Propositions, added to the thesis 'Packaging Design, a methodical development and simulation of the design process'

by Roland ten Klooster, MSc Industrial Design Engineering, September 2002

1. Design of packaging is not as professional as could be expected on the basis of its complexity and the market size of the packaging branch. This insufficient professionalism explains to some degree why superfluous packaging is being used.

2. By splitting up the design process into logical steps, writing these down on cards and by letting designers order these cards, a picture is created of how designers work. This method of unfolding can contribute to the insight and to the systemization of the design processes of many kinds of products.

3. Designing with functions instead of with requirements makes the design process clearer and more effective.

4. Designers of product-packaging combinations think and act following a more or less uniform design process with a structure and priorities.

5. The design of packaging is often more difficult than of other kinds of products, because the functions the packaging has to fulfil vary considerably across the life cycle, such as the phases of filling, transporting, displaying and final use.

6. By designing the product and its packaging simultaneously and interdependently, greater innovations will be reached than if designing sequentially and separately. By integrating these designs the costs and environmental load can also be reduced.

7. Too few industrial design engineers are assigned to design packaging. Otherwise, convenience of use of packaging would be much better.

8. The attention that companies pay to packaging depends on the costs of packaging relative to the sales value of the packed product. This also explains why the foods sector pays more attention to packaging than the non-foods sector does.

9. Ecology and economy can be diametrically opposed, because investing in luxury tends to generate larger economic profits.

10. The recycling of glass would improve considerably if separation by colour would be done more consistently and if the packaging is kept unbroken during the collecting.

11. The media have often presented wrong images of packaging. They have not given a fair chance to solutions that would have been more friendly to the environment.

12. The canting skate (also known as klapskate) Rotrax, with its seven-bar mechanism, is an example of good design based on wrong starting points.

13. The Dutch term "platteland" (flat country where one lives more simply) can only have been contrived in the Netherlands.

Stellingen behorende bij het proefschrift 'Packaging Design, a methodical development and simulation of the design process'

door Roland ten Klooster, september 2002

1. Het verpakkingsontwerpen kent niet de professionaliteit die verwacht mag worden op basis van de complexiteit en de omzet in de verpakkingsbranche. Dit gebrek aan professionaliteit verklaart enigermate waarom er onnodig verpakkingsmateriaal gebruikt wordt.

2. Door het ontwerpproces op te delen in logische stappen en deze op kaartjes te zetten en te laten ordenen door ontwerpers, wordt een beeld verkregen van hoe ontwerpers te werk gaan. Deze wijze van expliciteren kan een bijdrage leveren aan het inzicht in en de systematisering van ontwerpprocessen van veel soorten producten.

3. Ontwerpen vanuit functies in plaats vanuit eisen, geeft een duidelijker en effectiever ontwerpproces.

4. Ontwerpers van product-verpakking combinaties denken en doen volgens een min of meer uniform ontwerpproces met structuur en prioriteiten.

5. Het ontwerpen van verpakkingen is vaak moeilijker dan het ontwerpen van andere producten, omdat de te vervullen functies aanmerkelijk uiteenlopen in de verschillende schakels van de levenscyclus, zoals het afvullen, transporteren, tentoonstellen en het uiteindelijk gebruiken.

6. Door het product en zijn verpakking tegelijkertijd en in nauwe samenhang te ontwerpen, worden er grotere innovaties bereikt dan indien product en verpakking sequentieel en onafhankelijk van elkaar ontworpen worden; zo kunnen ook kosten en milieubelasting worden verminderd.

7. Er worden nog te weinig industrieel ontwerpers ingeschakeld bij het ontwerpen van verpakkingen, en daarom neigt het gebruiksgemak van verpakkingen suboptimaal te zijn.

8. De aandacht die bedrijven aan verpakkingen besteden, hangt sterk af van het aandeel van de verpakkingskosten in de verkoopwaarde van het verpakte product. Dit helpt mede te verklaren waarom de food sector een hogere prioriteit legt bij verpakkingen dan de non-food sector.

9. Milieu en economie kunnen op verpakkingsgebied lijnrecht tegenover elkaar staan doordat investeren in luxe veel extra inkomsten kan genereren.

10. De recycling van glas zou aanzienlijk toenemen indien veel consequenter kleurgescheiden ingezameld zou worden en de verpakkingen bij het inzamelen niet gebroken zouden worden.

11. De media hebben vaak verkeerde beelden van verpakkingen gegeven. Diverse milieu-gunstiger verpakkingsoplossingen hebben daardoor juist geen kans gekregen.

12. De klapschaats Rotrax met het zeven-stangen mechanisme is een voorbeeld van een goed ontwerp gebaseerd op verkeerde uitgangspunten.

13. De term 'platteland' kan alleen maar in Nederland bedacht zijn.

Packaging Design

a methodical development and simulation of the design process

Roland ten Klooster

Packaging Design

a methodical development and simulation of the design process

Proefschrift
ter verkrijging van de graad van doctor aan de Technische Universiteit van Delft,
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Bij zo ongeveer alles in het leven kun je een houding aannemen waardoor je beschermd wordt, een pose met codes, doordesemd van onuitgesproken afspraken. Bij het schrijven is het anders. Schrijven is volstrekt verstoken van verpakking.

In almost everything a self-protective stance can be taken, a pose with codes, steeped in implicit agreements. Writing doesn't work like that. Writing is completely devoid of packaging.

Leon de Winter

from 'Talent, het naakte verhaal', published in de Volkskrant, 28th of September 1998

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1 Introduction

Summary

Media and politicians often refer to packaging as being rather superfluous or even unnecessary. However, studying the literature and research in this field shows that packaging is very useful and, as a rule, is indispensable. Various sources show that assessments as to the use of packaging is complicated by the number of aspects that play a role in the realization and actual functioning of packaging. There is specific training, education and research on the subject of packaging, but the role is not as large as would be expected in view of the magnitude of the market. There is apparently no explicit design method nor specific training in this field, at least not published. Especially concerning the step from designing an image to the realisation of the packaging little or no systematics can be found. It is quite possible that designers each follow their own methods in practice.

