- **System-level design**. Includes the definition of the product architecture and the division of the product into subsystems and components. The final assembly scheme for the production system is usually defined during this phase as well. This phase usually ends with a geometric layout of the product, a functional specification of each of the product's subsystem and a preliminary explanation of the final assembly process.

- **Detail design**. Includes the complete specification of the geometry, materials and tolerances of all of the unique parts in the product and the identification of all the standard parts to be purchased from suppliers. The output of this phase is the control documentation for the product (computer files describing each part of the product with all the specifications).

- **Testing and refinement**. Involves the construction and evaluation of multiple preproduction versions of the product. Early prototypes (alpha) are usually built with production-intent parts. These prototypes are tested to determine whether the product will work as designed and whether the product satisfies the key customer needs. Later prototypes (beta) will answer questions about performance and reliability. A sales plan is also developed here. Here the output is the needs for production.

- **Production ramp-up**. The product is made using the intended production system. The purpose of this phase is to train the work force and to work out any remaining problems in the production processes. Products produced in that phase are sometimes supplied to preferred customers and are carefully evaluated to identify any remaining flaws.

This development project as expressed by Ulrich & Eppinger (2003) is generic and most like the process used in a market-pull situation (the most common in industry). For other kind of products: technology-push, platform, customized... several variants are introduced.

3.4.2 Packaging development process

As stated before in the packaging description, the packaging can be considered as a product, and that is the way it will be treated here: a product with a specific development process. It is extremely hard to find references in the literature about the packaging development process. In the past it was considered, according to Hine (1995) that the development of the packaging was often done separately from other design activities. Nowadays there is another tendency based on some significant sources that stress that the integration of product and packaging development would be beneficial for both activities (Esse, 1989; Harckham, 1989; Kooijman, 1995; Paine, 1991; ten Klooster, 2002).

Jönson (2001) provides some key factors that influence in the technical development of packaging materials and packaging system:

- **Production flexibility and efficiency**, everything changes really fast so the packaging systems should be designed taking in consideration that these quick changes can make products obsolete.

- **Distribution development**, as is expected that good transports will increase in the next years, is important to take the distribution system into consideration. This increment of transports will create serious problems in the delivery times. The packaging design can provide new and efficient solutions to this problem.

- **Environmental responsibility**, this one is very close related to the previous. As transport is acquiring increasing importance, the challenge is how to reduce transport pressure on the environment. Packaging modularisation would have much a greater impact on transport emissions than clean engines, eco driving and new fuels.

- **Life style changes**, new generations are willing to adopt new environmental issues in the products but they will not accept limitations on the products.

- **Technology development**, the advance in the new technologies will provide a wide range of possibilities when designing the packaging system and choosing the packaging materials.

The packaging development process is also treated by De Maria (2000). In this text book, the different phases of this process are considered as expressed in figure 3-8.

Of course packaging projects can vary a lot in complexity; while some projects will be very simple others will demand a lot of planning and testing and may take more than two years. It does not mean that the packaging has not to be studied in simple cases, even in these cases previous study could report benefits in costs and lead times. But the packaging of a product with technological devices that are usually more sensitive has to consider more aspects than the packaging for pencils. So this process should be considered as a general guide for the packaging development giving more importance to different aspects depending on every particular project.

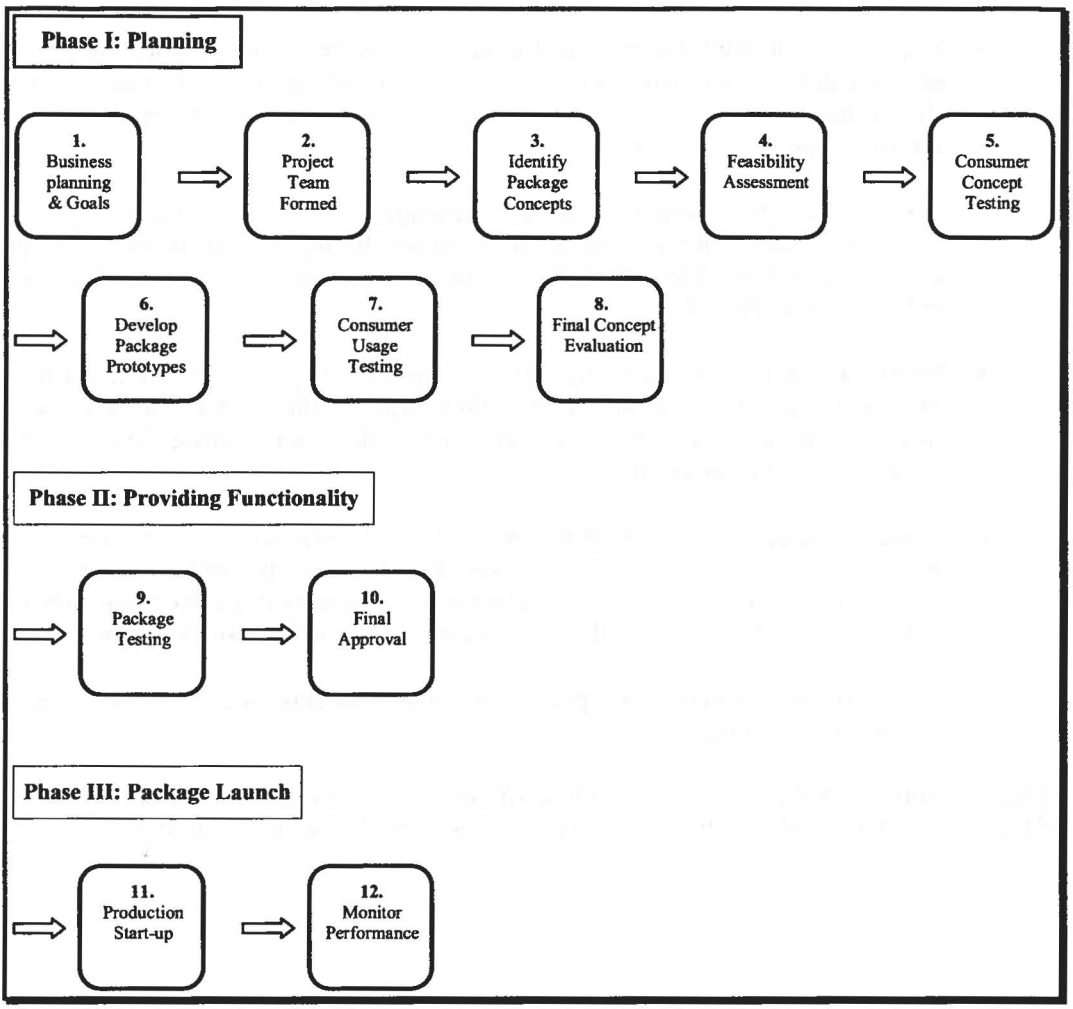


Figure 3-8: Packaging development process. De Maria (2000), page X.

3.4.3 Integrated product development

The integrated product development (IPD) is defined by Andreasen and Hein (1987) as: *"an idealised model for product development, which is integrated in terms of creation of market, product and production, and which clarifies integration between project and management, including the need for continual product planning. Product development should be integrated with other development activities, and contribute to renewal and adaptation within the company"*. This procedure model as expressed here is an evolution of a document appeared in Professor F. Olsson's doctoral thesis (Olsson, 1976), denoted the Product Origination Process. In 1982 this model was revised and renamed by Olsson, Andreasen, Moller and Hein, and two years later, a paper presented this new procedure model under the name Integrated Product Development (Hein et al, 1984).

The IPD is divided into five different phases by Andreasen and Hein (1987). These phases are:

- Investigation of need. Basically is a marketing task that consists in identifying the need and deciding the transformation which will meet that need. The output of this phase (and consequently the input of the next phase) is a perceived need, defined by a product type and process type.

- Product principle. Definition of the principles behind the product and its composition then make it possible to determine the type of production technique which is to be used. The output of this phase is a clarification of the product's use and its general principles.

- Product design. Detailed definition of the product. It is important that these details of the product are chosen to suit a technology which matches the expected market volume or the selected strategy for volume adaptation. In this phase the output is a demonstration that the product works.

- Product preparation. The goal of this phase is to demonstrate that the product can be produced. Once the production system has been established, the necessary demonstration can be performed by means of a preliminary production run. Here the output is the demonstration of the produced product with the desired quality.

- Realisation. The content of this phase is ongoing production and sales. The output is the proof that the product can be sold.

There is another initial and very important phase that is the recognition of the need, without this phase nothing could be carried out. All these phases are showed in the figure 3-9:

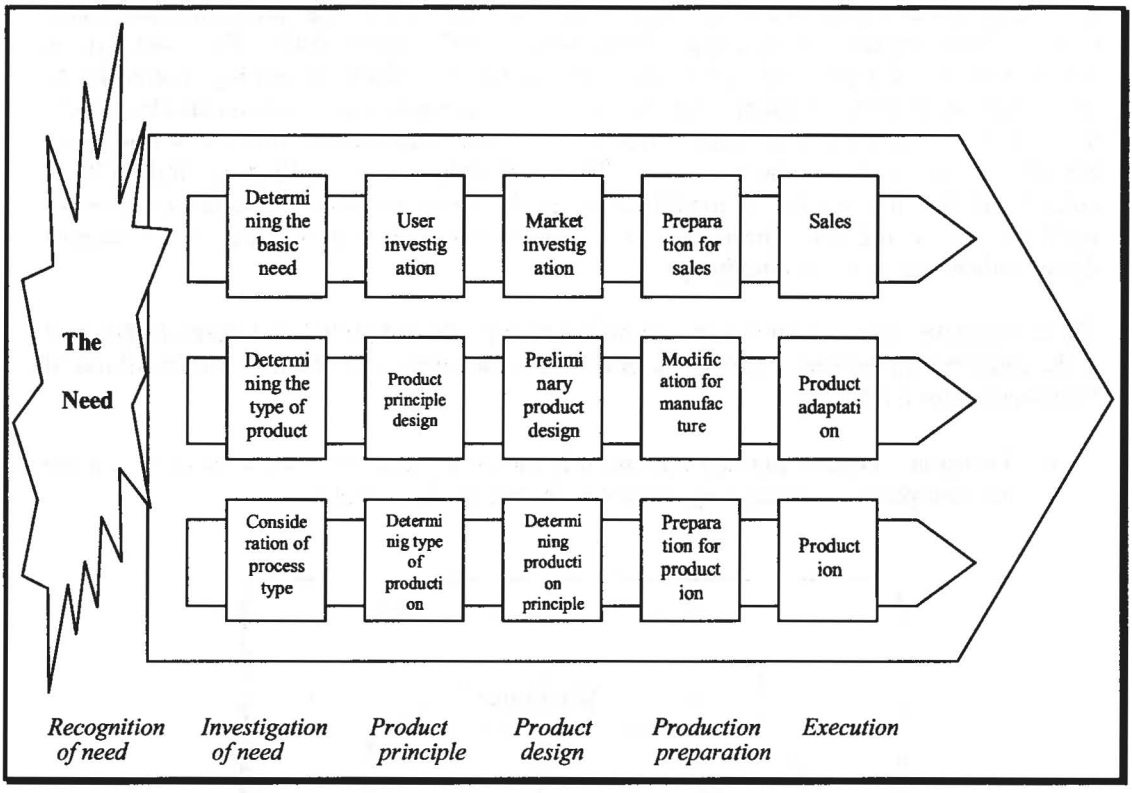


Figure 3-9: Integrated Product Development. Andreasen & Hein (1987), page 27

3.4.4 Concurrent engineering

The basis of concurrent engineering (CE) were first settled during the 80's (Prasad, 1997; Capuz, 1999), but was not until 1988 when the Institute for Defence Analyses (IDA) first used this term and defined CE as: *"a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support . This approach is intended to cause the developers, from the outset, to consider all elements of the product life-cycle from conception through disposal, including quality, cost, schedule and user requirements"*. (Winner et al, 1988). It is also considered that the primary goal of CE has always been the minimization of costs over the complete life cycle of a system while maximizing its quality and performance (Huang, 1996; Winner et al, 1988).

There is another definition formulated by Barba (2001): *"CE consists in the coordination and integration of the different development activities that come up in the company when dividing the processes of design and manufacturing in a new product"*

Some authors instead this term of *concurrent engineering* use *simultaneous engineering* for referring the same concepts. The adjective "concurrent" is mainly used in the bibliography from USA and Great Britain, while "simultaneous" is preferred by the European authors (Prasad, 1997; Capuz, 1999; Barba, 2005). In any case, it is important to remark that both terms can be considered as synonymous.

The CE produces a reduction of the time to market, what results in a competitive advantage (Huang, 1996; Prasad, 1997; Capuz, 1999; Jarvis, 2003; Barba, 2005). This reduction is essential for the new products as nowadays life-cycles of products are getting shorter due to the globalization of the economy and the consequent increase of competition (Barba, 2005). These authors express as well other benefits of CE, like reduction of *costs* and a significant improve in the *quality* of the processes. The *costs* reduction is justified by Barba (2005) considering that the number of modifications in the advanced phases (the most expensive modifications) is reduced. Prasad (1997) says that now *quality* is inherent in the product design rather than being an afterthought.

There is another characteristic of the CE highlighted by Prasad (1997) and Barba (2005) that is the coordination between customer, suppliers and subcontractors. There two possibilities of coordination for the CE:

- **Two-phase contractual agreement**. It is shown in figure 3-11. Manufacturers engage in a two-phase contractual agreement with their trading partners.

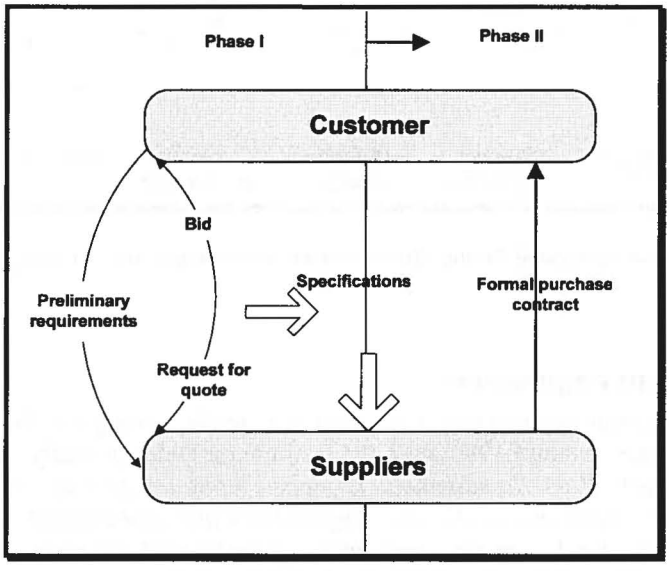


Figure 3-10: Two-phase contractual agreement. Prasad (1997), page 179

- **Partnership and Mutual Learning**. This alternative includes subcontractors and suppliers as partners from the beginning. It is shown in figure 3-12.

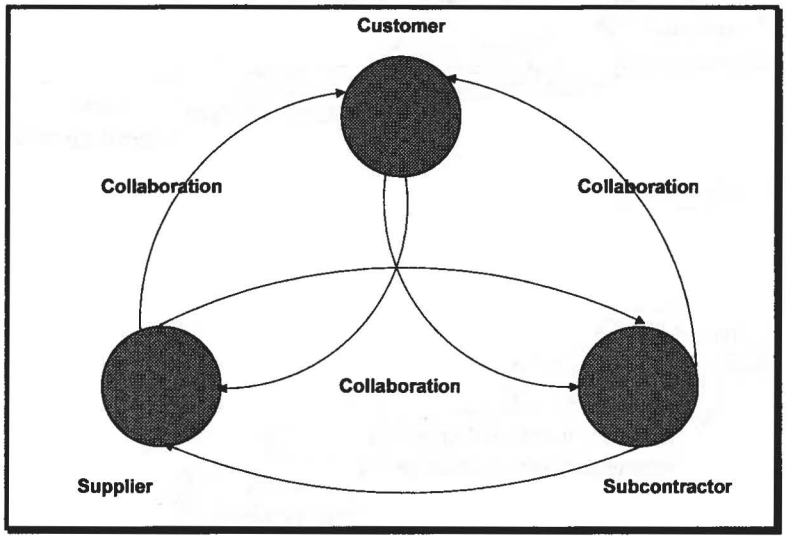


Figure 3-11: Partnership & mutual learning. Prasad(1997), page 179

The study carried out by Clark and Fujimoto (1991), demonstrate that the studied companies (Japanese companies from the automobile industry) developed new products faster than their competitors due to the "close connection" between product engineering and production engineering (Barba, 2001).

There is another study performed by Takeuchi and Nonaka (1986), where interdisciplinary teams with a high degree of simultaneity are described as the best organization for developing new products. It is expressed by them that to act concurrently reduces the development time of the product with the advantage that the product should be easier to manufacture. They as well named a team that develops sequential activities as "relay race" team, while concurrent teams are named as "rugby teams. These two definitions are explained in figure 3-13.

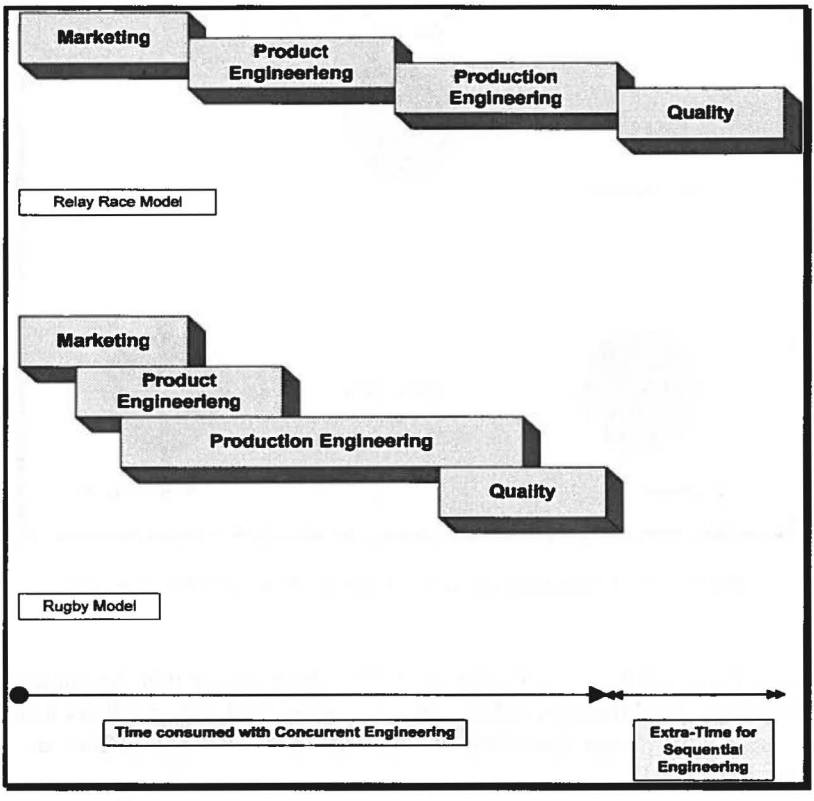


Figure 3-12: Time reduction for CE. Barba (2001), page 57.

This concurrent engineering promoted for all this authors, has a very important clue that is remarked for all of them (Prasad, 1997; Capuz, 1999; Barba, 2005) that is the flow of information among all the different departments of the company that want to run concurrently. This information has to be fluent and transparent, if not the chances of a successful concurrent development process are null.

Cross functional teams

A Cross-Functional Team is composed of people with varied levels of skills and experience brought together to accomplish a task. As the name implies, Cross-Functional Team members come from different organizational units Functional Teams may be permanent or ad hoc (www.humtech.com/opm/grtl/ols/ols3.cfm).

Cross-functional teams offer a range of benefits that may not be so readily attainable with a less-structured group of individual specialists. Cross-functional teams are particularly useful for both generating and implementing new ideas (Jann, 2004)

The organization of teams in product development is a very common activity. Two classic organization structures are *functional organization*, where the organizational links are primarily among those who perform similar functions and *project organization*, where the links are among those working on the same project. Later on the matrix organization was conceived. In matrix organizations, individuals are linked to others according to both the project they work on and their function. Two variants of this matrix were developed:

heavyweight project organization and *lightweight project organization.* A heavyweight project organization has contains strong project links. The project manager has here complete budget authority and is heavily involved in performance evaluation of the team members. Although each participant in a project also belongs to a functional organization, the functional managers have relatively little authority and control. This kind of team is also called *integrated product team* and *product development team.* A lightweight project organization contains weaker project links and relatively stronger functional links. (Ulrich & Eppinger, 2003). These four product development organizations are shown on figure 3-14:

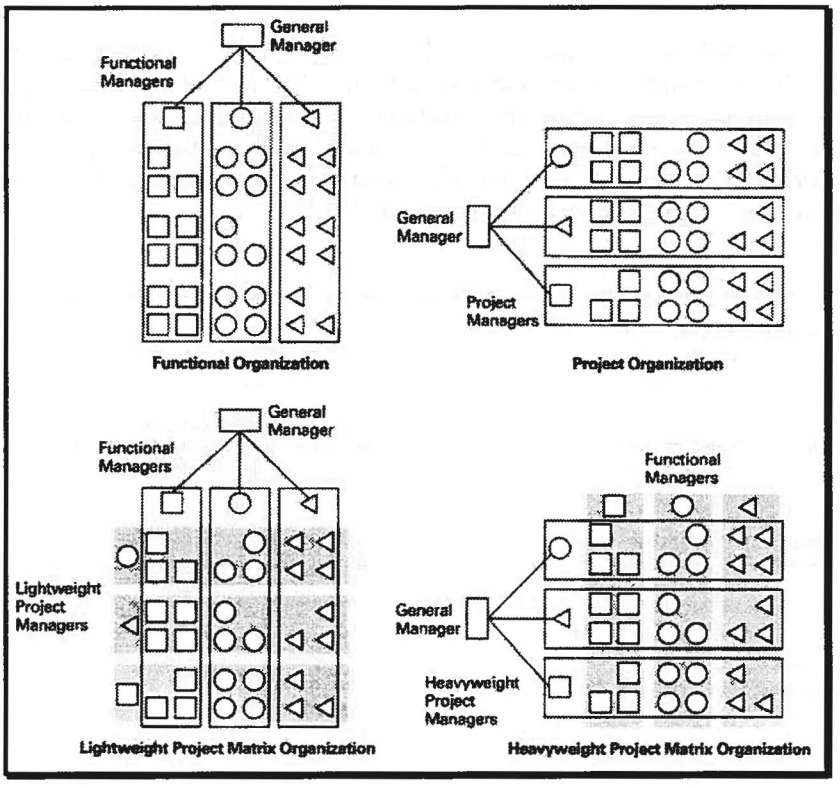


Figure 3-13: Various product development organizations. Ulrich & Eppinger (2003), page 27

In all project organizations, the employees typically have two managers, one project manager and one functional manager, but the reality is that either the project or the function tends to have stronger links. In the heavyweight project matrix organization it is typically the other way around. The links between individuals do not solely depend on the formal project organization but also on informal links as the physical layout (sharing the same office, floor, building, or site). The organizational trend in trying to implement product development concepts as concurrent engineering and Integrated Product Development is to work in cross-functional teams (Klevas, 2004). Ulrich & Eppinger (2003) claimed that one reason for new product development failure might be lack of cross-functional representation in the project team. Wheelwright & Clark (1992) argued that the most promising organizational structure for managing product development is the heavyweight project team. The reason for this is that this kind of teams, if managed properly, has the best opportunity to improve communications,

stronger identification with, and commitment to, a project, and a focus on cross-functional problem solving.