We believe that a documented method for the design of packaging can be of benefit to the practice and training of designers of combinations of products and packaging. A method could enable them to follow a more efficient design process, to achieve both ecological and financial savings, to make good use of innovative opportunities. An explicit method could also help decision-makers by providing them with a tool for integrally tackling packaging problems. The underestimated complexity of packaging, the short time-to-market, the limited tests that are executed on packaging concepts, the restriction of costs of packaging materials, are reasons to look for a more detailed model of the design process.

The result of this chapter is the formulation of research questions in which the central question is: What method can packaging designers use to design packaging effectively and efficiently such that it incorporates all the essential functions, and as many of the desired functions as possible.

1.1 Introduction

In her Speech from the Throne in 1992, the Dutch Queen spoke of 'superfluous packaging' (Nederlandse Staatscourant, Buitengewone editie [Netherlands Government Gazette, Special Edition], 178A, 1999, p.4): *): "Producers accept their own responsibility by taking back their products in the waste stage and by reducing the amount of superfluous packaging.* Many consumers will probably agree with this phraseology because they do indeed see packaging as superfluous, as a study conducted by the joint Associations of Housewives in North Brabant (Konsument & Huishouden, 1993) confirmed. More than 3,000 consumers were asked to state which packaging they felt were superfluous. The resulting top ten showed the first four as: plastic carrier bags, foil-packed biscuits, milk cartons and the plastic bags used for meat products.

If packaging was superfluous the question could be asked why it still exists today. It is then very easy to seek out publications that lead to the conclusion that packaging is far from superfluous. Research carried out in India by the United Nations at the end of the nineteen eighties shows that 70% of the food cultivated ultimately goes to waste because it is either left unpacked or is not properly packed in the first place. Comparative figures for the United States of America show percentages of 17%, other studies come up with 4% (Hine, 1995, p.19). The Arab Medical Packaging Organisation shows losses of 40% for edible oils and about 30% for meat, sugar and vegetables in 1990 in Egypt. Schoonman (1991, p.4) writes that the decline in a variety of stomach and bowel disorders could probably be connected with the burst of growth seen in the packaging industry in the last few decades of the 20th century. Like Hine, she too observes that a world that packs its food is a world that throws away considerably less amounts of food. Whereas in Western Europe only 2% of the food is thrown away due to inadequate packaging, the figures in Africa would be between 30 and 50%. There are no known studies that have been conducted in the non-food sector, but it may be assumed that packaging is also important here. Kooijman (1996) states that our world would be a completely different one without packaging. Many problems would be unsolvable, product waste would be tremendous. Society would be completely different. He also points out that packaging fulfils a very useful function and may on no account be dispensed with. INCPEN, the industrial council for packaging and the environment in Great Britain states that packagings saves waste (Incpen, 1987). A report on packaging, drawn up at the request of *Vereniging Milieudefensie* (Friends of the Earth Netherlands) by Jansen, Koster and Strijveen (1990), points out that the amount of packaging is linked to the standard of living and the technological and economic level of development of the population. *"Packaging is an expression of societal progress."* (p.1).

Paine (1991, 1992) wrote several manuals on packaging and says that the basic functions of packaging are for the purpose of product identification and the product's safe delivery through the distribution channel to the end-user. In his manuals, Paine even uses several definitions of packaging. In the introduction he says that packaging is *"... an essential link between the product maker and his customers"* (p.3) and somewhat later he refers to well-designed packaging as being *"... the main way of ensuring safe delivery to the final user in good condition at an economic cost"* (p.3). In the three definitions on page 5, Paine mentions three different perspectives. Firstly, packaging is a coordinated system for the delivery of goods through the chain and to enable them to be used. Secondly, packaging is a means of ensuring that the product is delivered safely and in good condition to the end-user at a minimum of cost. Thirdly, packaging has a techno-economic function in optimizing the cost of delivering goods at a maximum return and profit. Viewed from these perspectives, packaging can be seen as protection for products that ensures that the products inside them can ultimately be used or consumed at an acceptable cost; in fact: *small economic and ecological machines*. Nevertheless, many people do not regard packaging in this way and still see it as superfluous. This could be connected with the role packaging plays in trends in our society, such as the ability to prepare meals faster and easier, keeping products fresh over a longer period of time, the globalization of trade, home delivery services, etc. Packaging could be seen as the (co) instigator of such – regarded by some as unwelcome – trends.

Generally speaking, packaging is therefore not superfluous, yet there is some packaging that indead can be regarded as superfluous or excessive and the Dutch Queen, although we should not have doubts about her words, would have meant this.

In this case packaging is regarded as excessive if the same functions can be fulfilled with less of the same material. It is up to the packaging firms to ensure that the packaging is made with the least amount of material. And to a large extent it may be assumed that this is already the case. After all, too much material implies that it could be less expensive. In practice, however, minimization is not customary as is seen from various studies and results achieved in this field (for example Plato product consultants, 1994).

In a forum debate a spokesman of the (Dutch) Ministry of Housing, Physical Planning and the Environment (ECN, 1998) mentioned that in his opinion no major innovations had taken place in the field of packaging and that he thought the efforts were being focused on increasing the level of consumption and ease of use only, and that even the aspect of price was of secondary importance. In response to this study, Hekkert et al. (1997) claimed in the same debate that there were still many more opportunities regarding the efficient use of packaging, and that existing engineering rules often result in excessive use of material. In a published paper (Hekkert et al. 1998) they show that in their opinion many options are available to reduce the future material input for packaging and that a reduction of CO_2 emissions by this sector (i.e. packaging) with a factor 2 is possible in Europe. They claim that "a substantial share of this reduction can be achieved without any changes in consumer behavior" (p.1).

The growing amount of smaller households in many West European countries (more furniture, more equipment, etc.), demographic and lifestyle trends such as people living longer, individuals in a family eating separately, the pretreatment of food, the demand for fresh products and growing economic welfare, are parameters which influence the amount of packaging material to a greater extent than reduction programmes on the design of packaging. Although other trends like the growing amount of people eating out mean the opposite, because ingredients are bought in catering sized packs, INCPEN (2000) says the following in a published factsheet: "These changes are likely to have far greater impact on the quantities of used packaging than anything the packaging industry does, even though material use per pack will continue to be reduced in response to commercial and environmental pressures." In the annual report from 1999 of the Packaging Committee who evaluates the Covenant II (see section 4.7.3) the results of a study on the same subject executed by Kooijman in the Netherlands are presented and these show that the amount of packaging waste coming from households will increase by 5% per year (SVM-Pact, 2000). It is stated by

SVM-Pact that this amount is compensated by the results of the measurements taken by the business sector in the areas of prevention and recycling.