3.4.5 Design for X

There is another important benefit of the CE; many X-ability aspects of product development are built into the product (Prasad, 1997; Capuz, 1999; Barba, 2005). Design for X is one of the most effective approaches to implementing CE (Huang, 1996). According to Huang (1996), the "X" includes performance measurement of product life cycle aspects, and "design" stands for design to ease the "X".

In the "X" can be included manufacturing and assembly (DFMA) for example. Traditionally, the idea was that a competitive designer should be familiar with manufacturing processes to avoid unnecessary costs. But the complex technology incorporated with many products and the sophistication of manufacturing techniques make this view of the product development process invalid. One way of achieving this idea is making manufacturing engineers to be part of a concurrent engineering design team. (Huang, 1996).

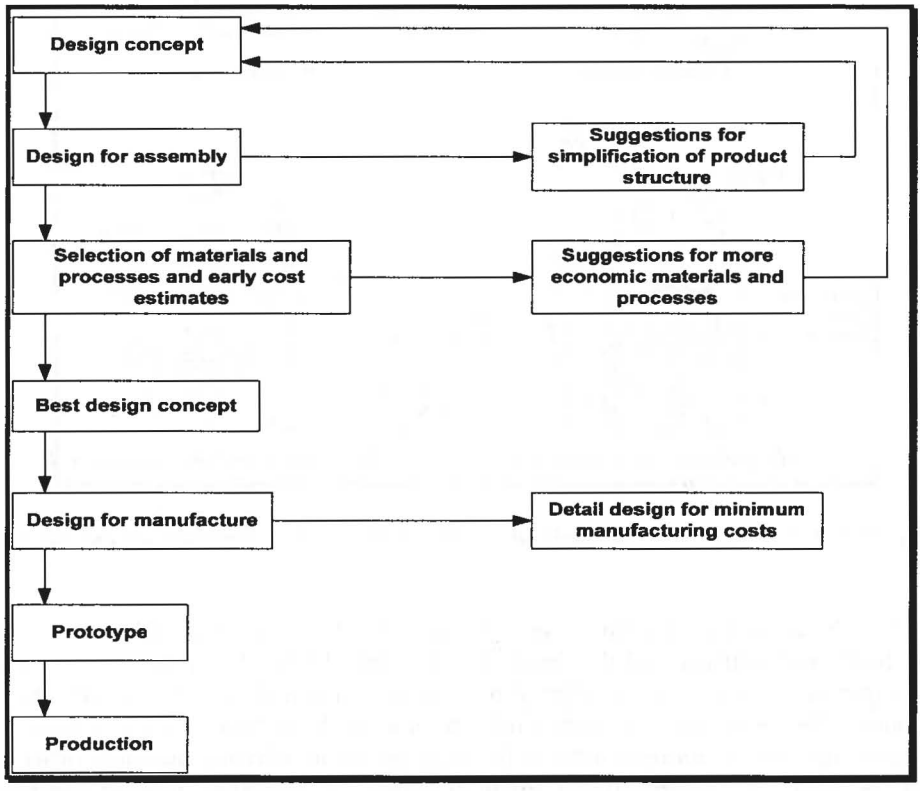


Figure 3-14: Typical steps taken in a concurrent engineering study using DFMA. Huang, 1996, page 20.

Packaging can be as well considered when designing a new product. Nowadays, the computer technology that enables aerospace engineers to design and test aircraft wings has moved into the field of packaging. Package designers today can render three-dimensional, rotary drawings

of thermoformed trays and other containers and subject them to the hard knocks that often reveal structural inadequacies. When the design and engineering team members are confident that the customer's requirements have been met, they can whip their design off through a modem for immediate review and approval. This electronic design makes also possible a fluent communication between customers and designers. (Erickson, 1999).

There is another design considered as well by Huang (1996) that is important for this thesis that is de design for life cycle. CE represents a common sense approach to product realization in which all elements of the product life-cycle from conception through manufacturing to disposal are integrated into a single continuous feedback-driven design process. The growing importance of including environmental issues in design has amplified the impetus for companies to more formally consider the entire life-cycle of a product, from cradle to grave or even to "reincarnation" through recycling and reuse. "Demanufacture" is the process opposite to manufacturing involved in recycling materials and product components after a product has been taken back by a company. (Huang, 1996). Figure 3-16 illustrates an optimum product design procedure. In usual product design and product optimization, the third step, the formulation of an optimization problem and solving the problem, receives the most attention. However, steps one and two are essential for obtaining the most satisfactory design solutions.

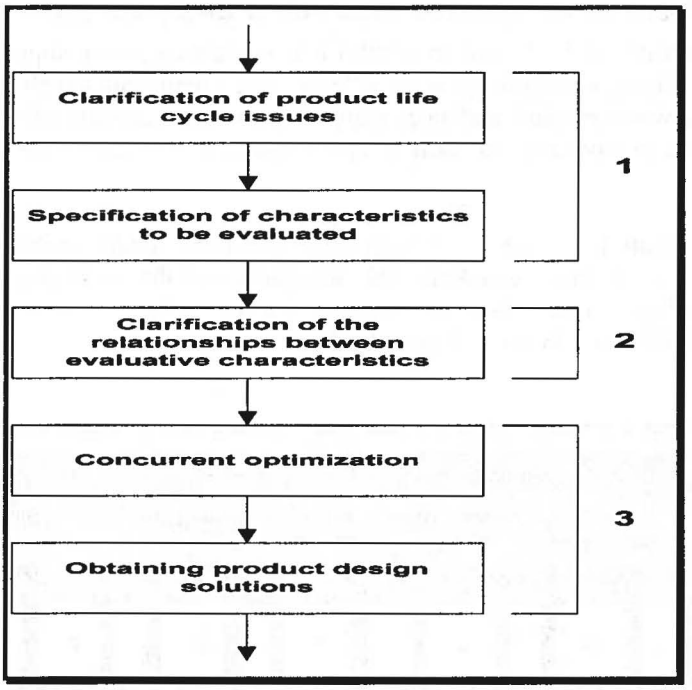


Figure 3-15: Flowchart of optimum design for product life cycle issues. Huang (1996), page 425.

3.4.6 Material Requirement Planning (MRP)

MRP is a system for effectively managing material requirements in a manufacturing process. Information systems have long been an important part of the manufacturing environment. In the 1960s, manufacturers developed Material Requirements Planning (MRP). According to

the American Production and Inventory Control Society, Inc. (APICS), MRP is a set of techniques that uses bill of material data, inventory data, and the master production schedule to calculate requirements for materials. It makes recommendations to reorder materials. Furthermore, because it is time-phased, it makes recommendations to reschedule open orders when due dates and need dates are not in phase. Time-phased MRP begins with the items listed on the Master Production Schedule and determines the quantity of all components and materials required to fabricate those items and the date that the components and material are required. Time-phased MRP is accomplished by exploding the bill of material, adjusting for inventory quantities on hand or on order and offsetting the net requirements by the appropriate lead times. Running a report from MRP begins with an estimate of what products will be required in the next time period (an arbitrary length of time, often but not always one week), taken from the master production schedule. The MRP software calculates the times required to manufacture the products, using the factory's estimated time to assemble each product. Then, the system explodes the product into lists of parts required; using the bills of materials (a Bill of Materials describes a product in terms of its assemblies, sub-assemblies and basic parts) developed by the engineering department. The parts are ordered at times back-dated from the dates of assembly and the relevant paperwork is generated (http://computing-dictionary.thefreedictionary.com/Material%20Requirements%20Planning)

3.5 *Concurrent development of product and packaging*

In the survey carried out by Bramklev (2004) it is revealed a strong support for integrating product and packaging development especially in those companies which find a potential in the interplay between product and packaging to meet the demands of the customer in a product life cycle perspective, but also to those who strive to reduce packaging-dependent costs.

Taking into account the product development procedure model created by Ulrich and Eppinger (2003), a variation considering the introduction of the packaging development into the product development activities, and based on the survey before mentioned, is created by Bramklev et al (2005) and shown in figure 3-17:

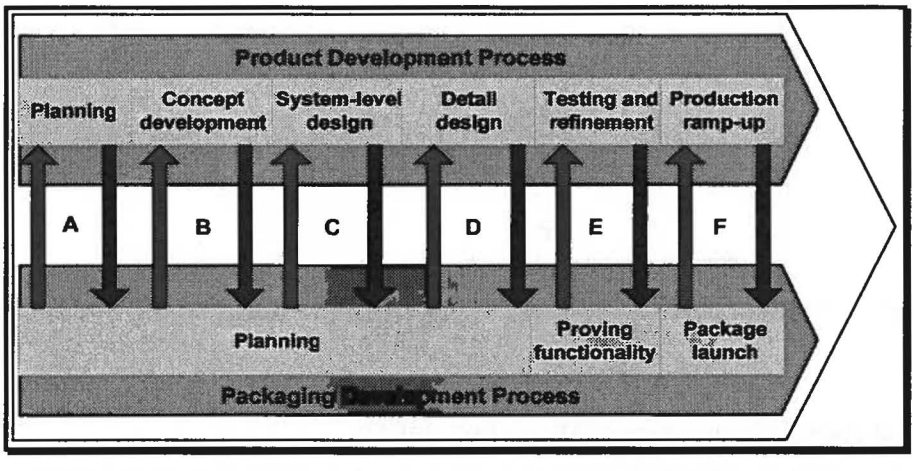


Figure 3-16: The proposal for an integrated product and packaging development. Bramklev et al (2005)

A- co-ordination of product planning and packaging planning
The packaging strategy should be established during this phase and included in a separate or combined (together with the product) mission statement(s). The survey results also indicate that the majority of projects are prioritised on the basis of expected yield and market potential; it is recommended to provide a technique for the integrated evaluation of packaging influences on expected product yield and product market potential

B- co-ordination of concept development and packaging planning
Packaging and product should be simultaneously specified (target specifications). When packaging development sequentially assesses feasibility of packaging, this constitutes valuable information for the generation of product concepts and selection of product concept. When the product concept is chosen, it is important that this information is passed on to the packaging development, so that the steps for consumer concept testing, development of package prototype and consumer usage testing may be coordinated with the test of product concepts.

Considerations should be taken regarding the possibility to decompose product functions and thereby simplify the product by allowing the packaging to assume "supportive" functions. The "supportive" functions can be identified by carefully studying the product life cycle.

C- co-ordination of system level design and packaging planning
The product and packaging architecture (layout) are established within this phase. For both product and packaging the concepts of platform, modularity and integral architecture are to be considered. For the functional specification of each product subsystem, one must decide the corresponding geometric layouts of the packaging as well as the packaging materials.

Secondary and tertiary packaging are especially emphasised in order to provide efficient and effective product development.

D- co-ordination of detail design and packaging planning
It is important that the marketing function fulfils the regulations and restrictions on product and packaging, to secure the protection and safety of the product. It is also important that marketing calculates those costs that are associated with the packaging and the launch of the product. Concurrently production should optimise the product and packaging features to minimise failures. Here the primary packaging is especially emphasised.

E- co-ordination of testing and refinement and proving functionality
For the coordination of these two phases, information valuable for the establishment of test plan should be shared between product development and packaging development, which may ensure that every detail has been tested, thus contributing to the final choice of concepts (product and packaging).

To support testing and refinement, methods and techniques for the evaluation of reliability and durability should be developed. It is important that regulatory approvals are guaranteed not only for the product design or packaging design, but also for the interaction of product and packaging.

F- co-ordination of production ramp-up and package launch

Product development should provide results from test production to packaging development in order to make decisions regarding purchase of packaging materials and/or installation of additional equipment explicit. In turn, packaging development should provide results of test manufacturing to product development so that decisions regarding how well the package performs technically are established.

It is also important in this phase to identify and correct any remaining problems associated with packaging production facilities.

It is important to note that the true integration occurs at the operational working level. Based on the list of activities presented above, methods and techniques can be found in the literature supporting these tasks at least regarding the design and development of the product (Bramklev et al, 2005).

3.6 *Point of departure*

This chapter of the thesis is intended to express which parts of the frame of reference are going to be used during the interviews and also in the analysis of the companies. In other words everything has been discussed before is summarised here.

- **Product life cycle.** All the phases except use and retailer are going to be treated here. Making special emphasis in the product development and the distribution, but also discussing the other activities considered in the product life cycle.

- **Products.** A product is "*something that is made to be sold, usually something that is produced by an industrial process...*" (http://dictionary.cambridge.org), and this is what is going to be considered as a product in this thesis. The kinds of products that are going to be considered are mainly *consumer products*, at least the final products produced by the companies are. But as suppliers are also considered here, some *industrial products* will be treated. All of them will be *generic products* with a brief touch of customizing in some specific aspects.

- **Packaging.** It is going to be considered as another product. Primary secondary and tertiary packaging will be considered even though sometimes is difficult to understand where does one ends and the other one begins.

- **Product development.** Mainly the product development expressed by Ulrich & Eppinger is going to be considered. All the phases treated there are going to be the support for the questions regarding product development during the interviews. But also CE is going to be very important to try to understand the way companies develop products. The integration among the different activities of the company and sometimes also among their suppliers. DFX will as well an important point of departure for the questions related with the designing phases of the product development.

- **Concurrent development of product and packaging.** Finally, but probably the most important reference for this thesis, comes the model proposed by Bramklev et al (2005). This model will be the basis, and the knowledge of its implantation in industry is one of the most important goals of the thesis.

4 CONDUCTING THE CASE STUDY

As it has been introduced in the methodology chapter, this research project has been carried out through several cases study. For each one of the cases, both qualitative and quantitative data has been collected by means of interviews, observations and document analysis. The data has been gathered during several meetings, web mail and phone calls with the companies. In this way, the analysis of the first data collected supplied the necessary basis for the following data looked for and so on.

The description of every case is structured as follows:

- A brief company introduction
- Product, packaging and production/assembly description
- Distribution process description
- Development procedure model description
- Conclusions for the case: potentials and integration between product and packaging

The purpose of this research study was established as: *"To examine and evaluate the advantages achieved through concurrent product and packaging development on an operational level in industry".*

To guide the investigation and fulfil the purpose two general research questions were formulated. These general questions together with the consequent supportive ones (introduced in the methodology chapter as well), have constitute the basis for the collection of data. The two general research questions are:

1. *What are the advantages for the companies to integrate product and packaging development?*

2. *How integrated product and packaging development should be implemented?*

Because of these two focuses that the study holds, the data and the results obtained for the individual cases are divided into two important parts. First one regards to the advantages or potentials found out within the analyzed case. These potentials are presented connecting to the previously proposed expected advantages. The second conclusion part refers to the procedure model for the development of products applied within each company connected to the *Ulrich & Eppinger* procedure model.

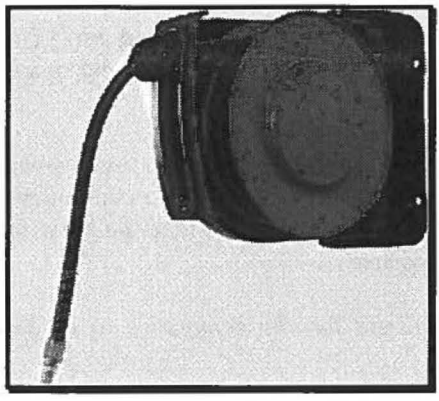
4.1 *Nederman Case*

4.1.1 Company introduction: Nederman

Nederman is one of the leading global suppliers of products, customer solutions and services in the business of fume extraction, high vacuum cleaning systems and retractable reels. The company, founded in 1944, has grown from a small and local metal workshop into a global organisation with own sales companies and distributors around the world. The Nederman Group sales in 2003 amounted to MSEK 735 (app. 79 million €). The company has 485 employees of which 150 in Sweden. The Nederman Group is owned by EQT. (http://www.nederman.com/fact.html).

There was no real knowledge of the case situation it was going to be faced when first meeting this company. It was, besides, the first case to analyze. After that first encounter, Nederman procedure for developing products was believed to situate somewhere between a total and no integration. With these conditions following data was looked for.

4.1.2 Product description: Hose reel ser. 882

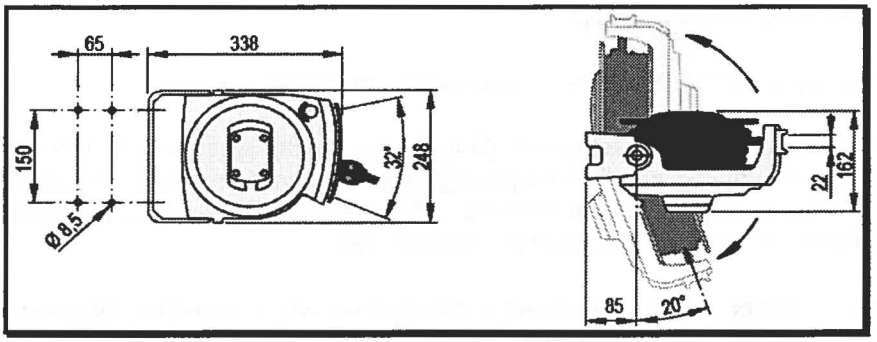


Picture 4-1: Hose Reel ser. 882 by Nederman

Packaging is considered as another part of the product. Nederman takes into account when developing the product, not just the packaging of the final product but the different packaging systems for the different components that forms the product. In this way, it becomes important to analyze the potentials of developing the different components together with their own packaging and the impact of this procedure into the global process, that is, the interface between everything that happens to the product during the product life cycle.

The problems that can appear in this process can be related with problems of the products that are supplied to them or with other difficulties appeared during the distribution or the installation processes. As in Nederman they do not produce but they assembly, they keep a constant interaction with their suppliers in order to get together good solutions. This special characteristic makes that when a "redesign" is needed because there is a problem or because

they are inefficient in the processes, their suppliers have to change some aspects of their products to satisfy the new specifications of Nederman.



Picture 4-2: Product dimensions

4.1.2.1 Components and assemble process description

Housing in EPS package

Picture 4-3: Housing and EPS package in the mounting line

Plastic device that works as housing introduced inside an EPS box. The housing is conformed as a unique piece where there can be distinguished different parts that will be described afterwards. The shape of the main part of the housing is circled with a rectangle part perpendicular to this circled surface in one of the sides. In the middle of the housing there is a tube that easily enables the assembly of the rest of the components of the hose reel.

This component comes in to the production process in pallets containing 63 units stacked directly on the top of each other on the pallet. Between 10 and 11 pallets are received every week.

The EPS package is used as a support for the production (assembly) process as well as part of the final package of the hose reel. In this way the EPS package is considered as:

- Packaging for the incoming housings into the production (assembly) line (saves money because the incoming goods need a package)

- Packaging for the assembly process (otherwise it would be necessary something else to help the assembly process)

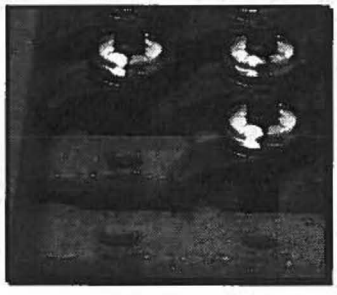
- Packaging for the distribution process of the final hose reel

Nederman designs the EPS package in 3D and gives all the specifications required to their suppliers. These suppliers buy the EPS package and insert on them the plastic housing device. Since the housing is not taken out from the EPS packaging it saves time (and consequently money) because it is placed directly in the assembly line.

They tried to change the EPS boxes into paperboard because in Germany they do not recycle the EPS and they had problems with it, but they failed in this project due to the high cost of the machines for folding the paperboard boxes. Another clue for this failure was that is very difficult to build a paperboard box with the exact measures and with low tolerance, aspect that becomes extremely important as the box is used as an assembly tool.

This use of a component's package as a package for the final product is not normal, but here it is possible because the housing is the main component of the product.

Ratchet



Picture 4-4: Ratchet

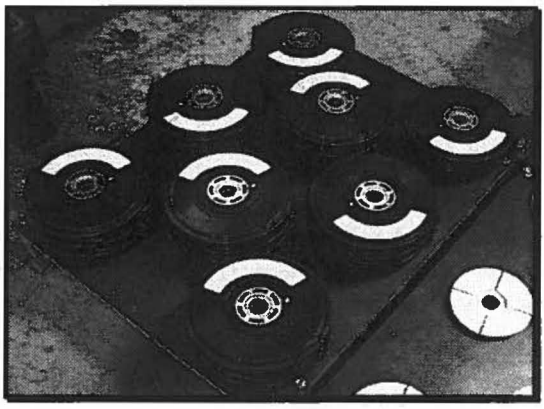
The ratchet locks the reel at a specific point when hose payout stops. A pull on the hose disengages the lock for instant rewinding.

The ratchets come in the production (assembly) line on a package which is given back to the suppliers. This packaging consists on a panel with holes shaped as the piece, where the ratchets are placed. Each one of these panels contains 54 ratchets and approximately 28 panels are loaded on a pallet.