In this study (the study itself is not public) Kooijman made a model of the amount of packaging material used per household in the Netherlands in 1997, based on different sources and concluded that an average household in the Netherlands buys 980 kg of products, for which 105 kg of packaging material is used (primary and secondary, one-way and the loss of returnable packaging). This study also shows that demographic developments, changing consumer behaviour like individualisation and eating habits, economic developments and legislation concerning safety, labeling and transport, cause an increase of the use of packaging material. Besides that, it is not difficult to prove that hardly any company will change their packaging because of environmental reasons. For most companies return on investment is the most important issue and chosing the wrong packaging and/or process costs too much and will restrict future developments. More of these realistic visions can be found at several institutes like Voedingscentrum and Milieu Centraal in the Netherlands and Packforsk, the Swedish institute for packaging and distribution. Packforsk has developed a model which compares the energy representation of the product with that of the package (Erlöv, et al, 2000). The model shows that the growth of overestimated packaging, i.e. that the packaging is adding more to the product than needed for transport and distribution, is linear, but the growth of the environmental impact at underestimated packaging is exponential as one damaged package/product may waste an entire pallet load (p.4). According to this vision, further minimalisation is hard to realise.

Besides all of this, it is known that in practice many product managers or other decision makers like to do more work on their own list of 'results' than on the benefits of the company they work for. It is known that many design projects have a scope with a maximum of one year because it is said that this is the mean time before product managers leave the company. This was affirmed by a presentation of a meal producing company who showed the amount of salt in several meals. Every change (about 7 in 9 years) was not caused by market research but simply by the arrival of a new product manager. Another example is the graphical redesign of a packaging for rice which took place three times in one year, just because three new product managers succeeded each other. Although research into this is not done in this study, it will be clear that personal incentives of decision makers are very important in all kind of projects and that these are in many cases not stimulating to reach higher objectives like less harm to the environment. A Norwegian study into the results of measures taken to reduce the amount of packaging waste concluded the same (Roine and Brattebo, 2001).

Still many projects show that savings in the amount of packaging material can be achieved. For instance, two packages were (re)designed within the framework of a research programme (Te Riele, 1994) with a lower impact on the environment without it being at the expense of the economic aspects; so-called Eco-design. In both cases, the environmental impact was reduced and the functionality was maintained without an increase in cost. Some 13 additional packages were redesigned in the follow-up projects of the Eco-design programme between 1992 and 2000. The redesign of the packages resulted, as was intended, in a lower environmental impact. Von Weizsäcker et al. (1996), also give examples of redesigned packaging, especially transport packaging, with a lower environmental impact than conventional packaging. Another source is the already mentioned *Stichting Verpakking en Milieu* [Foundation Packaging and Environment, SVM] which, in response to agreements reached between government and the packaging industry in 1991 (laid down in a covenant to reduce the amount of packaging material), publishes a new number of examples of economy measures annually (e.g. *Verpakkingsontwikkelingen 1999* [Packaging Trends 1999], (SVM 1999). Similar publications are issued in other countries too, giving examples of a reduction in the amount of material used in packaging, such as the *Catalogue de la prévention des déchets d'emballages*, published in France by the *Ministère de l'environnement* (1999). This manual follows the rule: determine the functions of packaging and reduce the material until one of the functions becomes critical. In Germany, the commercial organization that was founded to collect packaging for businesses operating in the private sector, and to ensure its transport to recycling firms, *Duales System Deutschland (DSD)*, held a competition in 1995 with the goal of reducing the amount of packaging material 'Innovation Prize for Packaging' (DSD, 1995). The brochure, published as a result of this competition, contains numerous examples of reductions in packaging material. Other manuals are also published that contain examples of how to reduce the amount of packaging material such as CBL's *Actieboek Verpakkingen* [Packaging Activities] (CBL, 2000) and Fost Plus (1997) *Zo weinig mogelijk, zo veel als noodzakelijk* [As less as possible, as much as necessary]. Numerous MSc projects have also been carried out by students at the Delft University of Technology in which packaging has been improved in terms of direct cost, integral costs, the amount of material used and/or environmental impact.

Packforsk shows that a lot of progress has been made by industry and trade in reducing packaging material (Erlöv, 2000).

It may be concluded with the opinion that in many occassions packaging can be (re)designed with less material without losing its functions, as long as investments and profits can and will be made and that packaging designers try to reach the optimum situation between underestimated and overestimated packaging design.

Another typical aspect of packaging is that it knows as many experts as users, concerning opinions in the media. Because of this firstly some attention is given to the relation between packaging and the media.

The 'lavish' side of packaging has apparently to a large extent determined the views held by the general public on packaging. From the point of view of communication, Schoonman (1991, p.139) puts forward the following argument on the subject of packaging: *"a product which people generally do not even think about, easily becomes the victim of very simple reasoning"*. She claims that the packing and packaging industry have never communicated on the subject of barrier characteristics, optimum logistics, marketing, ease of use, and the other useful aspects of packaging. Hine (1995) goes one step further than Schoonman by claiming that consumers may not be expected to have an understanding of the many functions packaging fulfils. This means that packaging has become synonymous with garbage and waste. Of crucial importance here is the visibility of packaging in the disposal stage: litter. This has resulted in a high societal sensibility to the subject. Burall (1996) says about packaging: *"packaging is, by definition, ephemeral and is therefore seen by some as unnecessary and wasteful; it also suffers from the high visibility of litter"* (p163).

In Intermediair No. 5 of 4 February 1999 (p.14), Van Dieren (1999) concludes that: "In the years after 1989 the role of the industry was strong, and the role of the environmentalist movement, weak. We had become hypnotised by the packaging problem. It had become a hot item. This drew our attention from matters that were far more essential: the development of the major infrastructure, economic growth, Schiphol." In other words, Van Dieren claims that the environmental problem caused by packaging is less essential than other matters. In the Netherlands, waste originating from packaging is approximately 3% of the total amount of waste generated. Packaging represents 3.3% percent of the total Western European CO_2 emissions (Hekkert et al, 1998). This is probably less than most consumers would expect. On the one hand, this does not seem particularly substantial, but on the other hand it is not a figure that can be neglected either.

Halfway through the 1980's the environmentalist movement achieved several successes in the field of packaging: the campaign against Heineken in 1987 because the brewery had used heavy metals in the colour pigments for their plastic crates in order to achieve the desired bright, recognisable colour, and the campaigns against the use of PVC as packaging material.

Many businesses then started to realize that it was much better to avoid becoming the subject of environmental debate because of their packaging. A large number of firms drew up strategies on how to act and communicate should they become an object of media attention (Schoonman, 1991). Fortunately, there were many firms that attempted to use as little packaging material as possible, and that formulated a mission statement that includes the environment. So, these policies started to become common practice. Firms have also become aware of the fact that they need to communicate honestly in all fields, and to present themselves coherently or else they risk customers running away. Unilever for example, does not use bleached paper liners in carton boxes, even not if their clients, like Aldi, ask for it.

In the United Kingdom a Code of Practice, the 'Packcode' (Incpen, 1998), has been accepted by many associations and companies representing over 85% of the companies in the packaging chain with the goal to minimize the environmental impact of packaging. The code goes further than the single market requirements of the European Packaging and Packaging Waste Directive (see Chapter 4) and is a challenge in the use of existing packaging and packaging formats. It also reinforces and builds upon the European Packaging Standards, developed by CEN in support of the Directive. (Draft ISO Standard 14021 provides further guidance on environmental issues). A "Guidance on Applying the Code" has been formulated in which many aspects are enumerated and explained (called a checklist).

Highly illustrative of the position of packaging in the media is the extremely lengthy debate on PVC. A packaging material which requires the transport of chlorine for its production, and which can also give rise to hazardous chlorine compounds at the end of the chain, for instance when the material is incinerated. On the other hand, this material offers properties that cannot be achieved by using other materials or combinations of materials without having a considerable effect on the processing, cost price or shelf life (of broccoli and fresh meat for instance). In many cases, the packaging industry is able to offer good alternatives but the retail (the party who determines the price in many occasions) still feels that the price is more important. Numerous arguments were put forward in the magazine European Packaging & Waste Law No. 77 of May 2000 (Agra-Europe, 2000) both against and in favour of using PVC. In a very extensive study into the role life cycle analyses (LCA's) played in many decisions, Bras-Klapwijk showed in 1999 that a clear-cut discussion on PVC can never take place given that there are no neutral environmental analyses, and because several of the environmental effects cannot be quantified (Bras-Klapwijk, 1999). Nevertheless, probably also due to this study, the debate on PVC is still expected to continue for years to come.

The consequence of this difficult position for PVC (for many people a synonym for packaging) is that there is hardly a supermarket in existence that does not carry PVC as packaging material, while in their own publications some of the supermarkets themselves say that they have no PVC in their outlets. The social debate has made businesses more vulnerable and therefore they, maybe, prefer to keep silent.

Nor are the media always independent when expressing their opinions on packaging in relation to the environment. The Dutch Consumers' Association, the *Consumentenbond*, for example, includes the amount of packaging in the analyses of certain products (televisions in the *Consumentengids*, April 1997), while packaging is completely ignored for other products (video recorders, July 1998). In the *Consumentengids'* assessment of televisions a column was included on the environmental aspects, which investigated the presence of toxic substances in the plastics that were used (bromine, antimony and chlorous fire retardants), the number of components used, the packaging material, and the reusability of the various components. Picture quality, sound and the environment are the aspects that carry the most weight when determining the test score. Quite remarkably, no link was made with the actual weight of the television itself, or with the amount of energy it consumes, an environmental impact which cannot be insignificant in relation to the material used in the television itself. It is theoretically feasible that a heavier television is packed in less packaging material because its weight makes it less vulnerable to damage, and, consequently, the total amount of material used is less. The final scores, which have a major effect on consumer purchasing behaviour, are partly influenced by the assessment of the packaging. Such an assessment would therefore seem to be anything but objective. If a choice has to be made in terms of the sort of plastic used, the only assessment criterion used by the Consumers' Association is whether the plastic used for the packaging is PVC or another sort of plastic (*Consumentengids*, February 1996, p.88, December 1997, p.21). Numerous studies have been published on the environmental impact of different sorts of plastic (among others, Annema, 1990) showing that a greater differentiation is possible. Of all organizations, it could be expected of the Consumers' Association that it presents a more discriminating picture of packaging and thus of the packaged products.

As a result of the developments discussed above, packaging found itself in an awkward position. On the one hand it protects the products inside it and ensures the delivery of those products to future destinations unknown at the time of their production. Several studies showed that wasted product is far more damaging to the environment than the packaging material (f.i. Kooijman, 1996). On the other hand, it is still possible to further optimize packaging, and environmentally harmful materials are still being used.

This broad reflection on packaging gives rise to several questions. What is meant by the word 'packaging'? Why is there no widely accepted definition of packaging? How is it possible that there are different views on reduction of packaging waste? Who makes the decisions on packaging or who designs packaging? What do experts think of the functions of packaging? What are study programmes that can be followed in the field of packaging? These questions will be dealt with in the following sections.

1.2 The term 'to pack'

There is no unequivocal definition of packaging to be found in the literature. Paine (1991, 1992) gives several definitions of packaging as mentioned before. Different dictionaries give different definitions of the term 'to pack', linked to the many ways in which the term can be used. The European Commission (94/62 EC) defines packaging as:

"Packaging shall mean all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, 'non-returnable' items used for the same purpose shall also be considered to constitute packaging."

This broad definitions covers every item which is used during transport of products and is not very specific.

In Dutch dictionaries, the definition 'to pack' lays emphasis on 'wrapping' or 'making up a package for the purpose of despatch or sale': to enclose in a casing or cover, to make up as a packet or packets. The word '*emballage*' is also used in Dutch; this is defined in the dictionaries as a synonym for packaging, the description being given of: the goods are well-packed; cardboard and wood shavings are used to pack a variety of products; packaged medicinal drugs. 'To envelop' is defined in the same dictionary as to cover on all sides; a hard husk envelops the kernel; to conceal or obscure, as from sight. No link is made with packaging. To keep together, a prerequisite for the packaging of amorphous products such as liquids is defined as to ensure that what is together is kept together, to prevent it from coming apart.