The ratchet is taken by a robot that assembles it to the tube of the housing. The pallet with the panels is pre-assembled in the assembly line so the robot that picks up the ratchets can work easier. After picking up one ratchet, the robot follows some exact coordinates in order to pick

up the next one, and the tolerance for these movements is very low. Because of this low tolerance, a change in the panels is not worthy.

Recall spring



Picture 4-5: Recall Spring

At the beginning Nederman produced these recall springs in its own facilities, but they had a problem. The steel was supplied to them every eight months, so the amount of stock and therefore the opportunity cost of this investment were extremely high. Another problem appeared was that the material supplied changed and their old machines were not able to produce the springs with it, so they needed a huge investment in new machinery for continuing this production. Hence Nederman decided to subcontract this component.

The recall springs are received in standard pallets with combined wood collars. The use of these standard wood pallets instead of paper boxes is due to safety reasons. The springs can exploit during the transportation, so they can not take the risk of possible injury to the workers handling the recall springs. That is the reason why paper boxes are never used for the distribution of recall springs. Sometimes it is used another safety practice introducing the recall springs inside individual plastic bags so the springs cannot open.

On the bottom of the pallets it is placed a sheet of paper. At the beginning, it was used normal paper but because of the friction between the paper and the recall springs a lot of dust was generated. The dust was introduced in the springs and together with the grease made the springs useless. The solution came up changing the normal paper to wax paper that avoids dust generation.

The spring modules are removed from the pallet with wood collars and placed on a plate situated on the floor in the assembly line from where they are picked up by a robot and assembled into the set housing-ratchet.

Hose

The hose is probably the most important component of the final product. Nederman receives 130 pallets per year from their Italian supplier. At the beginning the hose was acquired in 200 metres rolls, with 10 rolls per pallet. Acting in that way the process was inefficient because

they were loosing a lot of metres of hose considering the part that was wasted at the end of the rolls and also the small amount of rolls that were sent in each pallet.

They came up with a new solution to their suppliers suggesting a longer hose roll of 6000-9000 metres. The rolls are placed inside a "Swedish potato box" (octagonal paperboard box) wrapped together with the pallet. So the amount of transportation volume that they use nowadays is 25-30% of the volume that they used before and hence less cost.

Another point is the hose wasted during the process. Before, with the pallets with 2000 metres of hose, waste figures were round 8% what means over 30 000 metres per year, but now this figure has been reduced until 1-2% (6000 metres) what means a reduction of 24 000 metres wasted.

The hose is taken and placed in the hose reel directly from the pallet which turns together with the box and unrolls the hose that is inside the box. The worker takes the hose and coils it to the reel. Then the worker tests the hose and closes the package.

4.1.3 Distribution Process Description

Storage

Once the production-assembly process is finished, a machine takes the single packages and loads them into a pallet. When 45 units are stacked in the pallet, the whole should be wrapped and is ready for transportation. At the beginning the pallets were loaded with 90 units of the product, with 15 boxes of 6 units in each one. This modification was motivated because of a change in the company's Management's policy.

There are two central warehouses of Nederman, one in Helsingborg and the other one in Canada which worked as suppliers for the different offices that Nederman has distributed over the world, supplying them with stock of the products. Nederman decided to eliminate that stock for the different offices and change it into direct delivery to the customers. Acting in this way the offices around the world now work as sellers and not anymore as distributors.

Two different kinds of orders can be distinguished, those that require delivering in 2 days, which make use of the available stock (in Helsingborg they have about 15 or 20 pallets in stock of the hose reel studied here), and the orders for delivers in 15 days, which are produced under the order and sometimes have some specifications in the packaging and the product (for example the incorporation of the brand that buys the hose reel). Working for stock in Nederman means having warehouses where about 20 rounds per year are carried out. During the first 6 months of the year the stock produced is calculated manually. For the next months, it is used a program that estimates the volume of stock that must be stored depending of the sales.

Transportation

There is no difference in the packaging of the products due to the way of transportation (just anti-humidity bags are used when ship transportation). The pallets are loaded with different products, with common final destination, and wrapped together as a unit.

Nederman does not have an own distribution system and uses different distribution channels depending on the place of distribution and the lead time. As distributor Schenker is used either by boat or by truck. When lead times are extremely short, the airplane is used with

some other companies (DHL) not just as transportation for the final product, but also as a delivery system for the components. This sometimes implies that the transportation costs exceed the cost of the component itself.

For the transportation a test is carried out in the company. When a product is finished, a pallet with several products is loaded in one of the trucks used for picking up the components from the suppliers. This pallet "travels" around the country for several days and then is checked to find the possible damages in the product during the transportation. This test provides the company with useful information for improving the transportation system by changing some aspects of the packaging system.

Handling
The single package is loaded by a robot to the pallet and then the pallet is transported by fork lift trucks to the warehouse for the storage. First of all it is necessary to distinguish between the single package handling and the half pallet handling.

With the new single package, there is an improvement in the process due to the elimination of the step of putting the single packages into the 6 packages boxes. These single packages are transported in half-pallets. For the half pallets, the handling is similar as for the euro-pallets, but the number of pallets used is double now contributing to a lack of efficiency in the handling.

4.1.4 Development procedure model description

For developing products, Nederman has a procedure model. This procedure model helps them to organize the different activities of the product development on an easy way. It is used as a guide so the outputs given and the inputs received for each area of the company follow specific rules and therefore the communication inside the company is structured and clearer.

There is a flow of activities and packaging is considered as another component of the product within all of these activities.

The procedure starts with a pre-study or a product study. Marketing and Sales, and Production and Design Engineering decide which the inputs for the model are depending on factors such as the volume of the production. There can be distinguished three phases in this procedure: *pre-study phase, project time phase* and *production phase*. The time required for the whole development process of a product varies on a range of 9-24 months depending on the product. Particularly for the case analyzed, the complete project took 4 years. The hose reel was defined in 2 years but some changes were introduced in order to increase the number of possible uses.

The whole company is involved in some way in the development process. The different areas take part in the process in a specific order: Marketing, Sales and Technical, Purchasing, Production Engineering, Production and Logistics.

The packaging development team normally consists on design engineers and purchasers. First they design a rough prototype, usually one year before starting production. With this prototype they go to the package designers, outsource companies, and at this point is when the interaction between product and packaging starts. These companies receive the information and specifications from Nederman in meetings where they, as well, provide Nederman with

some feedbacks and suggestions of the product and packaging. So the interaction is in both ways and occurs several times along the process. The knowledge and past experiences of these packaging companies are very valuable for Nederman so it is very important to take in consideration all the advices and suggestions these companies will provide to them. This way of acting is the same they follow with other suppliers they have, so the idea of the package as a component of the final product is really carried out. Since the packaging development is introduced just after the prototype design, it can be considered that the interaction between product and packaging starts early in the process.

This interaction in Nederman is just established for products with a high demand. They consider that the effort of the concurrent development is not worthy if the amount produced is not higher than a certain number (5000 units). Packaging has a low priority in those cases because they consider the amount of money they would save is less than the effort they have to make for having special packaging considerations.

4.1.5 Results

4.1.5.1 Potentials

The potentials or benefits found out within the case are connected, if possible, to the advantages, proposed by previous authors, which were somehow expected at the beginning of this research study.

Costs reduction

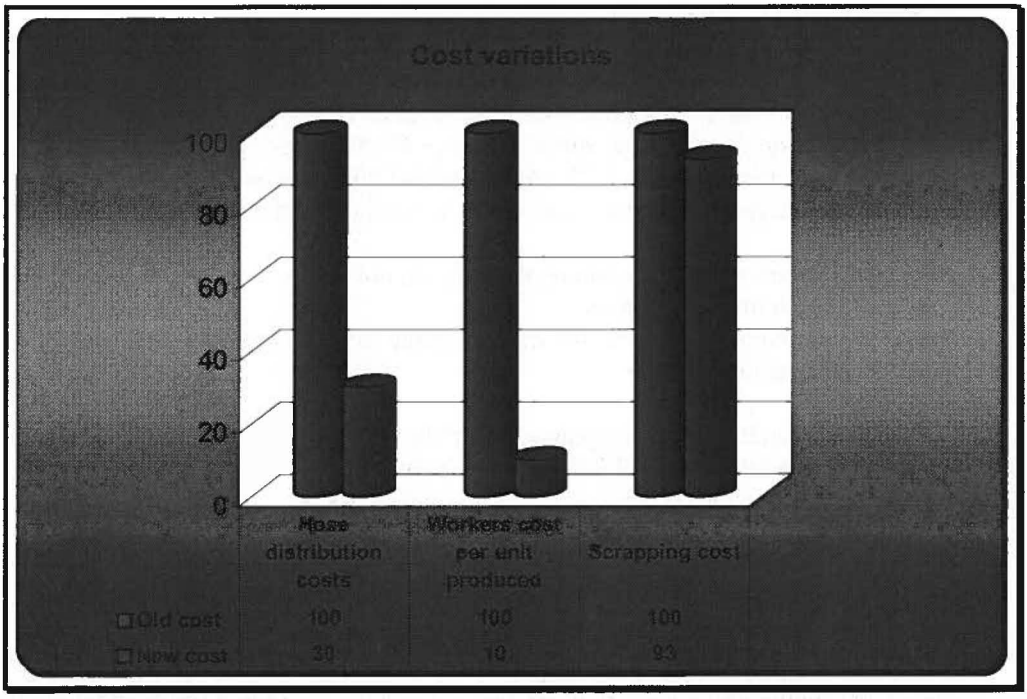
- Nederman introduces the packaging development early in the product development and it makes that the decisions resulting from this integration, also affect the specifications requested to their suppliers. Indeed, packaging used for the supply of components is usually also in charge of Nederman and the benefits that can be achieved because of the components can be translated into benefits for the final product since *"every cost reduction is important for the final product"*.

- A perfect example of that is the case of the hose. The hose is an important component of the final product. The new solution for the hose packaging provides important advantages. The longer hose rolls of 6000-9000 metres inside the octagonal paperboard box improved significantly the volume utilization during logistical activities. Nowadays, the volume utilization is 25-30% of the volume that was used before with the subsequent distribution cost reduction for this supplier of the 70%.

- Earlier it was necessary to have 2 operators working in the production/assembly for the hose component, where one had to make that hose roll switch without disturbing the assembly. Now, because of the longer rolls, that is reduced to 1,5 guys and that is also a cost reduction that affects the total cost on the product.

- Because of the automation of the production/assembly line, the total number of workers for this activity has been reduced from 6 to 1.5. Thanks to this automation in the processes the production volume has been increased from 10000 units with 6 operators up to 25000 units with 1,5 operators. This fact can be translated into a reduction of the 90% in the cost of workers per unit produced.

With all this information it is possible to present a graphic with the cost in percentage value reduction for all these activities. When the company was asked about the total reduction in costs after the implementation of a concurrent engineering, they considered very difficult to define the total cost reduction. Anyway they assure there are no increases in costs in any activity due to the change in the way of acting.



Graphic 4-1: Percentage costs reductions

Lead times reduction

- Nederman decided to design the EPS packaging of the housing provided by their suppliers in order to use it as supportive tool during the assemble process and as part of the final packaging. With this decision, they helped the handling processes as now there is no need of moving the housing from the original packaging to a device on the assembly line and then again to put it on another different packaging for the distribution.

- However, regarding lead times reduction, it is impossible to provide real benefits due to major changes in the last years for the company. Nederman has gone from small stocks in each country to one central European stock.

Quality of processes and environmental impact

- The tailor-made packaging for the supply of components provides with much more efficient handling activities. For instance, it is not necessary to move the housing from

the package where it is supplied in, using that package as supportive assembly tool and part of the final packaging. The panels containing the ratchets and the recall springs are preassembled in the assembly line so making easier the handling-assembly work. The hose is taken and placed in the hose reel directly from the pallet so there is no need of handling the previous 10 hose rolls per pallet.

- Because of the more efficient handling activities, the process in general, and the assemble activities in particular, become easy-to-automate processes.

- Another advantage from the packaging integration in the hose is the reduction in the amount of hose wasted during the assembly process. Before packaging considerations were taken, waste figures were round 8% (over 30 000 metres per year), but now this figure has been reduced until 1-2% (6000 metres) what means a reduction of 24 000 metres wasted. Explained by the interviewee, scrapping costs contains three parts:

1. They purchase and pay for something that they do not use
2. They handle it in their production
3. Due to environmental demands, the cost for scrap material (recycling or waste) is in most European countries high

With the new handling the scrapping cost is reduced by about 6-8%, which means that Nederman can produce about 1500 more products annually.

- Marketing is an important part within the product development process (Ulrich & Eppinger, 2003) and the packaging is in general considered a crucial tool under a marketing point of view (Armstrong & Kotler, 2005). Integrating packaging development in the product development process, the marketing aspects are analyzed simultaneously on product and packaging so the different features required can be shared and supported between both the product and the packaging resulting on a more optimum set product-packaging. For example in Nederman, some hose reels are produced under order for specific customers (Würth). The design of a hose reel, in some special colours and with some brand details, and a packaging, in which the brand of the consumer can be printed, becomes favoured by the concurrent development of both product and packaging.

Impact on productivity/utilization of resources

- The production volume has been increased from 10000 units (when the number of workers was 6) up to 25000 units (with 1,5 workers). The reduction of scrapping hose material involves higher production of 1500 units. These improvements on productivity can be considered indirect effects of packaging integration.

- Two different kinds of procedures can be distinguished in Nederman. The factor that influence which one of the procedures has to be followed is the production volume; high volume products when more than 5000 units are produced and low volume when the units produced are less than 5000. For the high volume production processes, the packaging and the product are developed together (as we have expressed, packaging is considered during the development process) while for the low volume, the process is done sequentially.

- When concurrent development is not performed, the sequential development can show two variations.

1. The first one is to consider, when the product development is finished, a standard packaging option that cover the basic needs of the product and distribution process but that is not the best packaging solution. Acting like this, there is not a real packaging development process. This possibility presents no important time consumption (probably less than the concurrent development one), but provides with an inefficient packaging system.

2. The second alternative is to develop a packaging system when the product is already developed. This alternative provides a good packaging system (probably similar as the one achieved with the concurrent development), but the time spent is long resulting on a total lead time higher than the one for the concurrent development.

   Hence, considering time and quality, the optimum results can be probably achieved just with a concurrent development process resulting the best solutions in both packaging and lead times.

- For the low volume products in Nederman, packaging solution is chosen according to the first above mentioned possibility; a functional standard package is selected that covers the basic needs of the product and the subsequent distribution processes. With this way of acting, the lead time will not be increased, but the quality of the packaging system is affected in an important way.

- With this criterion there are two possibilities for the product and packaging development in Nederman; the product can be developed together with the packaging thus the best packaging characteristics can be achieved. The second one is just to choose, once the product is developed, a package adapted to standard specification therefore the packaging system is not going to be very efficient. It can be concluded that there is not really a packaging development process for low volume production since the packaging is not really interesting for them; it is just something necessary.

- The three factors that, more or less, decide whether to develop packaging solution or not are *"technical, marketing and the result from the discussions with the suppliers. All of those are considered during the project meetings"*.

- The investment that the company has to do when developing concurrently product and packaging is worthy just with high volume production, because just in these cases what they get out from the better packaging system compensates the money and time spent in this packaging development process. Normally, Nederman contacts its suppliers and holds discussions regarding numbers/market segments/specific demands for transportation and so on. After one or two meetings they usually have a good picture of how to proceed. The main thing for Nederman not taking the effort when low volume production *"is cost, development/production cost for a specific packaging/stock cost"*.

- It is important to remark here that this idea of not being worthy to do things concurrently for low volume production comes from an intuition more than from facts and figures. That is, nothing really proves they are doing right acting this way for low

volume production. In fact, there is a case in the company (an exhaust extractor) in which they did not consider the packaging during the development process and they found out at the end that the total cost of the packaging was the 60% of the total cost of that product. That situation gives an idea of the importance the interaction between product and packaging development has and the amount of money that can be with the right resources utilization.

- It has been confirmed in the case studied that integrating the packaging development into the product development influences the product development itself because several decisions related to product design and supply of components (typical aspects when developing the product) can vary according to the development of the packaging (EPS provided together with the housing, hose packaging). Therefore, taking into account the packaging earlier in the development process guarantees a more efficient product development reducing the risk of failure and consequent need of redesign.

4.1.5.2 Integration between product and packaging

The development process in Nederman consists of three phases as they express: *Pre-study* or *product study phase, project time phase and production phase.*

Some similarities and relations between this development process and the one described by Ulrich & Eppinger (2003) can be expressed:

- The *pre-study* or *product study phase* is the stage of the development process where marketing and design engineering start defining the specifications that are going to require to the product. That is, these two areas establish all the requirements they will ask the product to fulfil. This first phase as is defined by Nederman can be related with the Ulrich & Eppinger phases, *planning* and *concept development.* In these two phases Ulrich & Eppinger also suggest that some production costs should be estimated as well as it is important to assess production feasibility.

- *Project time phase.* In this stage is where the other areas of the company start to get involved in the development process. In this phase, suppliers are identified and they start to get involved in the whole project, providing Nederman their experience to better accomplish the possible problems. In this stage, the product is getting defined and also the selection of materials is carried out. According to Ulrich & Eppinger, this stage can be identified with their phases, *system-level design* and *detail design.*

- *Production phase.* This is the final stage for Nederman. A preproduction version of the product is realised here. Production is carried out trying to follow the production system specifications previously defined. This stage can be identified with the phases *testing and refinement* and *production ramp-up* corresponding to Ulrich & Eppinger development process. The main difference with these phases is that Ulrich & Eppinger recommended to build several prototypes, while for Nederman the number and modifications of these prototypes is reduced. Ulrich & Eppinger also proposed that the transition from production ramp-up to ongoing production has to be gradual, while in real-life processes, this transition is not as gradual as expected.

For the packaging, the development process starts one year after the beginning of the general development process. As Nederman considers packaging as another component of the final

product, it is difficult to distinguish the different phases of the packaging development process. Nederman affirms that one year after the development process starts, a prototype of the packaging is created and provided with all the requirements to the company that will create the packaging (SCA). Afterwards this company provides Nederman some modifications to the proposed packaging and also some comments to improve the interaction between product and packaging. In other words, the interaction between product and packaging starts here. When Nederman was asked about the phases of the packaging development, they considered quite difficult to separate the processes they have into structured phases. But they agree that the processes they carry out when developing packaging have several similarities with the generic development process for a packaging. For an external observer, considering the model of integration of product and packaging defined by Bramklev et al (2005), the integration between product and packaging within Nederman could be something like this:

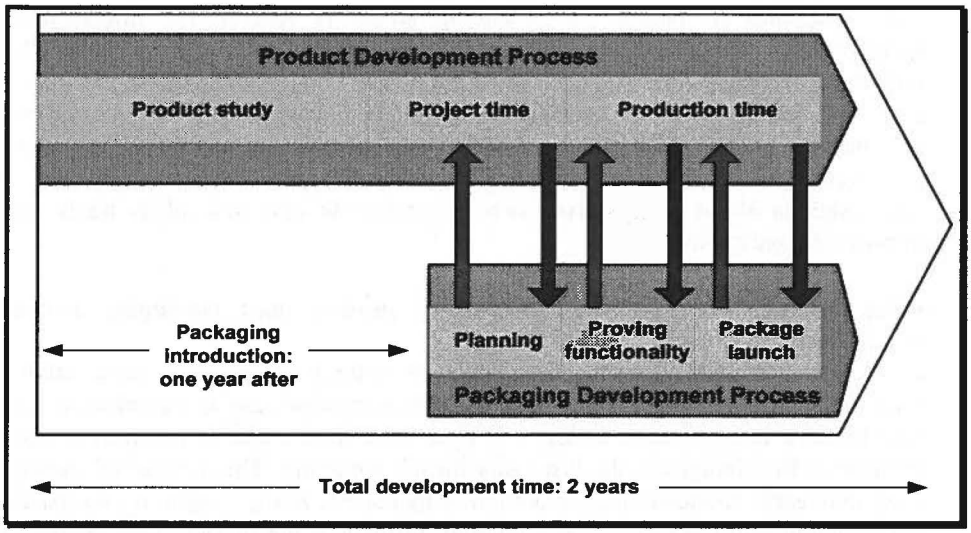


Figure 4-1: Integration between product and packaging for Nederman

As Wheelwright & Clark (1992) expressed, great products and processes are achieved when all the functional activities fit well together, they not only match in consistency, but they reinforce one another. This reinforcement can be attained by the cross-functional integration of these activities. Ulrich & Eppinger (2003) consider that this cross-functional integration should be achieved by the establishment of cross-functional teams for the development of new products. Nederman has development teams in where marketing, sales, purchasing, production engineering, production and logistics work together to strengthen their power.

4.1.6 Concluding with supportive research questions

- ***How is the procedure model for developing products in Nederman?***
  The procedure model helps Nederman to organize the different activities of the product development on an easy way; it is used as a guide. The whole company is

involved in some way in the development process, but it is not until the project time phase when the packaging (and all the other suppliers as well), are starting to be considered.

- ***How is the concurrent development process? What is the role of packaging in this process?***
  There is a flow of activities; within all them, features of the product regarding packaging, installations... are taken into account in order to improve future processes. Packaging is considered as another component of the product. Usually one year before starting production, a prototype of the product is sent to the packaging designers, outsource companies, and at this point is when the interaction between product and packaging starts. When this interaction starts, the information flows continuously from Nederman to their suppliers and from the suppliers to Nederman.

- ***What activities are considered concurrently? Which are the contact points?***
  The companies in charge of packaging solutions receive the information and specifications from Nederman in meetings where they, as well, provide Nederman with some feedbacks and suggestions of the product and packaging. So the interaction is in both ways and occurs several times along the process. The first contact point is the moment when Nederman provides the packaging supplier with the first prototype/idea of the packaging. Since there, almost every week they hold conversations about suggestions, new requirements and new ideas about how to improve the packaging.