The French word '*emballage*' means packaging, to pack, packaging material. The emphasis is on that which is added. Strangely enough, *emballage* in the Dutch packaging community usually refers to the empty packaging which is returned to a filler or to the packaging which is ready to be filled.

The Oxford Dictionary defines 'to pack' as to 'put things together into a bundle, box, bag, etc., for transport or storing' and 'package' as a 'bundle of things packed, parcel, box, etc., in which goods are packed'.

The Cobuild English Dictionary (1995) defines 'to pack' as follows: When people pack things, for example in a factory, they put them into containers or parcels so that they can be transported and sold.

Synonyms for 'to contain' are 'to hold'; 'to be able to hold'; 'to comprise (to embrace, to enclose)'; 'to restrain (to hold back)'; 'to curb'; 'to check'; 'to repress'; 'to restrict'.

Fodor (1998) and Marconi (1997) point out that semantics is an absolute philosophical minefield. Some people expect a dictionary to define a word as they think it should be defined. Fodor claims that attempts to define are better left alone. On the basis of this view it is impossible to give an exact definition of packaging, but it *is* possible to give an indication of what is and what is not typical packaging by giving examples. This would mean that while it is impossible to specify the functions of what is called packaging, it is possible to give a reasonable indication of which functions or combination of functions can and cannot be attributed to the term 'packaging'.

A definition of 'packaging' could be in the form of an enumeration of all potential functions, but the degree of materialization and the additional functions fulfilled by the packaging (which are not directly related to the meaning of the word 'packaging'), are also important. This needs further explanation.

If wooden furniture is rubbed in with oil, then the oil will probably not be referred to as packaging, despite its function: to protect the furniture from cracking and from discoloration due to dryness and UV-light. A soap dispenser purchased with no contents from a shop selling luxury goods, will be referred to by one person as packaging because liquid soap is 'packaged' inside it at home, whereas another person will refer to it as a consumer good, despite the fact that the empty soap dispenser functions exactly the same as the dispenser purchased filled with liquid soap. The oil fulfils very few packaging functions and is present in a non-physical sense, the soap dispenser fulfils more functions than packaging functions alone, and can be regarded as a consumer good.

SVM also had difficulty in defining packaging. This was evident from a list, the organization published in connection with implementation of the Packaging Covenant II, of what is, and what is not packaging. Examples of products that have been discussed are CD Jewel Cases, sewing thread bobbins, electric drill storage boxes, etc.

It may be concluded that functions play an important role when formulating a definition of packaging, but that additional functions and degree of materialization must also be taken into account. The functions of packaging and packaging design are dealt with below.

1.3 The functions of packaging

Like Hine, as indicated above, Kooijman (1996) also claims that it is no easy matter to assess the functions of packaging. Packaging functions are often enumerated in the literature, but this is never the same twice. Most enumerations of packaging functions end at the point when the packaged product reaches the user. *Vereniging Milieudefensie* (Friends of the Earth Netherlands) defines the functions of packaging as: protection, transport and distribution, control, transaction, use and disposal (Jansen, et al.; 1990, p.3) and thus includes the stage after use. After having been used the packaging must be suitable for reuse, recycling or must allow to be responsibly incinerated or dumped. This is in line with current European legislation as established by the European Commission in the Packaging Waste Directive of 1994 (94/62 EC). This directive states that attention must be given not only to the end of the life cycle phase of the packaging, but also to the potential environmental impact during its production, its use and its disposal.

The most important functions that must be fulfilled by packaging are according to Paine (1991; one of his enumerations): containment, protection and presentation, communication, machineability, convenience in shape, size and weight for handling and storage. Because of the complexity when dealing with these functionalities when making decisions on packaging, Paine (1991, p.5) describes packaging as *"a complex, dynamic, scientific, artistic and controversial segment of business".*

Soroka (1996) gives the following functions in a publication issued by the British Institute of Packaging: containment, protection/preservation, transportation, information/selling. In line with this, Lox (1983, 1992) mentions: a protective function, a commercial function and a control function.

So far, the following functions have been mentioned and a further study of the literature would undoubtedly add the following to the list:

- in relation to the product to be packaged: containment, keeping together, envelopment, protection, product identification;
- in relation to bridging the gap between producer and user: storage, transport, distribution, control (control can be subdivided into several aspects);
- in relation to selling: sale, presentation;
- in relation to communication: informing;
- regarding the packaging process itself: machineability;

- regarding use: use, convenience in shape, size and weight;
- in relation to the post-use stage: recycling, responsible incineration or dumping.

It may be concluded that packaging fulfils numerous functions, that many disciplines are involved in the design of packaging, and that the actual design of packaging is apparently an expertise in itself.

The formulation of a sound, comprehensive definition of packaging, which includes all the multidisciplinary aspects, although taking into account the view of Fodor and Marconi that the definition of a term is a philosophical minefield, might possibly shed some light on the superfluousness of packaging.

1.4 Packaging design

Firms engaged in the packaging of products or have products packaged for them, in most cases choose or design (or have designed for them) the most suitable packaging. Designers play a major role in realizing products and are seen as those responsible for many developments which take place because of their designs (Papanek, 1985). This can be in the field of food, drugs, durable goods, industrial goods. Because packaging is manufactured from engineering materials, a comparison with industrial designers is obvious. Hine (1995), however, claims that most packaging designers are not industrial designers but designers with a graphic design background. Cordia (1996) comes up with a possible reason for this. She believes that graphic designers are engaged in work intended for the promotion of sales and consequently are in contact with marketing disciplines. Industrial designers, whose efforts often lead to technically innovative results (as opposed to PR-oriented graphic designers) and who are engaged in innovative technologies, are conversely seen as the perpetrators of cost centres. These activities are not regarded as essential to ensure the continuation of a business. Not everyone will agree with Cordia's views. After all, industrial designers have marketing disciplines in their field of study and are aware of the importance of graphic design.

Visser (in Riezebos, 1996) points out that design and the choice of materials when designing packaging are usually inspired by considerations of a business economics nature or are 'coerced' by the trade (p.166). In package design there is little coordination between the packaging's communicative and technical functions, says Visser. In Buijs (2000) a case of Visser of the design of packaging is presented and this view is confirmed. A new line of packagings was designed and the case does not pay any attention to the material used, the construction of the packaging and the amount of material. This was probably not part of the order. In literature the term *packaging design* is mostly used for graphical design while designing the package is often called 3-dimensional packaging design. A book about packaging design (Koopmans, 2001) in relation to branding of products focusses strongly on graphical design and gives several warnings about changing the packaging material or the shape of the packaging. "Creative packaging can be the cause of the greatests production disasters." (p.102)

'Coercion' or dictating how the goods should be packed is customary in the business. The German retailer Aldi for example, is dictating the design of the carton box. Dutch retailer Albert Heijn (Albert Heijn, 1995 and 1998) published a booklet setting out guidelines for transport packaging and updates this booklet quite regularly. If these guidelines are ignored then the likelihood of doing business with Albert Heijn is reduced. A large customer is apparently in the position to make demands, and should this be the case, then a packaging designer has little to say. On the other hand, Albert Heijn itself claims that packaging development is seldom considered a skilled job. In many businesses *"the buyer or the manager does it as a sideline"*. Albert Heijn sees this as a reason to make demands now and again, and thus be able to make improvements (Meijer, 1997). Nevertheless, it is also pointed out that changes may only be made after joint consultation. Smaller businesses can experience the suggestions of a major customer as coercive, and this could explain Vissers' assertion. It should be mentioned that Albert Heijn with succes started to redesign many packagings of their own brand and started to work with the whole chain involved, in order to avoid technical problems and to gain more market share (for example Koopmans, 2001; p.258-261).

Briston and Neill (1972) point out that packaging design is a complex matter. In their book, Packaging Management, the objective is *"to break the subject down into self-contained elements"* (p.4). They set out five criteria on the basis of which *"the complexity of packaging"* can be described: appearance, protection, function, cost and disposability. Hine (1995, p.116) says the following: *"In practice, even within industrial design firms and other multidisciplinary organizations, packaging is usually separated from other design specialties because it has its own sorts of demands and expertise."* Hine therefore says that packaging design differs considerably from other design disciplines, including industrial design. Hine (1995, p.195) also gives an insight into how packaging designers work: *"Package designers have traditionally used very long check lists of as many as three hundred specific and often difficult questions to help their clients define their goals and detailed, concrete standards for a successful package."* There are various check lists that can be found in the literature, usually for specific packaging. Judd, Aalders and Melis (1989) described a check list for the development of consumer packaging for export. Paine (1991) published codes and guidelines for several types of packaging such as shipping containers, retail packaging and packaging for consumer goods. Melis (1991) published a list of marketing and technical requirements for functional packaging design with 149 aspects.

In their packaging programmes, the Netherlands Packaging Centre in Gouda also uses check lists of aspects that can play a role in the development of new packaging (Oskamp, Janssen, 1990; Koopmans, 2001).

The nature of the work involved in the design of packaging is quoted from Donald Deskey Associates by Hine (1995, p.155): "Visualising covered only a small percentage of the work (13%), while most of the time was spent on gathering market information (37%) and doing technical research on materials (50%), only a small part is left over for convincing the client (10%)."

The gap between graphical packaging design, in many cases executed by offices which also do advertising, and three-dimensional packaging design is large. Many companies have had problems with designs which were not producable, were hard to fill or which disturbed the filling process in many ways. Examples (out of our own practice as three-dimensional packaging designer) show that many mistakes tend to be made frequently. Later on attention will be paid to the nature of these mistakes.

Recalls are also an indication that mistakes are made. According to the press, packaging frequently plays a role in the recalls that have to be made by businesses if defective products are brought onto the market; this shows that in practice certain aspects are overlooked (e.g. the Heineken glass splinters affair, 1995; Becel plastic spout on glass bottle, 1989;VSM roller for mosquito bits and jellyfish stings, 1999). Research carried out in 11 of the 15 EU Member States shows, among other things, that 12% of all detected violations of the Consumer Goods Act were due to faulty labelling (*NRC Handelsblad*, 10 January 1998) and thus also concerned the packaging. Out of our own practice several examples are known of recalls which were avoided because the mistake was found just before the product was distributed.

It can be concluded that the mentioned check lists are apparently either incomplete, not used, or insufficient attention is given to the packaging.

The image thus generated of the field of study called packaging design is that three-dimensional design is not practised on a highly professional level *("it is done in addition to one's other duties"*, Albert Heijn), that use is made of check lists (Hine; Judd, Aalders and Melis; Paine; Oskamp and Jansen, Koopmans), that most of the people involved are graphic designers (Hine, Cordia), that it is a specialization which is made up of many different disciplines (Hine, Paine), that mistakes that have major financial consequences are made repeatedly (the affairs referred to above) and that there is a gap between graphical design and three-dimensional design (Visser, Koopmans).

The combination of the aspects referred to above might possibly explain why this specialization is regarded as complex (Paine, Kooijman, Hine).There are apparently not enough packaging designers who are able to solve problems in the area of packaging design integrally, i.e. taking all the relevant disciplines into account. In this respect a parallel can be drawn with industrial design. After a certain time, the process of creating durable goods called for a person who could take up a position at the centre of the process to answer the: what, how, where, with whom, when, how many, etc., and thus gave birth to a specialization.

It would seem that the packaging industry has arrived at the point where the producers of durable goods stood many years ago.There was a need for industrial designers with an understanding of design methods, and skilled in the structurally solving of design problems. It seems that all the knowledge that has been gathered and published on the subject of packaging design is still fragmented and not combined in one methodology and there is an apparent need for methods to tackle packaging design problems more structurally. The following section deals with methods for packaging design as found in literature.

1.5 The literature on packaging design methods

Design methods are part of the research programmes of several renowned universities of technology like Massachusetts Institute of Technology, Stanford University's School of Education and Delft University of Technology. There is a remarkable lack of scientific literature in the field of packaging design methods. In those cases that involved high-quality research, it was mostly research into the sub-aspects of packaging problems, such as the packaging of food, the packaging of food in plastics, the packaging of fish or meat, the packaging of flowers, active packaging, package engineering, etc. Authors with several publications in this area are among others: N. Anayadike, J. Briston, A.L. Brody, G. Bureau, J. Davies, R.J. Footitt, G.A. Giles, Hanes R.S., J.F. Hanlon, W.A. Jenkins, A.S. Lewis, F.A. Paine, G.L. Robertson, M.L. Rooney, L. Roth, S.E.M. Selke, W.G. Soroka, W. Stern.