- ***What benefits are achieved because of product and packaging concurrent development?***
  The tailor-made packaging for the supply of components provides with much more efficient handling activities. The processes have become easy-to-automate. Regarding lead times it is impossible to know if time benefits are due to integration activities because of the changes in the last years for the company. The number of workers has been noticeable reduced and production is increased. Also, integrating the packaging development into the product development influences the product development itself because several decisions related to product design and supply of components can vary according to the development of the packaging

- ***How does the concurrent development affect the different activities along the supply chain?***
  The activities are easier to perform involving less time and money consumption because when the company creates the packaging all the logistical activities are considered. But not just the own packaging is considered by Nederman; also the concurrent engineering carried out with other suppliers makes them to consider their logistical activities. These logistical activities are improved because of the tailor made packaging (usually developed by Nederman) for the supply of the components; volume utilization is optimized for some components' distribution.

- ***Are all the problems solved with the concurrent development of product and packaging?***
  Considering packaging as another component of the product makes that more aspects and requirements that the product is going to need in future activities are defined from the beginning so the risk of mistakes or failures is decreased. But this risk is not

completely eliminated because always exists an uncertainty component about new requirements or new laws that can modify the optimal solution.

- ***What kind of indirect effects have being derived from the concurrent process?***
  The improvements on productivity and the automation of the assembly line can be considered indirect effects of packaging integration. The increase on productivity is related with the automation, and both are related with the fact that new packaging is easier to handle by mechanical artefacts. But this improvement was not considered when they were creating the new packaging; that is why it can be considered as an indirect benefit.

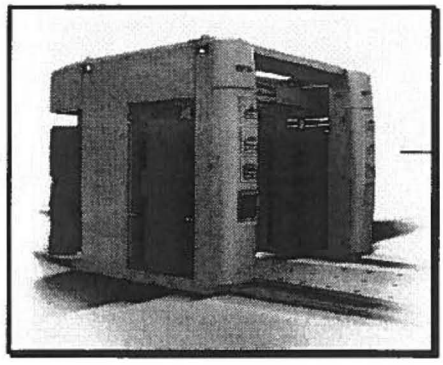
4.2 *Istobal case*

4.2.1 Company introduction: Istobal

Istobal was founded in 1950 and it is placed in L'Alcudia (Spain).The company is now a major firm exporting products to over sixty countries throughout the world, with a headcount of over four hundred employees. Nowadays the company is second larger seller worldwide of this industrial sector. The main products the company develops are: roll-overs, washing-drying tunnels, jet washes and roll-overs for trucks and buses.

This product case was believed at the beginning (when first call to the company) to reflect a total integration between product and packaging. That thought was confirmed when first meeting the company. The corresponding research questions introduced in the methodology chapter guided the interviews and meetings hold with the company.

4.2.2 Product description: Car washer machine M18+



Picture 4-6: M18+ Car washer machine

The M18 machine model is an indoors or outdoors car washer equipment (roll-over). Several galvanized steel parts form the main structure of the machine in the way of a frame through which the cars cross. Five wash brushes are placed inside the equipment, four vertical and one horizontal. The material of the wash brushes depends on the final use of the machine and the quality looked for in the washing process. Other parts such as a dryer, the rails and small components complete the entire equipment. The way this washer machine works is as follows: the car is parked in a specific place and the machine moves forward and back to wash the car. This roll-over equipment is the fastest within its category with a system for obtaining a high quality wash in just 2, 5 minutes.

The dimensions of the machine are: maximum vehicle access 2.3m (height) x 2.35m (width) x 5.2m (large) while the minimum bay size recommended is 3.1m (height) x 4.6m (width) x 9.5m (large). Because of these big dimensions the M18 car washer equipment is a heavy and bulky product, which involves important problems during the different activities along the product life cycle. It becomes really important to think from the beginning about all that possible problems in order to avoid them rather than to try to solve them once they occur.

As it will be described afterwards, the procedure model for the development of products in Istobal adds in a significant way the consideration of the packaging needs that the product will require when facing the different product life cycle activities.

These needs regarding packaging and distribution activities are taken into account inside the R+D+I department influencing in the design of the equipment to high extent. As a result, the M18 car washer machine presents six alternatives for being assembled-disassembled. The mean of having these six possibilities is to better take advantage of the conditions when distributing and assembling the product (making the most space utilization for instance), trying to optimize in each of the cases the different processes that the product faces. Four of the six alternatives can be seen on appendix, including the most and less disassembly options.

The production of the M18 car washer machine is carried out in the company's facilities. The different parts or pieces forming the machine are either produced by the own company or supplied from external companies. At the beginning of Istobal's history, the amount of out-sources components was high but nowadays there exits a big trend to produce as much components as possible inside the company in order to increase the quality and to speed up and improve time utilization.

All the different components are produced for stock and there exist big areas of continuous supply.

The sequence of activities followed can be depicted as it is in the figure 4-2:

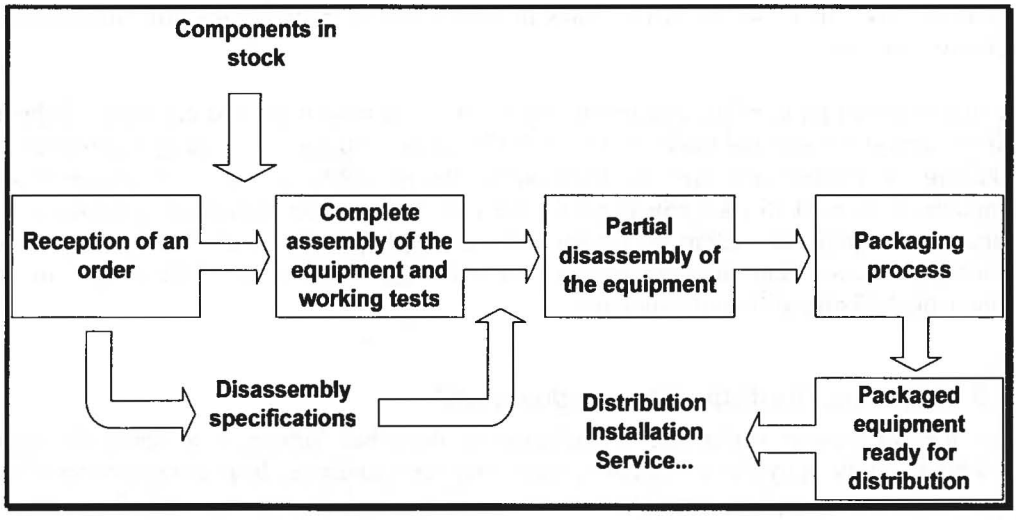


Figure 4-2: Sequence of activities

Once an order is received, the machine is assembled. After the assembly, several working tests are performed on the machines to ensure its correct working. Besides, each order has to specify the assembly-disassembly characteristics, that is, one of the six disassembly alternatives has to be included in the order; it is a required parameter for continuing the process. The car washer machines are assembled in the company's facilities and after being

entirely assembled they are partially disassembled according to the previous specifications of the order.

The assembly-disassembly specifications are based on packaging requirements. The ideal it would be to transport the equipment entirely assembled. But due to the large dimensions it is not always possible. Hence, the partial disassembly is very important always trying to disassemble as less as possible (in order to adjust to the distribution conditions), because the assembly cost outside the own facilities is much higher.

4.2.2.1 M 18+ packaging description

The car washer equipments are very bulky and resistant products which really do not need special additional protection during the distribution activities. That is why packaging for this kind of equipments is focused on the logistical function.

For packaging the product and according to the disassembly specifications, the different parts of the structure are placed over a base platform which serves as a support that holds the entire equipment. The dimensions of the base do not depend on the disassembly characteristics so the same type of base is adapted and used in all the cases.

The wash brushes are covered by meshes which protect them; without that cover the brushes lose efficiency in their use at the beginning because of the deformation they suffer when handling them. This cover is a new practice introduced for packaging as a solution of a previous detected problem.

When the disassembly alternative requires it, the loose parts are packed inside a standard corrugated box that is placed in the holes or empty spaces between the structures already stacked on the base.

The disassembled parts of the equipment are fixed to the base thanks to coincident holes in both the own structures and the base. But the holes in the structures are not specific holes for packaging the product and they are used during the assembly as well. The design of the equipment is thought to take advantage of the own holes of the structures (necessaries to assemble the equipment) using them also when packaging the product. Doing so, it is not necessary to have additional elements or to make new operations (like holes) on the components to fix the different structures.

4.2.3 M18+ distribution process description

When the car washer equipment is packaged as described before, it is ready for being distributed. All the activities carried out in the company's facilities, from the reception of one order until the packaged equipment leaves the facilities for being transported take no longer than two weeks. After these (no more than) two weeks it will depend on the transportation way for delivering the product, the total time until the equipment arrive to the final destination.

Istobal is the second world wide producer of this kind of equipment and 70% of the production is assigned to be exported. In order to improve time, cost and resources utilization and looking for optimizing the distribution processes, the better use of the distribution conditions is a key factor. That is why all those conditions are deeply analyzed early in the

development process of the product. As it will be described later, in the design of the products in Istobal, design for distribution activities is included.

Handling
Because of the weight and volume of these equipments it is really important to keep in mind these large dimensions and the problems regarding those, when the product is being developed. These important aspects must be considered somehow as soon as possible; otherwise, the more time it goes by, the more difficult it is to find solutions to the problems.

In the studied product, the own structure of the machine includes several rings destined just for handling the equipment. These rings let the machine to be lifted and better managed by means of cables hooked to the rings (see figure on corresponding Istobal's appendixes). The same rings are used to stabilize the equipment when it is loaded inside the truck as well. As shown in the figure there are three rings in both sides of the upper structure but only 2 of the 3 are used at the same time for handling the equipment. Those used will depend on the disassembly characteristics (the third one will not be used at all).

Transportation
The transportation of products in Europe is always performed by trucks. The company in charge of the transportation in Spain has special trucks with trap doors in the base of the truck which offer more available height when necessary. These trap doors are only used when M-18 model is transported providing a solution where a less disassembly is required. As expressed before, it is always better to disassemble as less as possible because of the costs. Unfortunately these special trucks are not always available, therefore the six different disassemble options play an important role during the transportation.

There is no transportation test to detect problems during this activity and the company tries to solve the problems when they face them. Past experiences are always an important tool for them when trying to solve and avoid these kinds of problems.

4.2.4 Product description: Roll-Over for trucks and buses (4PJ)

Picture-4-7: Roll-Over for trucks and buses 4PJ

The 4PJ machine is an outdoors washer machine for trucks and buses. This machine is also built mainly in galvanized steel parts, which form a frame through which buses and trucks cross. Some wash brushes are placed in the sides and the top of the equipment. The material of the wash brushes depends on the final use of the machine and the quality looked for in the washing process. Some other parts that have the machine are the dryer and some other small components to complete the equipment. The main difference between this washer machine and the M18+ is that in these big machines the space needed for the rails of the machine is much bigger than for the other machine.

The dimensions of the machine are: maximum vehicle access is 4.8m height x 2.7m width, while the minimum bay size is 5.7m height x 5.81m width x 6.6m large. These enormous dimensions make this machine even bulkier than the M18+. For this reason, the consideration of the packaging early in the development process is really important for the company to reduce costs and avoid problems during the transportation. For this product the packaging system was completely changed three years ago due to some problems Istobal had with the previous one. To solve these problems and to obtain the best possible solutions the whole machine needed to be changed, circumstance the company used to improve also the quality of the machine providing new technical advances to the new version.

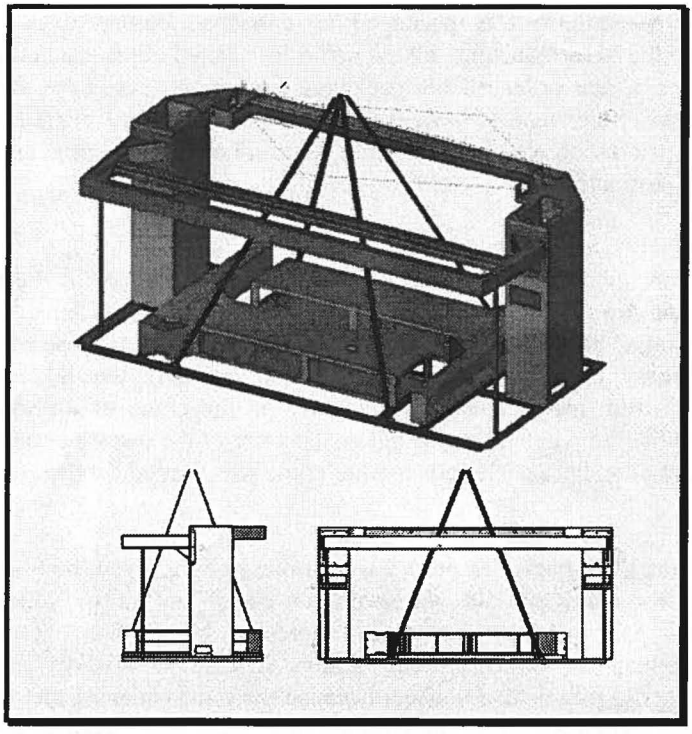
For the previous model the machine was disassembled in three parts, making these parts as three different packages that were sent to the final destination of the product. The dimensions of each part were more or less the same as a ship container to make possible the transportation by boat. But this kind of packaging resulted in several problems the company had to face. There were two main problems: high costs and inefficiency in transportation. The cost is always an important feature to consider when talking about packaging, and here the circumstance of sending three big packages for a single product was something difficult to assume by the managers of the firm. But there was another problem that appeared sometimes mainly when the three packages were sent far away: the possibility of losing or at least the possibility of a delay in the delivery of one package was bigger, and Istobal found that sometimes there were two packages on time in the final destination while the third one was delayed with the consequent delay of the whole product, as the three parts are needed for the assembly.

With these problems on mind, the R+D+I department developed a new version of the product with new features that solved all these problems that occurred with the packaging (and also some other features to improve the product itself). For this product the sequence of activities and the procedure model are the same as for the M18+, thus for any doubt consult them on the previous section.

4.2.4.1 4PJ packaging description

The main problems the old packaging had could be solved with one solution: reduce the number of packaging from three to just one. This easy solution was not as easy to carry out. But as they considered the packaging and the product concurrently they came out with a solution for all the problems: re-build the whole product to obtain a machine that can be completely disassembled in just one packaging.

This new packaging as shown in picture 4-9 has the same dimensions of one single packaging of the old ones. This reduction of space has given the company a considerable reduction of costs and the solution of the main problems appeared with the old version of the product.



Picture-4-8: CAD drawing of the new packaging

The new packaging allows the delivery of the whole product in just one package and with the dimensions of a ship container to permit the distribution by boat. As can be seen in picture 4-9, the machine is disassembled and all the parts are situated in a metallic platform (the drawings of this platform can be seen in corresponding appendix), also, in the empty space in the middle of the packaging, electronic pieces of the machine and the wash brushes are situated. These wash brushes are covered by meshes which protect them; without that cover the brushes lose efficiency in their use at the beginning because of the deformation they suffer when handling them. These parts allocated in the middle of the packaging, are usually stacked with screws using the existing holes for the subsequent assembly of the machine.

This platform has also four rings that are used with four bars which are used to lift the machine. Due to the high weight of the product the distribution and materials of these rings and bars has to be seriously considered, if not exists the possibility of breakage of the bars or rings and the destroy of the product.

4.2.5 4PJ distribution description

As the products have to be delivered along the world and they are very bulky and heavy, distribution becomes an important aspect to be considered by the company, and past experiences are usually used by designers to redesign and adapt new products.

When the roll-over equipment is packaged as described before, it is ready for being distributed. As for the M18+ machine, all the activities carried out in the company's facilities, from the reception of one order till the packaged equipment leaves the facilities for being transported take no longer than two weeks. After these (no more than) two weeks it will depend on the transportation way for delivering the product, the total time until the equipment arrive to the final destination.

Handling

As expressed before there are four rings and bars that are used to lift the product. Special trucks with a crane are used for this purpose. These special trucks have the possibility of lifting up the packaged product and leave it inside the truck. But as these trucks have cranes, there is also the possibility of using them for the final assembly, that is, the truck leaves the washer machine in the final destination, and later on the crane of the truck can help the operators to assemble the whole machine again. This use of the truck's crane reduces also the assembly costs and time, because before another crane was needed for the assembly.

Transportation

The reduction of the three packaged parts into just one has improved the transportation in the way of reducing lead times and also transportation costs. The transportation of products in Europe is always performed by trucks, as expressed before these trucks have special characteristics that help distribution and installation. When transportation has to be performed by boat, just one packaging is also needed, because the dimensions of the new packaging fit perfectly in a ship container. These dimensions were taken into account when the machine was designed to permit this kind of transportation in an easier way.

There is no transportation test performed by the company, so all the possible damages that can be caused in the machinery are solved with the information provided by the transporters and mainly by past experiences. Anyhow the damages occurred during transportation are not really significant due to the enormous consistency of the product and also because the sensible electronic artefacts are protected by the structure of the machine.

4.2.6 Development procedure model description for M18+ and 4PJ

The years and the experience of the company have shown that there are many problems and complications when distributing equipments as heavy and bulky as these washer machines. Because of this, the analysis in depth of all the factors influencing in some way over the product during the different activities further to its production, has got a special interest and importance inside the R+D+I team. Nowadays, they are more than 30 people working together in this department looking for more efficient solutions for the development phase.

In the last years, Istobal had to adapt to some changes adjusting the procedures to new rules regarding specifications and quality (ISO). Instead of taking these conditions as a setback, the company faced the new situation as an opportunity to improve its methods. Hence, because of the necessity of adjusting to the new quality normative and considering earlier problems already faced with their products, a new procedure model was developed.

In the new procedure model for the development of products in Istobal, all the activities that are carried out with the product after its production until its installation are analyzed before the design and development of the product are completely decided. In this way, the findings from these studies are used during the development phase of the product taking into account the future needs of the product when facing future activities, helping to optimize the processes and avoiding future problems.

This development of new products starts with the marketing area. The information of the market combined with the information obtained from their key customers, makes them find the possible opportunities of the market for new products or the need of improving one of their products.

When this opportunity is identified, the business area of the company in a meeting with the R&D department decides if it is possible and worthy for them to create a product that fulfils the needs of the market.

When the decision of starting the development of the product is taken, the procedure model they have "starts" its function. All the requirements and specifications of the new product (including also packaging and the distribution restrictions) are taken into account in a structured way with this procedure model. When all the specifications are considered, it is the time for the study of the components production, or if they can not produce them, to talk with their key suppliers to try to find a solution. The idea in Istobal is to try to produce all the non-standard components, while the standard ones are bought outside the company. The main reason for doing this is the higher quality control they can have for this "special" components if they do it inside the company.

Once the components are designed, it is time for the development and test of prototypes. These prototypes are tested in the installations for a variable amount of time depending on the product and the possible problems they can have.

Once everything is tested and approved by the engineers, the components are produced and the new product (or the improvement of the old one) is launched into the market. In the moment the first order appears, the production starts.

The consideration of the logistical and installation activities within the development procedure can be conceived as design for distribution and installation. However, because of the special characteristics of these products, packaging is deeply related to its logistical function on the products, so everything regarding logistical activities is directly connected to packaging.

Besides the packaging considerations through the logistical activities, packaging itself is included in the procedure model as another point to consider when developing the product. This consideration is revealed in the procedure model. The part of this procedure model regarding product specifications (including logistical activities and packaging considerations) can be consulted in corresponding appendix; on it, some points are important to be remarked and to be translated into English:

- **4.3.5 Requirements to avoid critical damages during storage.** After assembly and tests, it will be stored indoors, with a previous dismantling and adaptation of the packaging specifically designed for this machine.

- **4.3.6 Requirements to avoid critical damages during handling.** For correct handling and considering its weight, volume, load/unload and assembly, it will be necessary to consider when designing the existence of the suitable hook devices.

- **4.3.8 Packaging definition.** Due to the characteristics of the machine packaging is very important and consequently it will be designed as an assembly related to the model, which cost will be included in the cost of the basic unit of each model.

The above mentioned procedure model belongs to the 4PJ machine but it can be generalized to all the products in the company and to the M18+ model in particular.

Though numerical answers have been difficult to get out like in the other analyzed cases, all the people interviewed agreed on the clear benefits that they achieve right now with the packaging integration into product development. Besides, one of the assertions claimed by the interviewed people was that *"a key factor is to have as soon as possible all the requirements regarding everything for the product, including packaging. Once everything is specified, next is just to follow the specifications"*.

With this procedure model where product's needs along its life cycle, including packaging requirements, are contemplated, there is a clear reduction on time and costs. According to the interviewees, the time employed in considering packaging and processes' requirements while developing the products is minimum and besides, those requirements should be considered sometime anyway. Doing it from the beginning it is easier to get efficient activities because the more time goes by without considering the diverse needs, the more time and money is needed afterwards. The company is highly rewarded because of the great risk reduction. Taking into account the future situations avoids a lot of potential problems that usually are faced during the product life cycle and specially, during logistical activities.

4.2.7 Results

4.2.7.1 Potentials

Since it has been possible, for some data, to compare previous figures with the actual ones, this case provides some clear numerical figures supporting the benefits resulting from product and packaging integration. Most of these facts have been got with appropriate direct questions to company's personal.

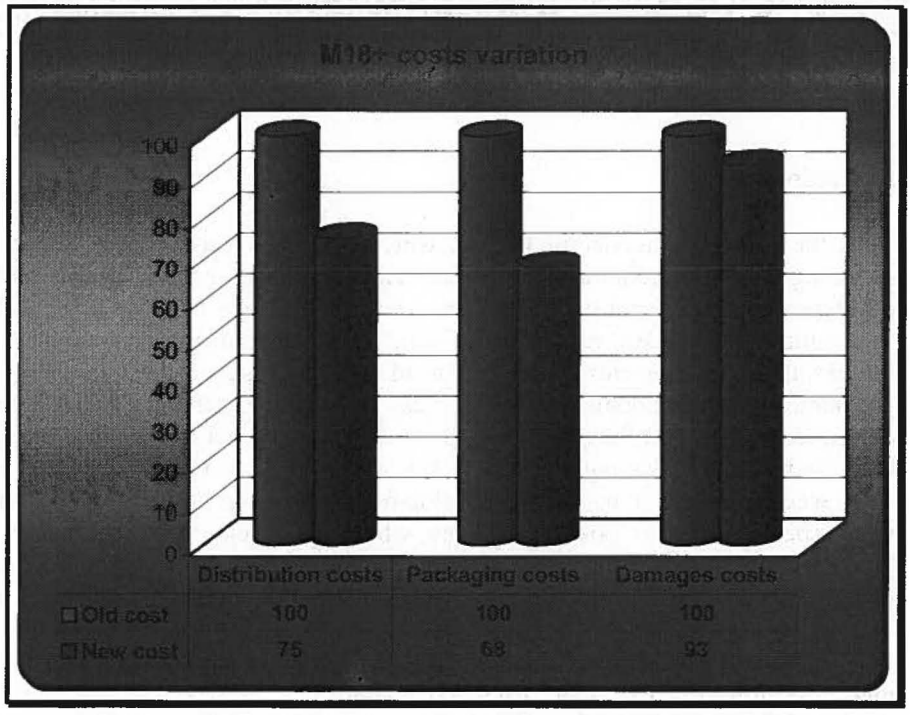
Costs reduction

- Regarding product costs (development and production costs) there exist significant benefits. Before the actual procedure model for developing products were performed, packaging costs (development and production costs) meant 5,6% of the total cost in the case of a machine like the M18+ model. The actual packaging cost for this machine has been reduced down to 3,8% of the total cost of the product. The new

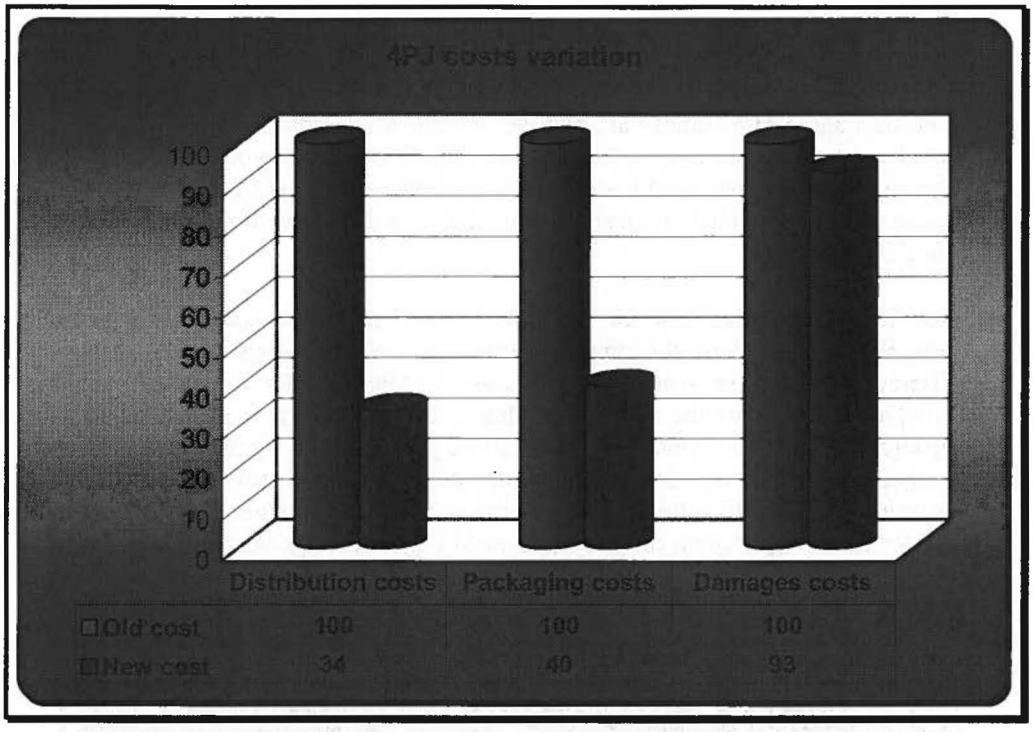
development procedure decreased packaging costs for the roll-over equipments from 9,3% down to 3,7% of the total cost of these machines.

- The packaging-disassembly alternatives for the M18+ machine, allow that a higher number of machines can be loaded inside the trucks. The volume utilization when loading trucks is optimized because the new disassembly alternatives provide a better space utilization. This optimization concludes in a 25% reduction in distribution costs for this product.

- For the 4PJ machine case an important change was introduced thanks to the new integration. Instead of the three different parts the previous model needed when disassembling it, the whole product was re-built in order to let the machine be completely disassembled in just one shape. The three parts were packaged as three different shapes. The volume of one of those parts was the same volume of the actual unique part. This new situation involves an important distribution costs reduction since the volume utilization needed for transporting one product has decreased a 66%. As for the transportation of every packaged part one truck was required, in average, considering transportation costs by trucks, the cost reduction can move upwards to 66%.



Graphic 4-2: Percentage costs reductions for M18+



Graphic 4-3: Percentage costs reductions for 4PJ

Lead times reduction

- With the procedure model in Istobal, where product's needs along its life cycle, including packaging requirements, are contemplated, there exists a clear reduction on development time. According to the interviewees, the time employed in considering packaging and processes' requirements while developing the products is minimum and besides, those requirements should be considered sometime anyway. It was difficult to get numbers of development times because of the new technologies influence (3D design techniques) but the time required for the development of products (considering both product and packaging development) is estimated to be reduced in approximately three weeks. It is prior within the development team to have as soon as possible as many specifications as possible because when the development and design of the product advance it becomes more difficult to go back in order to correct something because of new detected needs; and in those situations the time needed is much higher.

- The reduction in the 4PJ equipment from three different packages to just one meant noticeable time impact. Apart from the higher costs, the fact of the three shapes needed for every machine caused lead times problems, especially when sea transportation was required. The volume of each one of the three parts corresponded to a ship container volume. That situation implied possible problems by lost or delay in the deliver of the parts, founding out that sometimes there were two packages on time in the final destination while the third one was delayed with the consequent delay of the whole product (as the three parts were needed for the total assembly). The new packaging allows the delivery of the whole product in just one package and with the

dimensions of a ship container to permit the distribution by boat. It was estimated that about 1% of products (4PJ) transported before had problems regarding lost or delay. This risk of lost or delay has been almost eradicated.

Impact on productivity/resources utilization

- The volume production of the M18+ and the 4PJ machines is right now about 100 and 120 units per year respectively. These numbers mean an increase of approximately 10% on production volume, but *"It's hard to say if the number of sold product has increased due to a more efficient production. You can never say if this had increased anyway due to sales activities"*.

Quality of processes

- The company is highly rewarded because of the great risk reduction. Taking into account the future situations avoids a lot of potential problems that usually are faced during the product life cycle and specially, during logistical activities. The reduction on damages during transportation and production activities has involved a cost reduction of about 7% of the total cost.

- Since everything is well defined and specified within the procedure model, the different activities are carried out easily and involving less time consumption. The production of these machines is one activity favoured by the integration. Before, the equipments were assembled and afterwards it was necessary to wait until the necessary specifications regarding distribution reached the production team (the orders that caused starting the production of the machines did not specified any other need). Working tests were then performed and when the distribution conditions were identified, the process continued.

- According to the interviewees, it can be concluded that all the activities carried out, from the development of the products until their installation are better performed thanks to the new procedure where "everything" is considered and specified as much as possible.

Environmental impact

- As there is an important reduction of the transportation volume needed, the number of trucks and boats per unit of product has been reduced in both cases; therefore the environmental impact because of transportation's contamination has subsequently decreased as well.

- There exists a huge commitment to ongoing improvement in organisation and pollution prevention at all levels. Personnel training and motivation, involving all employees and co-ordinating efforts to comply with standards for quality, environment and customer requirements. Minimising both the use of natural resources (energy, water, etc.) and, the most significant environmental factor, the production of hazardous waste material, insofar as is technically and economically possible in accordance with the stipulations of Istobal's objectives and targets plan.

4.2.7.2 Integration between product and packaging

Comparing Istobal's procedure model with the Ulrich & Eppinger (2003) procedure model, lots of similarities appear. The different phases of each procedure model are related this way:

- *Needs identification*. This stage can be clearly related with the *planning* phase by Ulrich & Eppinger. Here the market opportunities are evaluated and the target market for the product and business goals is specified.

- *Feasibility*. The main characteristics of this phase are the study of the feasibility of the product and to estimate the manufacturing costs and the consequent economic feasibility of the new product. This stage can be identified with the Ulrich & Eppinger *concept development* phase.

- *Design*. In this phase are established all the specifications the product will need to accomplish the required features of the product. These specifications include, apart of the technical features of the product, the packaging needs for storage, handling, transportation, and in some cases for installation. This stage includes also the study of the product components, with the definition of the geometry and the choice of the materials as well as the design of a simple MRP to better control the production. Ulrich & Eppinger considered two different phases for the activities carried out in this phase by Istobal: *system-level design* and *detail design*.

- *Testing prototypes*. First prototype is built and tested here. This prototype may have some improvements depending on the results of the tests. The main objective in this stage is to test reliability and performance. According to Ulrich & Eppinger, this phase corresponds with the *testing and refinement* phase defined by them.

- *Production ramp-up*. The product is launched and key customers are interviewed about their "feelings" of the new product. Ulrich & Eppinger defined this phase with the same name.

It is important to notice that all the names of the phases carried out by Istobal are given by the writers according to a free translation of the ideas they declared during the interviews.

As expressed before, packaging is considered from the very beginning by the company. In the first phase, some rough calculations of the possible cost of the packaging are taken into account. Even though it is important to notice that it is not until the second phase when the packaging starts to get really involved with the product development. The stages of the packaging development process can be considered as *planning*, *testing (proving) functionality* and *package launch*.

Considering the model for the integration of product and packaging defined by Bramklev et al (2005), the integration between product and packaging within Istobal can be represented as follows:

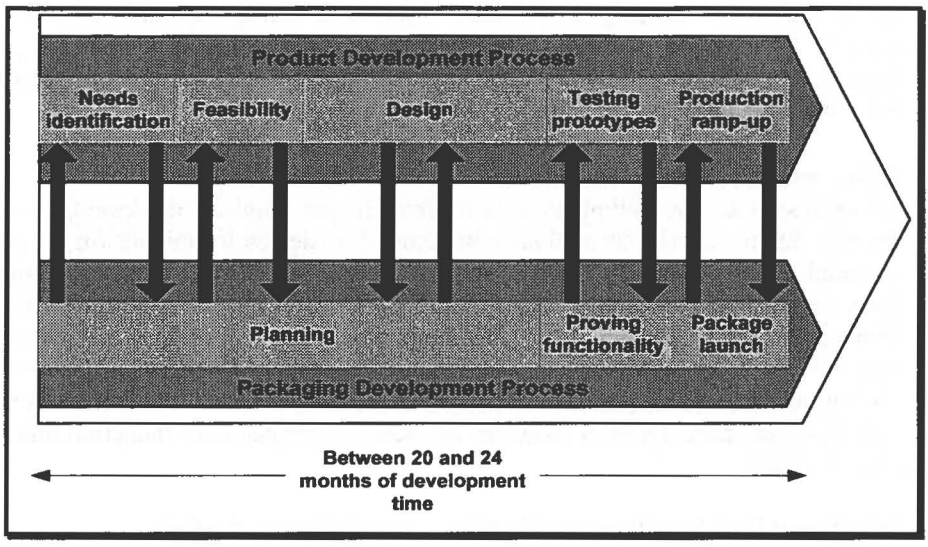


Figure 4-3: Integration between product and packaging for Istobal

Istobal's R & D department is constituted by more than thirty people, where engineers and designers are the most representative of it. This department is the base of the development team, but also workers from production, marketing and finances are involved in these teams.

4.2.8 Concluding with supportive research questions

This case can be identified almost with a total concurrent model as expressed by Bramklev et al (2005). For this kind of procedure model, the research questions can be expressed as follows:

- ***Why is the concurrent development implemented?***
  Due to the obligation of the fulfilment of the ISO normative, the company changed its procedure model to adapt it to the new normative. As everything was revised and modified, the company decided to create a new model for the development of products where everything was considered from the beginning of the process to get a more structured model in which the oversights and mistakes were almost eradicated.

- ***How is the concurrent development process? Why is it that way?***
  This question has been replied in the previous section of this case study.

- ***What activities are considered concurrently?***
  For the development process of product and packaging, all the activities are considered in parallel except perhaps the initial phase of the product development (when searching for needs) because in some cases the needs that are searched have to do just with the implementation of new technologies for the products (M18+). But some other cases, the needs are just failures in the distribution process (4PJ) that have to be improved, so packaging is considered in all the activities.

- ***Which are the contact points?***

Along the whole development process there is a continuous flow of information between the product development process and packaging development process. Actually it is considered by the company that both processes are merged just in one with the same development team.

- ***Which benefits, in terms of costs and lead times, are achieved?***
  As expressed by the company, it is difficult to get numbers of development times because due to the new technologies influence (3D design techniques for example), it is complicated to say if the reduction is just because of the concurrent development or these new technologies have something to do with it. But the time required for the development of products (considering both product and packaging development) is estimated to be reduced (because of the concurrent development) in approximately three weeks. Considering the cost, there has been a significant reduction in distribution and packaging costs for both products. As well a slight damages reduction makes total costs decrease.

- ***Which problems have been faced when concurrently developing?***
  The main problems occurred when developing were at the beginning of the implementation of the new procedure model. These problems arise because all the activities were completely different and the workers needed a time to adapt to this new way of acting.

- ***How does the concurrent development affect the different activities along the supply chain?***
  All activities along the supply chain are considered from the beginning and before product and packaging are designed. This situation gives the final product the opportunity to pass through all the activities with a high quality performance.

- ***Are all the problems solved with this concurrent development or some problems are not possible to avoid even with this method?***
  Not all the problems are solved, because always some new circumstances and requirements can arise once the product is already developed like some modifications in the distribution channels or even some law modifications. But as the engineers in Istobal said: *"The more requirements that can be defined from the beginning, the less risks and inefficiencies the company will have in the future".*

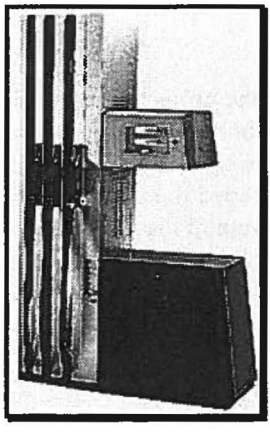
4.3 *Dresser Wayne case*

4.3.1 Company introduction: Dresser Wayne

The company was founded in 1892. Dresser Wayne develops, manufactures, markets and executes service of petrol pumps and electronic payment systems. Their domestic markets are Scandinavia, Estonia, Lithuania, Russia, Ukraine and Kazakhstan. In these markets they offer a complete product range as well as service. Company's last year turnover was 410 million SEK (44 million €), and there are 330 employees in their facilities.

First contact with this company was in charge of our supervisor. Before first contact was hold, it was believed some kind of integration was carried out within the company. The result from that first meeting revealed the no existence of such an integration but packaging redesign processes. When contacting the company looking for more data and in order to be able of getting out something interesting for this thesis, the focus was on those redesign processes.

4.3.2 Product description: Global Star HH



Picture 4-9: Global Star HH

The Global Star HH is a 390 Kg gasoline pump of 1,25m (length) x 0,52m (width) x 2,2m (height). This gasoline pumps has a capacity between 40-130 litres/min, depending on model, hanging hardware, connection dimensions, pipe length and pump-suction height.

New markets have opened up for European producers; all the countries from Eastern Europe have begun to develop their economies, so these growing markets generate a big amount of needs that all these companies want to fulfil.

This is the situation for Dresser Wayne, but all these new situations have always new problems associated. Since the company did not have any previous experience of delivering pumps to these countries, they were unaware of the magnitude of loads and other environmental conditions facing the pumps during handling and transportation to the sites

where they were to be installed. These problems originated several damages on the gasoline pumps during the distribution process (0,2 % of pumps were damaged), thus some changes were demanded for the company to try to solve these problems and the subsequent damages.

The first idea the company had was to strengthen those parts of the pumps that were damaged. The reinforcements consisted of pieces of wood that are placed on the pump to support the sensitive parts of the pump. But this solution, even if it solved the damages, increased too much the cost of the pumps, and this increase of costs was unacceptable for the company. These circumstances and initial solution made the company learnt an important lesson; an improved, more effective load carrying package might be a cheaper and easier way of solving the problem. The action taken by the company was to enrol one of its engineering designers in a packaging design course and with this knowledge launch a new project to develop new pump packing that improves the properties of it. This reduction in costs and lead times is not available in a document but the company claims for its significance.

Even though this reduction in costs and lead times was so significant, this case of considering the packaging as an important part of the product development, was not an isolated case since the company has recently found out there is a design problem with another newly designed pump of theirs. Designers just recently found out that they have designed the pump outside requirements of distribution; the pump is too large for their standardised wood pallets used as an assembly platform in production.

4.3.2.1 Old packaging

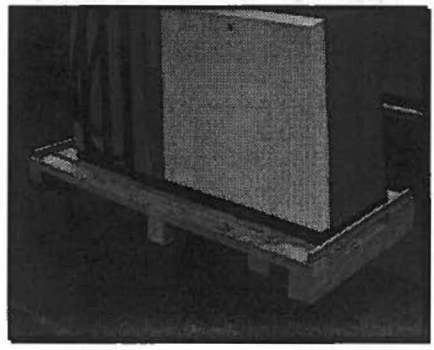
The packaging that was used when the project was launched consisted of large boxes and lids made of corrugated cardboard. The boxes came in 6 variants of corrugated cardboard and the measurements of the largest boxes were 2225x1612x792 mm. Those boxes were distributed collapsed to Dresser Wayne, who needed to mount a huge plastic bag over the whole gasoline pump before the box was mounted, mount the packaging over the pump (several meters high), mount the lid on top of the packaging and wrap it all together. Previous to this packing, the pumps were packed only in stretch film. Some problem areas were identified with those packaging:

- Two people were needed for mounting it
- Time consuming was higher than desirable
- Working postures were non-ergonomically
- The outer measurements of the packaging exceed the outer measurements of the pallet, so problems with fitting pumps into the truck occur
- Almost each of the pump variants required specific packaging
- High price of the total packaging
- Too much protection of the pump in proportion to number and location of damages
- It was difficult to identify the content of the packaging

4.3.2.2 New Packaging

In order to cover all the areas of the packaging life time, a number of departments were involved in the project of developing the new packaging. The departments of manufacturing, engineering, customer service and supply chain contributed with interesting information to this project. The draft of these requirements is included on corresponding appendix.

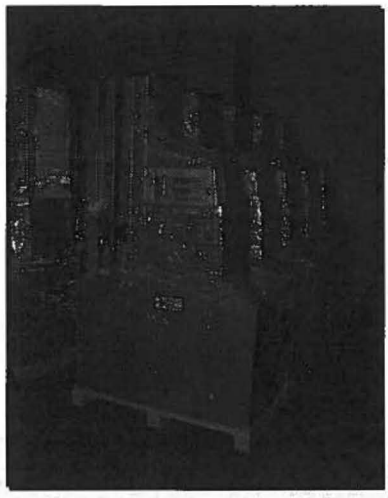
As well as the packaging, it is always important to consider how is a product going to be assemble and if some designs will help this assemble (as expressed before in the frame of reference with the DFA). Considering the pump, assembly is performed taking into account the afterwards packaging and distribution. As it is shown in picture 4-11, the assembly of a pump starts with the choice of a wooden pallet.



Picture 4-10: Pallet where pump is assembled

On top of the wooden pallet one part of the gasoline pump frame is assembled together with a number of hydraulic pumps (the number depends on the pump module). After the hydraulic pumps are assembled the frame, computer box and gas hoses are assembled. It takes approximately 4-5 days to assemble a pump. Once the pump is totally assembled, some tests are realised in the pump. After that, when the pump is approved, the packaging process starts.

Several discussions in where eight different ideas were considered resulted in the final packaging chosen (see picture 4-12)



Picture 4-11: new packaging for the pump

In the new packaging, the box with accessories is placed under the electronic head. A bubble pack (1000x150x4.2mm) is wrapt around the lower part of the pump. This is necessary because the cardboard can be weakened if it is exposed to humidity for a long time. The bubble pack will prevent the pump from scratches originated by unstable cardboard. Two sheets of corrugated cardboard are placed along the sides of the pallet and fastened to it. These sheets are fastened together at the upper part of the long side and create a safety barrier at the most exposed areas of the pump. A plastic hood (2755x2650x0.05mm or 2755x1900x0.05mm) is placed over the pump to cover the whole pump and also the sheets of corrugated cardboard. The hood protects the corrugated cardboard from humidity, and also prevents the pump from becoming soiled during handling, transport and storage. Later on, a stretch film is applied around the pump and cardboard. This stretch film is used for keeping the hood in place. To prevent the stretch film from gripping too hard around the cardboard, a pre-stretched film is used. Finally two stickers are placed on the packaging. These two stickers advice the handler about the possible problems he would have.

The new packaging solved some of the problems the company had before. Now the outer measurements of the packaging including the pump don't exceed the measurements of the pallet, protects the pump on conflictive areas, one employee is needed for mounting and mounting is less time consuming, visualization of the content (this will make handlers to be more careful), ergonomic advantages, reduction in the amount of material used (72-79% depending on pump module)... Even though there are still some weaknesses in this packaging, for example this packaging is difficult to reuse, the cardboard can loose its properties if it is exposed for long time to an extreme environment. Also some ergonomic aspects can be improved.

4.3.3 Distribution process description

The market for Dresser Wayne pumps is mostly European countries, so most of the products are transported by truck. The company has different contracts with different customers; some customers take care of the transport themselves and for some customers Dresser Wayne provide the transport. When the customers are using their own trucks it is inspected by the

company's personnel before they are allowed to load the truck. This is to ensure that the suspension is sufficient. However Dresser Wayne asseverates they don't know what happens after the truck leaves the company, often the pumps are reloaded on other trucks somewhere on the way to the final customer.