Kotler (1980) gives the initial impetus for a step-by-step method for packaging design in a book on marketing management. The first step to be carried out in packaging design is to draw up a description of the packaging concept. *"The packaging concept is a definition of what the package should basically be or do for the particular product"* (p.333) The main functions of the packaging can then be derived from this definition. Subsequently, they can be specified step by step. In that case, check lists can be adapted to ensure that during the design process no aspect will be omitted.

This approach is in line with the step-by-step detailing that Cordia (1996) sets out for industrial design: from product concept to functionality (referred to as the principal requirement) to sub-requirement and to detailed requirement.

The Draft Standard Prevention by Source Reduction of the EC (Mandate 200/Rev3) presents a list of performance criteria and states that design and evaluation activities will identify which of the performance criteria limits the ability to reduce weight and/or volume of the packaging.

Storm (1998), Houtzager (1999) as well as Johansson and Weström (2000) developed a method to design packagings with the least material as possible. A packaging solution is analysed and the weight of the design proposal is compared with alternatives. If there is a solution with less material, based on the weight of the solution, and with economic benefit, then this solution can be chosen.

Briston and Neill (1972) set out a critical path timetable (p.53) in addition to the management side of packaging design, which included the activities that have to be carried out and by which discipline (packaging, purchasing, engineering, marketing, manufacturing), plus a list of which disciplines are responsible for what component when establishing the cost price (p.56).

The first activity, according to Briston and Neill, is conducting a study into the most suitable material (p.55 and p.56). The choice of material is decisive for three activities that are carried out in parallel: cost study, storage tests and packaging design. They give an extensive description of practically all the aspects of importance for packaging design, which disciplines are involved, and how the process should be managed.

Esse (in Harckham, 1989) points out that when designing a product one should not hesitate to adapt the design, the construction or the configuration in order to be able to package the product better. *"They are closely integrated and need to emerge as one cohesive unit"* (p.108). Esse gives examples of minor product adjustments of the percentage of moisture in a foodstuff that makes it easier to pack. His starting point when designing packaging is *"obviously the protection of the product"* (p.108).

DeMaria (2000) explains all the steps needed for successful packaging development, especially for engineers and product managers. She focusses on the techniques necessary for creating, testing, and launching packaging. Her book is a good guide to manage processes of product design and, together with the book of Koopmans (2001), it can help in managing activities and departments in packaging design projects.

The unnecessary separation of the packaging and the packaged product is not beneficial to the total solution (Paine, 1991; Harckham, 1989; Kooijman, 1995). The packaging, either returnable or non-returnable, is – as the independent fulfiller of the function – generally complementary to the product and tends to become technically and functionally more complex and more important, and this, consequently, supports the views of Esse. Several reasons can readily be given for this development towards more intensive and complex interaction and interdependence. The pressure to have fresher products under the pretext of 'healthier', because the product is not pretreated, whether or not in combination with the wish for a longer shelf life, demands more complex solutions such as gas-filled packaging of foods. This involves filling the area that surrounds the product with gasses such as carbon dioxide, nitrogen, oxygen, either separately or as an optimum mixture, to achieve the best possible environment for the product. Such developments, whether they fall under the category of useful innovations or not, make the packaging design process more complex: the upgrading of packaging values (Dirken, 1991).

Additionally, products and product components are becoming continually more sensitive: electronic equipment, for instance, when the lowest possible amount of static electricity can be fatal for the packaged goods. This calls for solutions which are increasingly refined technologically. When designing the product, taking the maximum protection the packaging is able to offer at an acceptable cost, makes it possible to design a solution for product and packaging at the same time. This can be illustrated by the following example.

A presentation made at Ilec in Venlo in June 1997 by two mechanical engineers (L. Geujen and J. Remmen) employed by Océ van de Grinten, a photocopier manufacturer, demonstrated that a different approach to the packaging problem can lead to totally different solutions. Generally speaking, packaging is usually added to a product. The division between the specializations of packaging designer and industrial designers makes it difficult to find solutions for overlapping problems. The mechanical engineers asked themselves why a certain kind of photocopier required such a large amount of packaging material. Research showed that the main reason for the packaging was to protect the machine from vibration during transport. The machine was subsequently subjected to thorough testing and the outcome showed which sources and vibrations were causing the damage to which parts. These parts were then redesigned to make the machine less sensitive to vibrations and shocks. Through discussions and instruction it was discovered that 70% of the new machines after this partial redesign could be transported without any packaging material at all.

It is evident that designing packaging is an activity in which, in addition to all the disciplines involved, the product that is to be packaged is crucial, and that there must be a thorough understanding of that product. Also in that sense, packaging design is a complex affair. Integrating product design and packaging design would probably be beneficial. Although many publications about packaging can be found, it also appears that the specialization of packaging design still not has been adequately professionalized. As far as known, there is no documented method available which describes the steps a designer has to go through while designing packaging. To obtain more clarity about the packaging design specialization, a short list has been drawn up of the study programmes available in this field.

1.6 Study programmes

There are several specific study programmes available in mainstream education in the field of integral packaging design in Europe. However, attention is given to separate, relevant fields of study. The situation in the Netherlands will first be dealt with before moving on to discuss some study programmes available elsewhere in Europe and the rest of the world.

Attention is devoted to packaging in the various study programmes in the field of product development, food technology and the visual arts. The Haagse Hogeschool takes the lead in this sense in the Netherlands, offering specialization in packaging, but not a complete study. In the last two years of their study, students at the Haagse Hogeschool may specialize in packaging development. Since the beginning of the 1990s about ten students a year have chosen this specialization. This study programme focuses in particular on the development part of the design process. As the starting point for the development of packaging, designers following this programme are usually given a description of what the packaging must look like; in other words: the concept. While it is important how such a concept is conceived, the priority is on the development process. Graduates, by now more than one hundred over all, have no difficulty in finding work in the packaging community.

The Agricultural University Wageningen had a part-time chair in the packaging of foodstuffs, which was occupied by Kooijman between 1990 and 1995. This chair has since been discontinued. The subject of packaging is still available as an optional course at the Department of Food Technology and Nutritional Sciences, Division of Food Science. The subjects studied are: materials, production techniques (in brief), the interaction between product and packaging (the emphasis is on this subject), shelf life modelling, etc. Approximately one student a year graduates in a packaging-related subject.