As expressed before, the market of the eastern countries is growing for the company, with the consequent distribution problems. Pumps transported to old soviet countries are reinforced with pieces of wood placed on the pump to be able to withstand the effects of the very bumpy roads.

The company does not perform any test for the distribution in general, so Dresser Wayne tries to improve the packaging by looking to past experiences and damages that occurred to their products.

4.3.4 Development procedure model description

For Dresser Wayne, the procedure model for the product development follows more or less the phases described by Ulrich & Eppinger. When the company was asked about it no clue was given about these phases, just the recognition of the existence and the asseveration that it follows a usual structure of a product development.

The packaging is not really considered by the company. In this case they started with a standard packaging provided by SCA. Usually they finish a product and when it is ready to be shipped the packaging is considered. This consideration consists in sending SCA the characteristics of the product developed. Then SCA designs a packaging for this built product or adapts an old packaging to it. No interaction between product and packaging development processes occurs on it. For this special case, they noticed that the packaging used was extremely inefficient. Damages and high costs made them realize that something was wrong with the existing packaging so they tried to modify it but not just with SCA help, but with the interaction of a company's engineer. With this interaction they probably tried to do a more tailor-made packaging, which better adjust to the product characteristics. But this collaboration with the packaging suppliers was something sporadic, and in the future no collaboration was carried out.

4.3.5 Results

Dresser Wayne case cannot be considered a good example for the integration of product and packaging. There is not existence of such an integration concept because the two development processes are carried out sequentially not affecting to each other. As declared by the interviewees, what is done is *"to adjust the packaging to suit the pump instead of integrating the packaging into the development process of the pump"*. Therefore, it is not possible to talk about advantages or potentials resulting from a product and packaging integration.

The case studied within this company reflects a redesign process; but this redesign process is not performed on the product. After important problems and inefficiencies were faced and detected, a packaging redesign was proposed. The realization of the changes included in the redesign let Dresser Wayne to improve activities solving diverse important problems. Anyway, those changes did not affect at all to the own design of the product.

What has been done in this concluding chapter is to present the mistakes and problems faced, comparing them, when data is available, with the improvements got through packaging

redesign. All the possible improvements achieved in the course of a redesign process, are definitely likely benefits that could be reached if product and packaging integration is done in an early basis. With this reasoning, the following results intend to support somehow the advantages of a concurrent development procedure of product and packaging.

4.3.5.1 Potentials

Costs reduction

- The packaging change for the pump involved reduction in costs and lead times which is not available in documents neither direct data, but the company claims for its significance.

- The number or workers required for mounting the pump has been reduced from 2 to 1. That implies reduction costs of 50% of worker per unit.

- With the new packaging, the set pump-package does not exceed the dimensions of the pallet; space utilization is then optimized with the consequent distribution costs reduction.

Lead times reduction

- The assembling or mounting process took 4-5 days for the old packaging. The days have been cut in approximately 1 day in average.

Quality of processes

- Logistical activities have been noticeably affected by the new "transparency" condition since the visualization of the product improves handling processes; handlers are more careful when loading and moving the pumps and in this way, the risk of damages is reduced.

- The new packaging solution, by protecting the pump on conflictive areas, provided besides the almost elimination of damages in the pumps during distribution activities. The percentage of those damages was calculated in 0, 2%. Now it has been reduced in a 95 %.

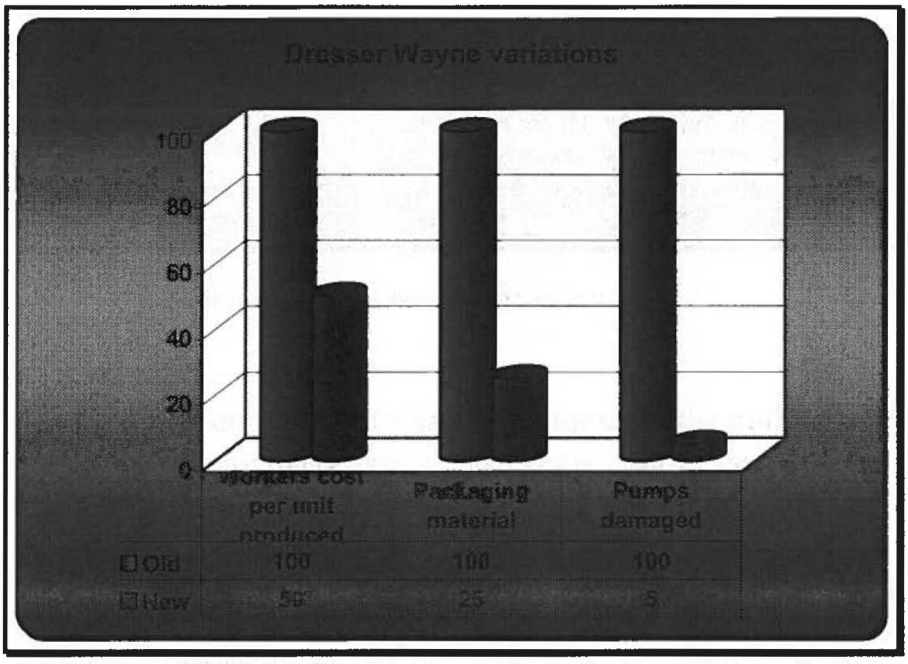
- The old packaging system caused non-ergonomically working postures. With the new solution a more ergonomic process has been got; nevertheless, there still exist some ergonomic aspects that can be improved.

Impact on productivity/resources utilization

- It was believed that the pump protection was too much in proportion to number and location of damages. Depending on the pump model, the reduction of the amount of material used with the new packaging is 72-79%.

Although the changes introduced by the new packaging provided with advantages in costs, times and efficiency terms there are many weaknesses in the packaging that need to be

considered within the company. The new packaging is difficult to reuse and besides, the cardboard can loose it properties if it is exposed for long time to an extreme environment. Though packaging costs have been reduced, they are still higher than the desirable ones.



Graphic 4-4: Percentage variations for Dresser Wayne

4.3.5.2 Integration between product and packaging

As expressed before, the common Ulrich & Eppinger (2003) development process for mechanical products is going to be considered here, with all its phases. For the packaging development process, the De Maria concept is going to be used, but with a significant reduction of time of the global process. This reduction is probably due to the elimination of some stages of the phases described by De Maria.

The enormous failure of this case shows that packaging is not really important for this company. Even though they have reduced very much the costs when considering the packaging as an important phase of the product, the other case commented before where the company failed again with the distribution system demonstrates the company still thinks of the packaging as something else, not as part of the product itself.

When asking to the company about the integration of product and packaging, the answer was: *"it is not a common practise to take the packaging into consideration during the development process. It is nothing that is considered until the pump is developed and ready to be shipped. Usually the same or similar packaging can be used for new products as the products often have similar exterior appearance... we tend to adjust the packaging to suit the pump instead of integrating the packaging into the development process of the pump."*

Considering the model for the integration of product and packaging defined by Bramklev et al (2005), the integration between product and packaging within Dresser Wayne is represented in figure 4-4. This figure shows clearly that it is sequentially the way they carry out these development processes.

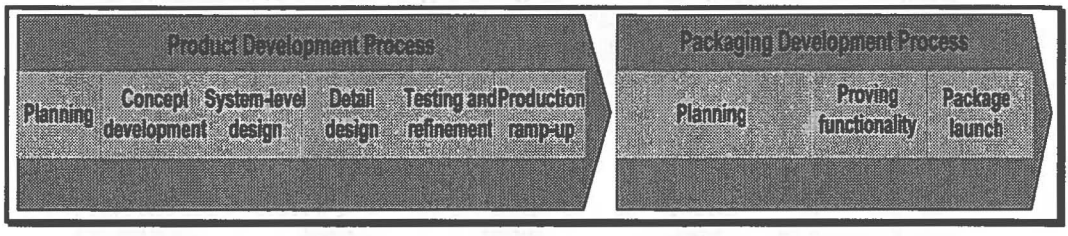


Figure 4-4: Sequential activities in Dresser Wayne

4.3.6 Concluding with supportive research questions

As has been expressed, this case has sequential development with redesign, so the supportive research questions for it were as follows:

- ***Why is not the process done in a concurrent way? Is it not necessary? Is it not possible?***
  Concurrent development is not even considered in the company. When the engineer in charge of the process was asked about why they did not consider a concurrent process to try to solve these problems the answer was clear: "*I personally think that the reason for not changing the development process into considering the packaging during the development process is that there are at the time huge pressure on the company to make the developments very quickly. We usually make the development based on requests from customers. If we do not come up with a product fast enough there is a risk that the customer will turn to our competitors. When there is lack of time we tend to concentrate on the product and not think about packaging and other "secondary" factors.*"

- ***Can be the entire process considered as successful?***
  The final result is almost satisfactory but some improvements can be done as well. Anyway, it is important to remark that a redesign ends in a complete lost of time and money that could be saved if things were done well from the beginning.

- ***Why was redesign necessary? and Which were the failures or origin of the redesign?***
  Redesign was necessary due to the terrific failures occurred in the distribution process, these failures affected the quality of the products, causing fatal damages in the pumps. There was also a high inefficiency in the packaging used, a lot of material was used and two workers were needed to assemble it around the pump, and the outer measurements of the set pump-packaging, exceeded the outer measurements of a euro-pallet.

- ***How is the redesign process? What is the difference with the original process?***

The main difference in the redesign is that now more aspects that influence the product along its life cycle are considered. In the redesign, packaging is considered in detail, with all the specifications and requirements the product will need. The original process just looked for a cheap and fast packaging. Anyway it is important to say that the redesign carried out in this company is just a redesign in the packaging and the product is not affected at all.

- ***Has the redesign solved the problems and the best solution has been reached?***
  The redesign has solved some problems, but not all the problems are solved, so the best solution has not been reached. It is very difficult to solve all the problems if the redesign is just performed in the packaging, it would be necessary to change some parts of the product (to reinforce the parts that are damaged for example) to help packaging in the protection aspect and therefore to obtain the best solution.

- ***Which problems have been faced when redesigning?***
  The main problem was the fact that the redesign was going to be applied just to the packaging and the product was not going to be modified. This circumstance caused that the new packaging had to solve all the problems, that is, the product was not going to help packaging to solve the problems, what ended in a narrower set of possible solutions.

- ***What costs and lead times are involved in the process? How are they modified?***
  For the whole process, including redesigning, the costs are the costs of the simple development (development costs, packaging costs, distribution costs...) of the product with the addition of the redesign costs (more packaging costs, damages' cost...). For the lead times, in this case is added to the development lead time, the total time for redesigning. For production lead time is reduced because the time for mounting the packaging is less once redesigned.

- ***Would it be possible to avoid these costs and to reduce these lead times by acting in a concurrent way?***
  Acting in a concurrent way, lead times would be clearly reduced because the extra-time of the redesign is completely eliminated, also there is a reduction in lead times for the processes with concurrent development if compared with sequential development. For the costs, the redesigning is always an extra-investment of resources, and also the extra-time can be identified with extra-cost.

- ***How does the redesign process affect the different activities along the supply chain?***
  Now the packaging can be transported in a euro-pallet, circumstance that will help transportation and subsequently will help in all the activities along the supply chain. Also, the consideration of these activities when the new packaging was been created help the set product-packaging to fulfil the requirements along the supply chain.

- ***What kind of indirect effects have being derived from the redesign process?***
  Non indirect effects were found for this particular case, all the effects were result of the study for the improvement of the set product-packaging.

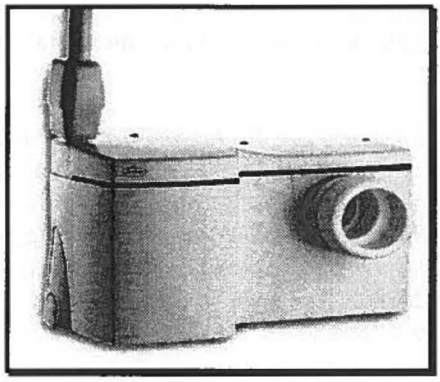
4.4 *Company A case*

Due to company policy it is not possible to include company's name. The company is a Spanish company working as a producer of pipes, bombs and sanitary mechanical devices.

4.4.1 Company introduction

Before the first personal contact with the company took place, a couple of phone calls were hold in order to know as much as possible about the product case that was going to be studied. Once we got a global picture of the company situation it was easy to prepare the interviews. The case was identified as in an intermediate situation between complete integration of product and packaging and no integration. The right supportive research questions for these conditions were the base for gathering data.

4.4.2 Product Description: Sanitary Macerator



Picture 4-12: Sanitary Macerator

The case studied in this Spanish company differs from the others analyzed cases in one important aspect. The product proposed for the research within this company had not been launched into the market yet and the company was in the middle of a new project for this product's development.

The macerator is a new model of an already existed and commercialized product of the company. This new model was pretended to be an advanced version of the existed one with diverse modifications in design and packaging.

The company faced several problems regarding normative laws and they realized the processes were not optimized. Package's weight needed to be reduced. It was thought that packaging could be an important feature causing the inefficiency in the different activities. That is why they decided to change the role the packaging had at that moment, with the intention of including its development somehow, when designing and developing the new macerator. The need of a packaging change motivates a new design for the new model.

When starting this case, the company had just begun the new project for including packaging into the macerator development.

Basing on the previous model and the already available findings from the study carried out inside the company (and in collaboration with an external company), we can provide with a general description of the product and the processes along its life cycle in order to the reader get an overall picture of the product (hence, dimensions are just to orientate).

The sanitary macerator is a macerating-pumping system that allows the building of fixed lavatory and bathroom facilities (WC, sink, bidet, urinal, shower) in non-usual places with easy installation in few hours.

The main components of the product are:

- The main body, which receives all the evacuation connections from the sanitary appliances.

- The motor set, which includes all the mechanical and electrical mechanisms.

The macerator has two side connections (1 ½"), for 40mm pipes, provided with non-return valves for the evacuation of other sanitary appliances and a evacuation connection to a 32mm pipe with anti-return valve.

Other general characteristics of the product are the maximum pumping height of 6m, the maximum pumping horizontal distance of 62m (or a combination of both distances) and the minimum discharge slope of 1%.

The macerator is designed to eliminate sewage, defecations and toilet paper. It must not be installed as food waste disposer connected to kitchen sinks or appliances equipped with pumps such as washing machines or dishwashers.

4.4.3 Distribution process description

The production and distribution of the new macerator model will be carried out in the same way it is being done for the other products in the company.

The company deals with more than 3500 different products and 15-20% of the products are supplied by external companies. The supplied components are stored in the company's facilities waiting for being required in further assembly activities. All the components produced in the several production processes carried out inside the facilities are stored in an intermediary warehouse as well.

When assembling the final product, the different parts and components are taken from the stock existing in this intermediary warehouse and the one containing the supplied products. The components in stock are used with the FIFO method (first in, first out) in this way the stock of material is renovating constantly.

After assembling the macerator it will be packaged and ready for being transported. As it has been already expressed, the company is in the middle of a new project where packaging development for the macerator is being considered while the macerator is being developed. Because of this situation we can not provide with the definitive packaging. Basing on the

previous macerator model and the findings we had access to of the project the company is carrying out at this time, the package that will be used for the new model will differ from the first one mainly in dimensions and total weight reduction (actually, those were required conditions for the new project). Apparently, the package will consist on boxes that perfectly adjust the dimensions of the product that will be partially dismantled for being packaged. The dismantled components will be placed inside the box as well.

In order to reduce costs, the company always tries to adjust to euro pallets for distributing the products. It is prior to optimize the space utilization when loading the products considering that the use of more than 80% of the volume is optimum.

The transportation of the product will be done mainly by trucks. Near 14 trucks leave the company for delivering the products and around 4 trucks are designated to exportation. Just when the final destination requires it, ships are used for transportation (Mexico, Morocco, Chile, Canada...).

4.4.4 Development procedure model description

Many areas within the company are involved in the development of products: Marketing, Commercial department, finances, Development department, Technical direction department, Quality department, Exploitation department...

This development process starts (as it usually does) with the marketing department. In this initial stage, a study of the market is carried out. In this study, tendencies, lacks and needs are studied, and a complete report of the market situation is presented to the general managers.

Once discussed and decided which product to do, development department starts its participation. The new application is registered there and starts the needs evaluation for the new product. Here it is important to be careful with the specifications requested to the product, more than necessary means a squandering, but less can be a reason for a future redesign. First sketches of the pieces are realised in this stage.

The next stage can be considered entirely economical. A complete costs study (not including packaging) is realized. This is a very critical part for the whole development process, as the next step of this phase is to study the viability of the launch of the new product. This study of the viability and the subsequent decision of continuing or not with the process will be strongly influenced by the previous costs study.

Obviously, if the project has been rejected, the development process ends here. If not, geometry and dimensions are defined, and first moulds are built. These moulds are for the plastic components and are designed and produced entirely within the company. Also a detailed MRP considering processes, times and components is created. The MRP is important for production efficiency.

Last step consists in the build of a prototype and the testing of it. The tests performed to the prototype provide some pieces of information to the engineers and designers to improve the product. These improvements do not end when the product is launched. When it is launched, key customers become "testers" and report the problems and suggestions for the improvement

There was no special procedure model for packaging. Once the product was developed it was decided the "best" packaging solution among the standard packaging alternatives (paperboard boxes, corrugated boxes, plastic bags...). Just when it was necessary, more complex packaging solutions were chosen. But all the decisions regarding packaging were something to consider when the development of the product was already done.

Therefore, there are no preceding acts in the company of integration (at none extent) of packaging development into one product development. There has not been interaction at all between these two activities within the company, so the design and development of the products have not been affected by the packaging before.

With the new macerator model, what was intended to do is to change the actual procedure for developing products in the company, including packaging in the development procedure. It was clear that the distribution processes were not as much optimized as they could be. The less effective feature that the company realized throughout these processes was packaging. The change was not considered before because it was thought the study's investment would not be worthy and the time consumption would be huge. But the company was forced to adjust to some law requirements. As mentioned before, among those requirements it was necessary a reduction in the package's weight (it was too heavy at that time) so taking advantage of that situation, the packaging was reconsidered completely.

The company, based on the old commercialized macerator model, started with the development and design (redesign indeed) of the new product where some modifications had been already carried out (at the time this thesis was conducted) in order to get a better mechanical product. With that first approach, a prototype was supplied to an external company specialized in packaging matters.

What was pretended to get out from this company is a complete packaging analysis for the new macerator. The analysis will include costs analysis, impact strength, packaging materials' quality, size optimization and environmental impact. And since the company is aware of its logistical problem, the packaging impact all through the supply chain processes is also important.

This analysis in depth was projected to be use for the final development and design decisions of the product. Some feedbacks regarding dismantle possibilities' designs have been already considered.

The company will decide the final product solution according to the best Time-Cost-Quality (quality expressed as impact resistances and strengths, forces) commitment.

4.4.5 Results

The conclusions we can draw from this analyzed case are merely based on expectations and thoughts of the company, because the product, the sanitary macerator, was in the way to be launched into the market hence, no results were available.

4.4.5.1 Potentials

- At the time this thesis was conducted, the called "A" company was investing an additional amount of money (there were no preceding activities like that) for a

packaging study. In spite of that "inevitable first" investment, the company expects to take advantage of it for future development processes and development cost reduction is expected for the future.

- The analysis carried out by the external packaging company was pretended to study different packaging alternatives in order to find out the best option to optimize the cost and functionality of the package.

- The concurrent development of product and packaging expected to have effect over the product design. There were anticipated limitations on the product, like accessories or conductions that project from the main body of the product and which difficult packaging or force to use bigger size packaging options. By developing packaging at the same time, all those parts can be studied and modified letting them to be dismantled.

- The main activities thought to be improved are distribution activities and specially, transportation. With the new product-packaging solution, the number of units loaded in one euro-pallet is going to increase from 12 boxes up to 28 boxes, keeping the same transportation height and ensuring a high protection level. The volume utilization is then improved in more than 50%.

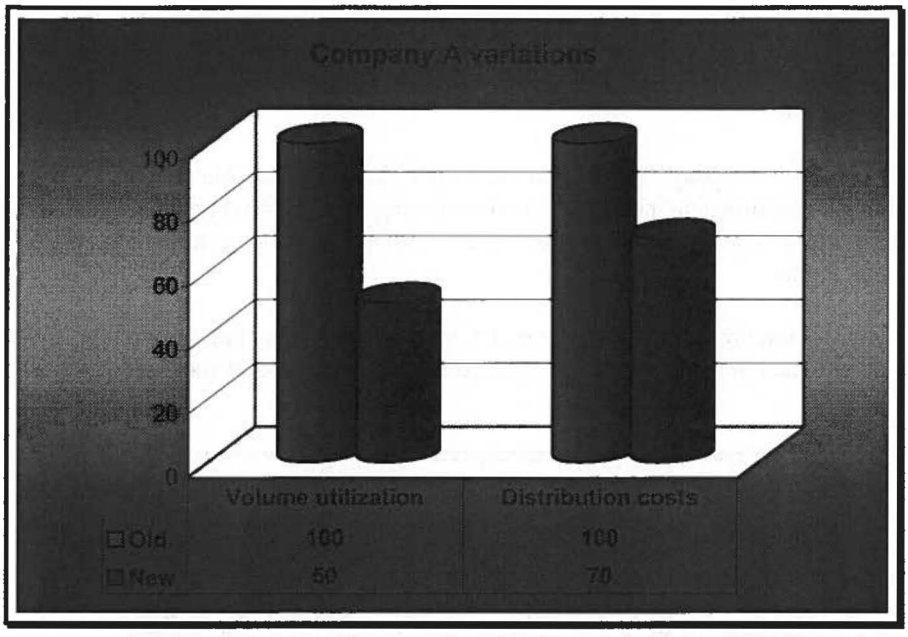
- The optimization of the transportation volume allows important distribution costs reduction. In fact, that reduction was calculated to mean approximately a 30%.

- Handling functions are affected as well, as the new packaging solution permit easier loading because of the smaller size and the reduction in the total product-packaging weight (due especially to the reduction on packaging weight). These functions' improvements will lead to times reduction.

- Due to the better transportation load, the environmental contamination is also reduced per unit of product transported.

- As the packaging analysis was carried out by an external company, several problems came up during the process; there were not almost interactions between the A company and the external one in charge of the packaging analysis during the process, so misunderstood features or detected problems were not so easy to treat. That is a clear example of the necessity of the company's global activities to integrate to each other.

- There was not before a real packaging development process within the company since packaging was erroneously not considered such an important feature in the global activities. With the help of the normative laws that forced them to several changes, they look forward to gain a lot in quality for the distribution activities.



Graphic 4-5: Percentage variations for Company A

4.4.5.2 Integration between product and packaging

As usual there are several similarities between company's procedure model and the one proposed by Ulrich & Eppinger. But there are also some activities realised in a different order than the one proposed by Ulrich & Eppinger.

- *Marketing needs*. Market study is realised here. It can be identified with the planning phase for Ulrich & Eppinger, but some activities considered by them are going to be realised later on (e.g. identify production constraints)

- *Concept development*. Needs and specifications for the product are considered here. First sketches are produced here. The main difference with the Ulrich & Eppinger stage is that no costs are estimated yet, but some activities from the design phases are carried out here.

- *Viability*. This is an extremely economical phase. The main difference between the procedure model of the company and the one by Ulrich & Eppinger is this phase. All the costs estimations and considerations are enclosed here with the identification (and cost assignation) of the production constraints. It is also important to notice that this phase has something peculiar that is the decision of doing or not the product. This decision is usually taken in the first steps of a process, but not here.

- *Design and MRP*. Packaging starts to be considered in this moment. First sketches were developed before, but now everything is specified. Geometry, dimensions and materials are chosen here. Also the moulds are designed and built in this phase. According to Ulrich & Eppinger, this phase can be identified with *system level design* and *detail design*.

- *Testing and refinement.* Prototypes are tested here, and some improvements are made on the product due to these tests. Ulrich & Eppinger have a similar phase with the same name.

- *Production ramp-up.* Production starts here. The introduction of key customers at the beginning allows the company to compile more information and suggestions about the possible problems of the product. Ulrich & Eppinger have a similar phase with the same name.

As said before integration between product and packaging is not an activity with a long tradition inside the company, but in the studied case this interaction starts working.

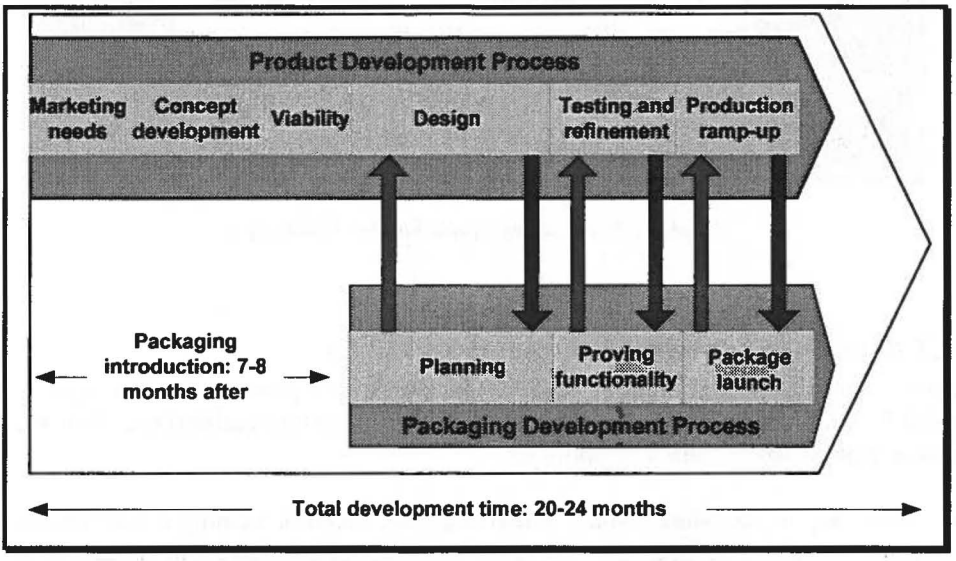


Figure 4-5: Integration between product and packaging for company A

4.4.6 Concluding with supportive research questions

- ***How is the procedure model for developing products in Company A?***
  For the development of products many areas within the company are involved. The development process starts in the marketing department. A big development team is in charge of the evaluation of the product needs. After economical and production estimations, prototypes are manufactured and tested.

- ***Does packaging something to do within the procedure model?***
  For the other products commercialized by this company, packaging is not considered until the product is completely developed and designed. Once the product is developed it is decided the "best" packaging solution among the standard packaging alternatives. Just when it is necessary, more complex packaging solutions are chosen. With the new

version of the macerator the company has decided to make use of an external company specialized in packaging solutions.

- ***Why this change? Was it necessary?***
  There existed some normative laws the company had to adjust to and it was believed it was time to make changes because the processes were not as good as they could be. Weight and dimensions of the packaged products were higher than desirable.

- ***Why was packaging part of the change within the development process?***
  It was thought that packaging could be an important feature causing the inefficiency in the different activities, especially for the distribution process.

- ***Why was not packaging considered from the beginning? Was it not possible, not worthy?***
  Packaging was not considered to be really important for the success of the company activities. The company is taking advantage of the actual situation for getting improvements regarding packaging issues.

- ***What did the change (with packaging integration) consist on? What are the differences with the old development process?***
  An external packaging company is hired to take part in the development process. When the product is being developed, this external company specialized in packaging analyzes a prototype of the product and evaluates the different aspects that can be important for the packaging solution and the product design itself.

- ***Is packaging introduction into the development process going to solve the "problems" that motivated the change?***
  That is the intention of the Company A; the external packaging company is asked to provide with a lighter and smaller packaging solution.

- ***Which problems have been faced because of the change?***
  As the people in charge of the packaging development are external to the company, it becomes difficult sometimes to take common decisions because they are not involved in the process from the beginning and it seems they have interest just on their "part of the work". Things could be faster.

- ***What benefits are expected to be achieved? How is the new development process expected to influence the activities along the supply chain?***
  Transportation activities are expected to be greatly benefited involving less costs and better conditions so letting to improve the quality of the processes. Space utilization is looked for being optimized resulting on better storage and transportation conditions.

- ***What costs and lead times are going to be involved or affected by the process? How are they going to be affected?***
  At this time, the development costs are higher than they usually are but it is because of the investment the company is doing with the new "general packaging procedure". But the company expects to take advantage of this situation and the cost of future development processes is estimated to be reduced. Costs for distribution activities, especially during transportation, are believed to be noticeable reduced. Development time will be somehow affected; before there was hardly time consumption for

packaging considerations and now, even if packaging and product study are performed somehow at the same time, it will end in higher time consumption.

- ***Are there expected or already found indirect effects derived from the procedure redesign process?***
  There are no available results so it is not possible to know what will happen as indirect effects.

5 CROSS CASE CONCLUSIONS

It has been introduced at the beginning of this thesis, that packaging, due to the important role that plays in logistical activities, is a feature increasing in importance in the last decade. The results of the study of product and packaging integration concept showed a clear support in the industry. What has been done during this research work is to look for advantages from such integration to illustrate the benefits that can be gained in order to the companies put resources on implementation.

All the research process has been faced with two focuses according to the general research questions established:

What are the advantages for the companies to integrate product and packaging development?
and
How integrated product and packaging development is implemented within the studied companies?

However, due to the general characteristic these two questions poses it was decided to support the investigation with additional specific research questions. These questions, introduced in the methodology chapter, have been adjusted to each specific case situation and answered at the end of every case studied. These answered research questions are going to be collected in this concluding chapter distinguishing between two different groups of questions; those connected to potential benefits and results of the integration and those related to the way the integration is performed in the diverse companies. Doing so, it will be easier to analyze the results and to draw proper conclusions.

5.1 *Potentials conclusions*

As expressed by the established general purpose, this thesis work intended "*to examine and evaluate the advantages achieved through concurrent product and packaging development on an operational level in industry*".

The key research questions related to the evaluation of the advantages found out in the different cases are next repeated. The results of these research questions will contribute to the cross case analysis for drawing conclusions of the potential benefits of integration. Afterwards, the potentials will be again connected to the advantages expected at the beginning of this thesis and analyzed by providing "values" to the diverse advantages according to every case's results.

These are the mentioned questions:

Nederman

- ***What benefits are achieved because of product and packaging concurrent development?***
  The tailor-made packaging for the supply of components provides with much more efficient handling activities. The processes have become easy-to-automate. Regarding lead times it is impossible to know if time benefits are due to integration activities because of the changes in the last years for the company. The number of workers has been noticeable reduced and production is increased. Also, integrating the packaging

development into the product development influences the product development itself because several decisions related to product design and supply of components can vary according to the development of the packaging

- ***How does the concurrent development affect the different activities along the supply chain?***
  The activities are easier to perform involving less time and money consumption because when the company creates the packaging all the logistical activities are considered by them. But not just their own packaging is considered by Nederman; also the concurrent engineering carried out with other suppliers makes them to consider their logistical activities. These logistical activities are improved because of the tailor made packaging (usually developed by Nederman) for the supply of the components; volume utilization is optimized for some components' distribution.

- ***Are all the problems solved with the concurrent development of product and packaging?***
  Considering packaging as another component of the product makes that more aspects and requirements that the product is going to need in future activities are defined from the beginning so the risk of mistakes or failures is decreased. But this risk is not completely eliminated because always exist an uncertainty component about new requirements or new laws that can modify the optimal solution.

- ***What kind of indirect effects have being derivate from the concurrent process?***
  The improvements on productivity and the automation of the assembly line can be considered indirect effects of packaging integration. The increase on productivity is related with the automation, and both are related with the fact that new packaging is easier to handle by mechanical artefacts. But this improvement was not considered when they were creating the new packaging; that is why it can be considered as an indirect benefit.

- ***Which problems have been faced when concurrently developing?***
  The main problem for the company was that the flow of information among all the companies involved a continuous communication among the company, what implies a lot of effort. It is of crucial importance that this information is very fluent, if not the risk of failure is very high. The problem they had to face was that they had to be very careful at the beginning (later on this fluent communication is realised automatically) to avoid the lack of communication among the parts.

Istobal

- ***Which benefits, in terms of costs and lead times, are achieved?***
  As expressed by the company, it is difficult to get numbers of development times because due to the new technologies influence (3D design techniques for example), it is complicated to say if the reduction is just because of the concurrent development or these new technologies have something to do with it. But the time required for the development of products (considering both product and packaging development) is estimated to be reduced (because of the concurrent development) in approximately three weeks. Considering the cost, there has been a significant reduction in distribution

and packaging costs for both products. As well a slight damages reduction makes total costs decrease.

- ***Which problems have been faced when concurrently developing?***
  The main problems occurred when developing were at the beginning of the implementation of the new procedure model. These problems arise because all the activities were completely different and the workers needed a time to adapt to this new way of acting.

- ***How does the concurrent development affect the different activities along the supply chain?***
  All activities along the supply chain are considered from the beginning and before product and packaging are designed. This situation gives the final product the opportunity to pass through all the activities with a high quality performance.

- ***Are all the problems solved with this concurrent development or some problems are not possible to avoid even with this method?***
  Not all the problems are solved, because always some new circumstances and requirements can arise once the product is already developed like some modifications in the distribution channels or even some law modifications. But as the engineers in Istobal said: *"The more requirements that can be defined from the beginning, the less risks and inefficiencies the company will have in the future".*

Dresser Wayne

- ***What costs and lead times are involved in the process? How are they modified?***
  For the whole process, including the redesigning the costs are the costs of the simple development (development costs, packaging costs, distribution costs...) of the product with the addition of the redesign costs (more packaging costs, damages' cost...). For the lead times, in this case is added to the development lead time, the total time for redesigning. For production lead time is reduced because the time for mounting the packaging is less once redesigned.

- ***Would it be possible to avoid these costs and to reduce these lead times by acting in a concurrent way?***
  Acting in a concurrent way lead times would be clearly reduced, because the extra-time of the redesign is completely eliminated, also there is a reduction in lead times for the processes with concurrent development if compared with sequential development. For the costs, the redesigning is always an extra-investment of resources, and also the extra-time can be identified with extra-cost.

- ***How does the redesign process affect the different activities along the supply chain?***
  Now the packaging can be transported in a euro-pallet, circumstance that will help transportation and subsequently will help in all the activities along the supply chain. Also, the consideration of these activities when the new packaging was being created helped the set product-packaging to fulfil the requirements along the supply chain.

- ***What kind of indirect effects have being derivate from the redesign process?***

Non indirect effects were found for this particular case; all the effects were result of the study for the improvement of the set product-packaging.

Company A

- ***What benefits are expected to be achieved? How is the new development process expected to influence the activities along the supply chain?***
  Transportation activities are expected to be greatly benefited involving less costs and better conditions so letting to improve their quality. Space utilization is looked for being optimized because of the new packaging dimensions and measures, resulting on better storage and transportation conditions. The design of the new macerator is influenced by the new packaging solution; in this way, the product in an early basis is considered to have possible disassembled parts, thus facilitating assembly and production activities.

- ***What costs and lead times are going to be involved or affected by the process? How are they going to be affected?***
  Because of the especial and with no preceding situation, the development costs are higher than usually but it is due to the investment the company is doing with the new "general packaging procedure". Anyway, the company expects to take advantage of this situation and the cost of future development processes is estimated to be reduced. Costs for distribution activities, especially during transportation, are believed and estimated to be noticeable reduced. Development time will be somehow affected; before there was hardly time consumption for packaging considerations and now, even if packaging and product study are performed somehow at the same time, it will end in higher time consumption.

- ***Are there expected or already found indirect effects derivate from the procedure redesign process?***
  There are no available results so it is not possible to know what will happen as indirect effects.

Considering the results of the research questions and in order to cross the results from the individual cases it has been defined a range of values for each advantage analyzed. The definition of the percentage ranges was done taking into account interviewees' experiences. They settled a range of values they considered that could be optimum for the company to achieve, another range considered as good, a third one were no real impact would be considered if obtained and the two last ranges where something has to be changed. In this way, for each "quantitative" advantage, the percentage values represent the reductions in costs or times got that would represent very good, good, indifferent, bad or very bad result for the company. Negative intervals involve negative reduction, that is, costs or times increases. The values matching with the companies' performances are (2, 1, 0,-1,-2). These values are realistic for these companies, but they should be considered as an orientation that will depend very much on the company activities. According to the results got along the study and the personal opinion of the people within the companies, the different cases/companies will be scored for the several advantages. The results are depicted below in matrix form.

Development costs reduction

- >10% → 2

- 1-10% → 1
- 0-1% → 0
- (-5)-0% → -1
- <(-5)% → -2

It has been difficult for the companies to match general costs and time reduction with integrated actuation so everything is very relative and therefore it has been considered that costs and times reductions are likely to be caused not just for integration issues, so little reductions can not be representative. That is why first little variations correspond to 0 in all the cases.

Assembly cost reduction

- >30% → 2
- 10-30% → 1
- 0-10% → 0
- (-10)-0% → -1
- <(-10)% → -2

Distribution costs reduction

- >30% → 2
- 10-30% → 1
- 0-10% → 0
- (-5)-0% → -1
- <(-5)% → -2

(Lead) times reduction

- >1 month → 2
- 1 week-1 month → 1
- 0-1 week → 0
- (-2)-0 weeks → -1
- <(-2)weeks → -2

For the other advantages analyzed, **impact on productivity/resources utilization, quality of processes and environmental impact**, no ranges are established and the values will be assigned basing on the qualitative results and interviewees' opinions. **Concurrent engineering** is another aspect that has been included in this analysis considering it as an important tool to integrate different activities.

Criterion / Company	Development cost reduction	Assembly cost reduction	Distribution cost reduction	Lead times reduction	Impact on productivity	Quality of processess	Impact reduction on environment	Concurrent engineering	Total marks for companies
Nederman	-	2	0	1	1	2	1	2	9
Istobal (M18+)	1	2	2	1	1	2	0	1	10
Istobal (4PJ)	1	1	2	2	1	2	1	1	11
Dresser Wayne	-	-	1	1	0	1	1	-2	2
Company A	-1	0	2	1	0	2	1	0	5
Total marks for criterions	1	5	7	6	3	9	4	2	

Table 5-1: Matrix with final results

Development costs reduction

For each company it is considered product development and packaging development, performed concurrently or not. In the case of Nederman it was not possible to compare actual development costs (with product and packaging integration performed) with other procedures' costs (with no integration) because the company's development procedure has not changed. According to the interviewees things are done in the same way for a long time and that is why there is no support within this case for a development cost reduction. For both, M18+ and 4PJ in Istobal, the development procedure model is the same capturing costs reduction of approximately 1- 6%. Since Dresser Wayne does not perform integrated development at any extension it is not possible to know what benefits could be gained; there is no support for the cost reduction in this case either. And finally, company A's development procedure is changing and additional investment is necessary for the improvement, so there is not costs reduction but increase. Anyway, future development processes will take advantage of this change and development costs could maybe be reduced in the future.

Assembly costs reduction

Nederman assembly process is highly rewarded by integrating product and packaging development and using it for the supply of components. The number of workers has been reduced and the automation degree is high, ending in easier assembly activities. Istobal in its two cases has showed better assembly processes due to the inclusion of packaging development into product development; since everything is deeply specified from the very beginning assembly activities are easier to carry out, especially for the M18+ assembly process with the six disassembly alternatives. Dresser Wayne case, again has nothing to say in this advantage, because the redesign process performed does not affect to the assembly

processes of the product. The company A does not expect costs reduction in the production/assembly activities for the macerator.

Distribution costs reduction

Nederman distribution activities were not considered to be very influenced by product and packaging integration. Product handling activities are better carried out and general distributions of the components involve costs reduction for the final product but the total costs reduction for the product is affected just at low extent. For Istobal, main advantages of its integration are distribution results; with the disassembly alternatives the company optimizes space utilization in both trucks and ship transportation, reducing costs in more than 30%. Dresser Wayne results can be used for this advantage considering the benefits gained by the packaging redesign as potential benefits from an integrated perform; packaging activities (packaging of the pumps), handling and transportation activities are improved after the packaging redesign. Company A expects its distribution processes, mainly transportation issues, to be greatly benefited with noticeable costs reduction; that was the main reason for the procedure's change.

Lead times reduction

When considering lead times, all times are really taken into account; time reduction in different processes can mean important total lead times reduction. But it is again important to remember that additional issues as new technologies, the own experience and so on, can affect significantly the activities and there is no way of judging those effects. Nederman's lead times are to some extent reduced because of the better assembly line and handling activities of the different components and the product. The two products in Istobal provides several time reductions; the development phase is estimated to be reduced in approximately 3 weeks and handling is much easier and faster to perform (due for example to the addition of the rings to lift the machines). Besides, for the 4PJ model, more important times reduction are achieved because of the logical improvement in packaging, handling and transportation activities of just one shape that is the third part of the previous used volume. Dresser Wayne also gains time reduction with its redesign process since packaging time is decreased, but that is not that significant. Company A's thoughts anticipate some benefits regarding activities' time specially distribution time (though due to the actual state time consumption is being higher than desirable in the development phase).

Impact on productivity/ resources utilization

Although it has been stated by the interviewees that it is hard to know the real reason for better production activities, the production improvements found out can be related somehow to integrated activities. That is the case for the first three cases, Nederman, Istobal M18+ and Istobal 4PJ, where production volume experiments increases since product and packaging matters are done concurrently. No production variation is either found out in Dresser Wayne or expected in company A.

Quality of processes

This is probably the proposed advantage best supported by the companies. They all claim for improvements in several processes, especially during distribution. But due to the quantity of improved processes and the results obtained of those improvements, Nederman, Istobal and company A get better values.

Environmental impact

In order to somehow judge environmental impact, wasted materials and environmental contamination have been taken into account. In this way, scrapping hose in Nederman involves a reduction of wasted material of 24000 metres. Distribution improvements in Istobal mean as well less transport vehicles per unit of product so environmental impact reduction is gained with the 4PJ machine. Packaging figures in Dresser Wayne show reduction of 7% of material used with consequent environmental benefits. One of the intentions of the company A's packaging external study is to analyze environmental consequences of the packaging used looking for better solutions in this environmental matter.

Concurrent engineering

Nederman can be considered as the company that better performs concurrent engineering. They deeply interact with their suppliers using it for improving their activities when assemble/produce their products; the integration is such that Nederman even design components' packaging for their suppliers' supply. In Istobal, concurrent engineering is not at that high extent (it does not hardly exist contact with their suppliers but components' supply is not as important as it is for Nederman). Anyway, all the other product life cycle activities are taken into account early in the processes. General procedures for Dresser Wayne were not provided so it is unknown how concurrently activities are done. Basing on packaging actuations, where things are done completely sequentially, correcting failures rather to trying to avoid them, it can not be established the company to carry out concurrent engineering for all the necessary features. Company A's new procedure is intended to restructure company's actuation regarding concurrent activities by integrating packaging and packaging suppliers in the product development phase. However, at this moment, packaging development process is somehow separated because it is carried out outside the company and the interaction between the two companies is not very fluent.

Regarding companies, there is a clear difference comparing results from Istobal and Nederman and the other two companies. The results give Istobal an average of 10,5 points, that is a little advantage compared with Nederman, but both of them are clearly superior to the others. For both companies there is a clear improvement in quality of processes, while the distribution costs are clearly reduced for Istobal and for Nederman these costs have not been affected significantly. These two companies have a procedure model similar to the one presented by Bramklev et al (2005). On the other side is situated Dresser Wayne. This company finally solves some of the problems originated not by integrating product and packaging development, but with a redesign what raises considerably the final costs of the total process. This redesign has been "penalised" in the matrix by the concurrent engineering criterion.

Concerning criterions, the following can be set as the general conclusions of the study carried out in the selected companies:

There is no a clear support in the results to confirm the reduction of development costs due to product and packaging integration, but it was neither possible to have enough access to relevant data to conclude anything about it. However, as one of the main basis of concurrent engineering and according to Capuz (1999), the integration of activities during development phases decreases the costs since the need of money investment is reduced. Regarding production and assembly processes, it can be said that these processes differ a lot concerning characteristics and importance from one product to another; thus, cost reduction associated to concurrent development will depend at high extent on the own characteristics of such activities within the company. Time reduction is key factor in concurrent engineering but

according to the results of the cases study, time reduction seems to be an advantage the companies are not directly looking for when integrating product and packaging. It can be then considered that time reduction is a fact when integrating but in some cases it is an indirect result. It is important to insist on the idea that additional issues as new technologies, experiences, etc, can affect significantly the activities and there is no way of judging those effects. This is the same case for the environmental impact and the impact on productivity; it is really difficult to know which the real direct causes of productivity variations are, but the production is well affected directly or indirectly, by concurrent development.

From the results got along the whole research process, according to the research questions answers and after evaluating the different companies' performances, there are two criterions that are clearly and directly improved because the integration of product and packaging: *distribution cost* and *quality of processes*. For the distribution, all the data collected and the interviews realized remark the importance of packaging when distributing. In fact, interviewees considered help-in-distribution as maybe the most important characteristic for the packaging. So the improvements realized in packaging by integrating its development with the product development, end with an improvement in logistical activities. Considering the quality of processes (quality in terms of cost, time and resources utilization), it is concluded that all the processes in general, specially the distribution ones, are improved. This is essential, because one of the main ideas when developing together two activities (or in Dresser Wayne case when redesigning) is to improve the processes and to obtain the maximum effectiveness on them.

Concurrent engineering, integration, and in the context of this study, the integration of activities during product and packaging development should be considered essential for the performance of activities and the overall business of the companies. The cases studied did not showed total integration between product and packaging, just Istobal reflected a similar integration with the model proposed by Bramklev et al (2005). That is why it would be good to study the implementation of real total product and packaging integration in order to generalize and extent the potentials.

Development and design costs mean between 5-10% of the total cost of the product. However, during the development phase, between 70-80% of the total costs along the product life cycle are established. (Capuz, 1999) Hence, it becomes much better and convenient to try to reduce costs during development process rather than once it is carried out.

It can be said that, as a general rule, the necessity of adjusting to normative rules or procedure requirements is seized by companies to improve their processes; somehow companies need a "push" to make them invest for new actions.

Regarding redesign processes, it is clear that redesign is a common practice within mechanical industry. Companies are, to some extent, continuously redesigning products and processes. The importance of being more efficient, effective and competitive in the market is well known and companies must be aware of the opportunities in order to take advantage of them. At last, every redesign process is meant to get better results and that involves things are not optimized from the beginning. It must be said also that sometimes it is necessary to change performances because of industrial progresses or new situations but things are done the best way it is possible. From the research results it can be deduced the great importance of integration and concurrent engineering, and particularly, packaging integration provides noticeable benefits during different important activities along the product life cycle, especially

distribution activities. Due to companies' policies it was hard to get figures supporting benefits; all the interviewees claimed for the clear advantages but when asking them for numbers the answers were not that clear.

Therefore, taking into account earlier in the development process the packaging and other activities required, guarantees a more efficient product development reducing the risk of failure and consequent need of redesign.

By cross casing the results it has been set that logistical activities and distribution, both in reduction of costs and the improvement of the quality for carrying out such activities, are the greatly benefited by product and packaging integration. This result emphasizes the idea of the great importance, in logistical support, packaging has. Packaging, far from be something forced to do, have to be considered an extension of the product, providing aspects and additional characteristics during several activities that increase the value of the own product.

5.2 *Integration between product and packaging conclusions*

This part of the thesis will try to summarize how the integration between product and packaging within the companies is and mainly what kind of integration would be the most beneficial. The supportive research questions for the companies related with this integration are:

Nederman

- ***How is the procedure model for developing products in Nederman?***
  The procedure model helps Nederman to organize the different activities of the product development on an easy way; it is used as a guide. The whole company is involved in some way in the development process, but it is not until the project time phase when the packaging (and all the other suppliers as well), are starting to be considered.

- ***How is the concurrent development process? What is the role of packaging in this process?***
  There is a flow of activities; within all them, features of the product regarding packaging, installations… are taken into account in order to improve future processes. Packaging is considered as another component of the product. Usually one year before starting production, a prototype of the product is sent to the packaging designers, outsource companies, and at this point is when the interaction between product and packaging starts. When this interaction starts, the information flows continuously from Nederman to their suppliers and from the suppliers to Nederman.

- ***What activities are considered concurrently? Which are the contact points?***
  The companies in charge of packaging solutions receive the information and specifications from Nederman in meetings where they, as well, provide Nederman with some feedbacks and suggestions of the product and packaging. So the interaction is in both ways and occurs several times along the process. The first contact point is the moment when Nederman provides the packaging supplier with the first prototype/idea of the packaging. Since there almost every week they have a

conversation about suggestions, new requirements and new ideas about how to improve the packaging.

Istobal

- ***Why is the concurrent development implemented?***
  Due to the obligation of the fulfilment of the ISO normative, the company changed its procedure model to adapt it to the new normative. As everything was revised and modified, the company decided to create a new model for the development of products where everything was considered from the beginning of the process to get a more structured model in which the oversights and mistakes were almost eradicated.

- ***How is the concurrent development process? Why is it that way?***
  This question has been replied in the previous section of this case study.

- ***What activities are considered concurrently?***
  For the development process of product and packaging, all the activities are considered in parallel except perhaps the initial phase of the product development (when searching for needs) because in some cases the needs that are searched have to do just with the implementation of new technologies for the products (M18+). But some other cases, the needs are just failures in the distribution process (4PJ) that have to be improved, so packaging is considered in all the activities.

- ***Which are the contact points?***
  Along the whole development process there exist a continuous flow of information between the product development process and packaging development process. Actually it is considered by the company that both processes are merged just in one with the same development team.

Dresser Wayne

- ***Why is not the process done in a concurrent way? Is it not necessary? Is it not possible?***
  Concurrent development is not even considered in the company. When the engineer in charge of the process was asked about why they did not consider a concurrent process to try to solve these problems the answer was clear: "*I personally think that the reason for not changing the development process into considering the packaging during the development process is that there are at the time huge pressure on the company to make the developments very quickly. We usually make the development based on requests from customers. If we do not come up with a product fast enough there is a risk that the customer will turn to our competitors. When there is lack of time we tend to concentrate on the product and not think about packaging and other "secondary" factors.*"

- ***Can be the entire process considered as successful?***
  The final result is almost satisfactory but some improvements can be done as well. Anyway, it is important to remark that a redesign ends in a complete loss of time and money that could be saved if things were done well from the beginning.

- ***Why was redesign necessary? and Which were the failures or origin of the redesign?***
  Redesign was necessary due to the terrific failures occurred in the distribution process, these failures affected the quality of the products, causing fatal damages in the pumps. There was also a high inefficiency in the packaging used, a lot of material was used and two workers were needed to assemble it around the pump, and the outer measurements of the set pump-packaging, exceeded the outer measurements of a euro-pallet.

- ***How is the redesign process? What is the difference with the original process?***
  The main difference in the redesign is that now more aspects that influence the product along its life cycle are considered. In the redesign, packaging is considered in detail, with all the specifications and requirements the product will need. The original process just looked for a cheap and fast packaging. Anyway it is important to say that the redesign carried out in this company is just a redesign in the packaging and the product is not affected at all.

- ***Has the redesign solved the problems and the best solution has been reached?***
  The redesign has solved some problems, but not all the problems are solved, so the best solution has not been reached. It is very difficult to solve all the problems if the redesign is just performed in the packaging, it would be necessary to change some parts of the product (to reinforce the parts that are damaged for example) to help packaging in the protection aspect and therefore to obtain the best solution.

- ***Which problems have been faced when redesigning?***
  The main problem was the fact that the redesign was going to be applied just to the packaging and the product was not going to be modified. This circumstance caused that the new packaging had to solve all the problems, that is, the product was not going to help packaging to solve the problems, what ended in a narrower set of possible solutions.

Company A

- ***How is the procedure model for developing products in Company A?***
  For the development of products many areas within the company are involved. The development process starts in the marketing department. A big development team is in charge of the evaluation of the product needs and after economical and production estimations, prototypes of the products are manufactured and tested.

- ***Does packaging something to do within the procedure model?***
  For the other products commercialized by this company, packaging is not considered until the product is completely developed and designed. Once the product is developed it is decided the "best" packaging solution among the standard packaging alternatives. Just when it is necessary, more complex packaging solutions are chosen. With the new version of the product studied, the sanitary macerator, the company has decided to make use of an external company specialized in packaging solutions.

- ***Why this change? Was it necessary?***

There existed some normative laws the company had to adjust to and it was believed it was time to make changes because the processes were not as good as they could be. The weight and the dimensions of the packaged products were higher than desirable and that involved non optimum processes.

- ***Why was packaging part of the change within the development process?***
  It was thought that packaging could be an important feature causing the inefficiency in the different activities, especially for the distribution process. The company is aware of the importance packaging is acquiring in logistical activities and they are willing to put resources on improving packaging conditions.

- ***Why was not packaging considered from the beginning? Was it not possible, not worthy?***
  Packaging was not considered to be really important for the success of the company activities. At this time, the company is taking advantage of the actual situation for getting improvements regarding packaging issues. The investment and the time consumption were considered to be huge and not worthy.

- ***What did the change (with packaging integration) consist on? What are the differences with the old development process?***
  An external packaging company is hired to take part in the development process. When the product is being developed, this external company specialized in packaging, analyzes a prototype of the product and evaluates the different aspects that can be important for the packaging solution and the product itself. The analysis performed by the external company will include costs analysis, impact strength, packaging materials' quality, size optimization, environmental impact and packaging impact all through the supply chain processes. This analysis in depth is projected to be use for the final development and design decisions of the product. Before this project, there was not packaging development process and packaging decisions were taken after the product was completely developed.

- ***Is packaging introduction into the development process going to solve the "problems" that motivated the change?***
  That is the intention of the Company A; the external packaging company is asked to provide with a "better" packaging solution (at least, a lighter and smaller packaging solution) which let the company to adjust to the normative requirements improving at the same time distribution processes.

- ***Which problems have been faced because of the change?***
  As the people in charge of the packaging development are external to the company, it becomes difficult sometimes to take decisions because they are not involved in the process from the beginning and it seems they have interest just on their "part of the work". Besides, development activities could be faster carried out if the interaction between packaging and product development's teams were more regular.

First of all it is important to talk about the development process of the companies. All the cases studied are referred to companies that create industrial products. That is the reason why the model used as a pattern for the theoretical study of the cases is the one created by Ulrich & Eppinger (2003). This procedure model will differ from one company to another, but the companies will always have a more or less detailed development process because it will help

them for the following reasons expressed by Ulrich & Eppinger (2003) (and defined in the frame of reference): *quality assurance, coordination, planning, management* and *improvement*. All the companies studied in this thesis have remarked in the interviews the importance of having a good procedure model because it makes their work easier and all the important things are considered when they have to be considered. They also declared that the procedure model helps the company to use the experience and knowledge acquired in previous development processes.

All the procedure models of the product development described before for every case and company have a similar structure and this similar structure is also similar to the structure proposed by Ulrich & Eppinger (2003). It is important to remark that all the procedure models described have been expressed as the companies described in the interviews, trying to keep the names they give to the different phases, even if in some cases they are more or less the same to Ulrich & Eppinger (2003) phases. The idea with this is to show that even if things are called different and the interviewees think their company develops products completely different to the other companies, if the procedure models are studied in depth all of them have the same final objective as the one described by Ulrich & Eppinger (2003).

For the packaging development process, the one chosen as a pattern for the thesis is the one created by De Maria (2000). Here the similarities between this theoretical model and the one carried out by the companies are not as clear as the ones for the Ulrich & Eppinger (2003) model. In general the processes are identified with the process proposed by De Maria, but it is just a theoretical idealisation to help comprehension and to state clearly the contact points. The real packaging processes are not clearly differentiated to the product development processes. For Istobal and Nederman for example it is extremely difficult to distinguish these two processes. On the other hand, Dresser Wayne has independent processes, but as they do not develop the package in the company (they use SCA services), it is difficult to identify the packaging development process clearly.

There are three cases (Nederman and Istobal, and lately Company A) where the consideration of the packaging is early in the process, but this consideration has several differences with the model expressed by De Maria (2000). For these companies the packaging is considered as another activity (or component) of the product so, even if there are some activities similar to De Maria's model, these activities are considered inside the development process of the product. This means that when integration is carried out in depth, the packaging development process looses its identity and becomes a part of the product development process. In other words, the two development processes carried out in parallel become merged and constitute an only development process with packaging as a part of it. It can also be considered as a procedure model with a design for packaging included.

For Dresser Wayne (and also in Nederman for some products) things are completely different. They do not integrate both activities they just create a product and then start to think about the packaging. For this kind of acting, considerations are different. It can be thought that they would follow a process similar to De Maria's (2000), but in fact this is not completely true. The set of activities and the order of them are similar to the theoretical model, but not as detailed as De Maria (2000) expressed, that is, several activities are skipped. This has a very easy explanation, which is that the main characteristic they ask to the packaging solution is to be cheap and fast. These kinds of solutions usually have disastrous consequences as are expressed on the cases description.

As expressed by the results, particularly the concurrent development of product and packaging and in general the use of the concurrent engineering, that is the use of as much activities as possible in a concurrent way, results in clear benefits for the companies. As derived from the results, the highest benefits obtained by a company correspond to Istobal, which has also the closest development procedure model to the one proposed by Bramklev et al (2005). For the other companies the relation between benefits and integration degree follows the same guideline as for Istobal; that is higher integration means higher benefits for the companies. That way, the order of the companies that get better results (as well as have higher integration) is: Istobal, Nederman, Company A and Dresser Wayne.

Even though it is important to point out that the model proposed by Bramklev et al (2005) is a theoretical model and hence does not reflect exactly the real way the companies act. The results of the cases analyzed conclude in a support to this theoretical model. This support is because the more similar a procedure model is (in the cases studied) to the proposed one, the higher benefits a company obtains.

References

Andreasen, M. M., Hein, L. (1987). *Integrated Product Development.* Bedford, UK: IFS (Publications) Ltd / Springer-Verlag.

Armstrong, G., Kotler, P. (2005). *Marketing: an Introduction.* 7th ed. Upper Saddle River, New Jersey: Pearson Education, Inc.

Arteology (2004). *Developing an Industrial Product*: http://www2.uiah.fi/projects/metodi/130.htm

Bakker (editor), M., Brody (editor), A., Marsh (editor), K. (1997). *The Wiley Encyclopedia of Packing Technology.* 2nd Ed. New York: John Wiley & Sons Inc

Barba, E. (2001). *Ingeniería Concurrente: Guía para su implantación en la empresa.* Barcelona: Ediciones Gestión 2000

Barba, E. (2005). *Innovación de Productos mediante Ingeniería Concurrente.* Barcelona: Ediciones Gestión 2000

Bjärnemo, R., Jönson, G. and Johnsson, M. (2000). Packaging Logistics in Product Development. Proceedings of the 5th International Conference: Computer Integrated Manufacturing (ICCIM'97). Singapore: Springer-Verlag 2: 951-960.

Bramklev, C. (2004). *Concurrent Development of Product and Packaging - towards an integrated development procedure.* Division of Packaging Logistics, Department of Design Sciences, Lund Institute of Technology at Lund University.

Bramklev, C., "Lecture notes from the course MTT032: Packaging Technology", Division of Packaging Logistics, Department of Design Sciences, Lund Institute of Technology at Lund University, Lund, 2005.

Bramklev, C., Bjärnemo, R., Jönson, G. and Johnsson, M. (2005). Towards an Integrated Design of Product and Packaging. International Conference on Engineering Design (ICED 05). Melbourne.

Byrne, P. M., Markham, W. J. (1991). *Improving Quality and Productivity in the Logistics Process.* Council of Logistics Management.

Cambridge University Press. (2005). Cambridge Dictionaries online: http://dictionary.cambridge.org

Capuz, S. (1999). *Introducción al Proyecto de Producción. Ingeniería Concurrente para el Diseño del Producto.* Valencia: Servicio de Publicaciones de la UPV.

Christopher, M. (2005). *Logistics and Supply Chain Management.* 3rd ed. Harlow, England: Pearson Education, Ltd.

Clark, K. B., Fujimoto, T. (1991). *Product Development Performance. Strategy, organization and management in the world auto industry.* USA: Harvard Business School.

Cooper, R. (1990). Implementing an activity cost system. *Journal of Cost Management* (spring): 33-42

CSCMP. (2005). *Supply Chain Management/Logistics Management Definitions*: http://cscmp.org/AboutCSCMP/Definitions/Definitions.asp

CSLUB foundation. (2004*). Glossary of the PI manual*: http://www.foundation.csulb.edu/fndgrant/sections/GLFEB97.HTM

De Maria, K. (2000). *The packaging development process: a guide for engineers and project managers*. Lancaster: Technomic Publication Co.

Denzin, N. K., Lincoln, Y. S. (2000). *Handbook of Qualitative Research*. 2nd ed. USA: Sage Publications, Inc.

Eisenhardt, K. M. (1989). Building theories from Case Study Research. *Academy of Management Review* 14 (4): 532-550

Erickson, G. (1999). Computer-Aided Design for Packaging. Pharmaceutical & Medical Packaging News

Esse, R. L. (1989). Package development, Manufacturing, and Distribution Strategy Considerations, in: *Packaging strategy – meeting the challenge of changing times*. Arthur W. Harckham (ed.). Lancaster: Technomic Publishing Company, Inc., 107-116.

Harckham, A.W., (1989). *Packaging strategy- meeting the challenge of changing times*. Lancaster: Technomic publishing company, Inc.

Hein, L., Pedersen, F. M., Andreasen, M. M. et al. (1984). Integrated Product Development: new potentials products. 2: 86-90

Hine, T. (1995). *The Total Package. The Secret History and Hidden Meanings of Boxes, Bottles, Cans, and Other Persuasive Containers*. 1st Ed. New York: Back Bay Books.

Huang, G.Q. (1996). *Design for x- concurrent engineering imperatives*. 1 ed. London, UK: Chapman & Hall.

Human Technology Inc. (2005).*Organizational Learning Strategies: Cross-Functional Teams:* www.humtech.com/opm/grtl/ols/ols3.cfm

Jann, D. (2004). Cross-Functional Teams. Chartered Accountants Journal of New Zealand. Vol 83. pp 63

Jarvis, M. (2003). Concurrent Engineering. *Work Study*. 48 (3): 88-91.

Johnsson, M. (1998). *Packaging Logistics – a value added approach*, doctoral thesis, Department of engineering logistics, Lund University

Jönson, G., Johnsson, M. (2001). *Packaging Technology for the Logistician.* 3rd ed. Lund: Department of Design Sciences, Packaging Logistics, Lund University.

Jönson, G. (1982). *Food Distribution in Europe.* USA: Michigan State University

Jönson, G. (2001). *Packaging Development – Update 2001.* Department of Design Sciences, Division of Packaging Logistics: Lund University.

Klevas, J. (2004). Organization of Packaging Competence and Product Development – Findings from a Case Study at IKEA. Department of Design Sciences, Division of Packaging Logistics: Lund University.

Kooijman, J.M. (1995). The environmental impact of packaging- performance in the food supply chain. Incpen: London, 1-44.

Lox, F. (1992). *Packaging and Ecology.* United Kingdom: Pira International.

Mishler, E. G. (1986). *Research Interviewing: Context and Narrative.* Cambridge, MA: Harvard University Press.

Nederman. (2002). *Facts about Nederman*: http://www.nederman.com/fact.html

Olsson, Fredy. (1976). Systematisk Konstruktion. Department of Machine Design, Lund Institute of Technology, Lund.

Paine, F. A., Paine, H. Y. (1983). *A handbook of food packaging.* 2nd ed. Glasgow: Leonard Hill

Paine, F. A. (1991). *The packaging user's handbook.* London: Blackie

Prasad, B. (1997). *Concurrent Engineering Fundamentals – Volume I.* Upper Saddle River, New Jersey: Prentice Hall PTR.

Punch, K. F. (1998). *Introduction to Social Research. Quantitative and Qualitative approaches.* London: Sage Publications Ltd.

Richardson, S., Dohrenwend, B., Klein, D.. (1965). *Interviewing: its forms and functions.* USA: Basic books, Inc. publishers

Roozenburg, N. F. M., Eekels, J. (1995). *Product Design: Fundamentals and Methods.* First ed. John Wiley & Sons, Inc.

Russell, B. H. (2000). *Social Research Methods. Qualitative and Quantitative Approaches.*

Saghir, M. (2002). *Packaging Logistics Evaluation in the Swedish Retail Supply Chain.* Printed in Lund, Sweden.

Schary, P. B., Skjott-Larsen, T. (2003). *Managing the Global Supply Chain.* 2nd ed. Copenhagen Business School Press.

Sierra Bravo, R. (1986). *Tesis doctorales y trabajos de investigación científica: metodología general de su elaboración y documentación.* Madrid, Paraninfo.

Takeuchi, H., I. Nonaka. (1986). The New Product Development Game. Harvard Business Review. Jan-Feb 1986: pp 137-146

ten Klooster, R. (2002). Packaging Design: a methodological development and simulation of the design process. Delft University of Technology.

Turney, P.B.B. (1991). How Activity-Based Costing Helps Reduce Cost. *Journal of Cost Management* (winter): 29-35.

Twede, D. (1992). The process of logistical packaging innovation. Journal of Business Logistics vol. 13 nr 1, 1992, pp 69-94.

Ulrich, K. T., Eppinger, S. D. (2003). *Product Design and Development.* 3rd ed. Boston: McGraw-Hill Companies, Inc.

Wengraf, Tom. (2001). *Qualitative Research Interviewing.* Trowbridge, Wiltshire, G.B.: Sage Publications Ltd.

Wheelwright, S.C., Clark, K.B. (1992). *Revolutionizing Product Development – Quantum Leaps in Speed, Efficiency, and Quality.* 1st ed. New York: The Free Press.

Winner, R. I., Pennell, J. P., Bertrand, H. E. *et al.* (1988). The role of concurrent engineering in weapons system acquisition. IDA Report R-338 Institute of Defense Analyses: Alexandria, VA

Yin, Robert K. (2003). *Case Study Research: Design and Methods.* 3rd ed. California: Sage Publications.

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