There has always been the opportunity to study packaging design at the Academy Industrial Design Eindhoven, renamed Design Academy, but also at the Art Academies at Amsterdam, Rotterdam, Arnhem and The Hague. When describing the evolution of design education in the Netherlands, the book *Holland in Vorm* [Holland in Shape] (Van den Heuvel, 1987), which gives an overview of design in the Netherlands between 1945 and 1987, mentions the Academy Industrial Design Eindhoven as the only establishment offering a programme in which packaging is specified as a subject. The emphasis at the academy is chiefly on outward appearance and aspects of how the user experiences the packaging. Less attention is given to the actual production of packaging and the options for filling packaging in an industrial process.

At the Subfaculty of Industrial Design Engineering of the Delft University of Technology the subject of packaging is offered as an optional course. The students are given a certain amount of basic knowledge regarding the functional side of packaging, packaging materials and the production of packaging. This course on packaging is followed by some 60 students a year.

Students are given the opportunity to design packaging as an MSc project and thus build up specialization in the field of packaging. Industrial Design Engineering, focusing on the design of durable goods, has never considered packaging as a specific professional field. This seems strange if the fact that virtually all products are packaged, is taken into consideration. It may be assumed that a certain amount of basic knowledge in the field of packaging would be normal. All the same, it is apparent that since 1970 more than one hundred MSc projects have been carried out which involved the design of packaging, and this probably explains why an optional course on packaging was established. In other words: the importance of packaging is not denied completely.

One educational programme in the Netherlands that devotes a great deal of attention to the knowledge side of packaging, but which does not stress the innovative design of new packaging concepts, is the part-time Packaging Course (OVK) taught at the Netherlands Packaging Centre (NVC) at Gouda.

There are several other universities in Europe that do devote more attention to packaging and/or packaging design. The Belgian Packaging Institute, in association with the University of Brussels, offers study programmes in Brussels in the Dutch language and in Verviers in French on packaging and conditioning and several courses on subjects such as plastic packaging, packaging management, small metal boxes, packaging of dangerous goods, printing of package materials, packaging design, etc. Also attention is paid to aspects as functions and norms.

The British Institute of Packaging also has similar study programmes on offer as the Belgian Packaging Institute, and both are qualified at the level of Higher Education. These study programs are also recognised by the UK's Brunel and Loughborough universities as an entry qualification for their MSc in Packaging Technology. The last mentioned course is a part time and distance learning education to become a MSc in Packaging Technology. Brunel University pays attention to the many aspects in packaging design like ergonomics, the use of finite elements methods, environmental issues, decoration techniques and typical product hazards like shock, vibration, moisture, oxygen. The design process is considered in two interrelated and inter-dependent parts: functional (i.e. three-dimensional design) and graphic design.

In Germany there are eductional programmes in Berlin, Dresden and Stuttgart. The *Technische Hochschule* in Berlin gives attention to packaging in food technology. A part-time professor (1 day a week) coordinates this subject, showing yet again that the subject is incorporated in existing studies and is not seen as a profession in itself. The aim however is to set up a professional study programme which is judged to the importance it has in the market and in society. The faculty of the *Technische Hochschule Berlin* in relation with environmental issues also does research into packaging issues, especially concerning the garbage stage of packaging. At the Technical University of Dresden, the Faculty of Mechanical Engineering gives attention to the construction and engineering of packaging machinery and equipment (Verarbeitungsmachinen und Verarbeitungstechnik). In Stuttgart there is a vocational course in packaging technology (Verpackungstechnik).

In France there are two eductional programmes. At the University of Reims is the Ecole Superieure d'Ingenieurs en Emballage et Conditionnement, which qualifies as MSc in Packaging. Much attention is paid to the combination of product and packaging, microbiology and safety. At a later phase attention is paid to packaging design and management. In Le-Puy-en-Velay The European Packaging College can be found. After the so-called A'Level with a scientific background, a University Diploma in Packaging can be obtained in a two years course. Among others, attention is paid to aspects like development of new packaging, design of visual solutions, technical solutions on materials and machinery, waste, recycling, the environment, legislation, purchasing, commercial techniques, industrial development projects, innovative packaging. Examples are given of projects which students can do during on-the-job experience. The examples show that this course is aimed at professionalism and the goal is to train students to optimize and design packagings and packaging processes to reach cost savings or higher quality levels.

In Sweden at Chalmers University in Gotenburg research is done into measurements and process development of electronic packaging for companies active in this field. At Lund University research is done into mechanical properties of packaging materials with the goal to find mathematical models. Education on packaging is restricted at both mentioned Universities.

Also some information outside Europe was gathered. The Carleton University of Ottowa, Canada, offers a study programme called 'Package Engineering and Design Survey of processes and materials used in the packaging industry'. In this study programme, which is part of the industrial design programme, attention is devoted to transport packaging and distribution packaging of mass-produced goods, the integration of marketing, product and brand familiarity and corporate identity in packaging design. Performance on packaging lines and filling techniques are not part of the programme. However, it can be said that the overview does show evidence of a combination of technical and commercial aspects and would therefore seem more complete than most other study programmes.

Another study programme available outside Europe is at The School of Packaging, a unit of Michigan State University (USA). An impressive list of research topics is published concerning product/package compatibilty, product quality and safety, analytical methods development, application of materials science to food and pharmaceutical packaging, estimation of product shelf-life by mathematical methods, human factors in use of packaging, solid waste management and packaging line performance.

Research into packaging materials, mainly in relation to food, is executed at many research centres and universities like INCPEN in Great Britain and Packforsk in Sweden. Packforsk has a number of programmes divided into basic research and applied research on packaging at a scientific level. Applied research concentrates mainly on board and paper for Swedish companies. Basic research has a broad range of subjects like ergonomics, environment, barrier materials, interaction of product and packaging.

It would seem that there are quite a lot of study programmes available at universities or higher professional education levels which deal with several facets of packaging and research is done at universities as well as at research centres. However, design methods or management are hardly mentioned in the studies, design programmes or in the research. It can also be concluded that there are many study programmes for types of services/products/markets with less turnover (see next section) than the market of packaging. Taking this into account, higher education to professionalize packaging does not yet reflect its economic importance nor its complexity.

1.7 A method for the design of packaging

A variety of reasons could be given for stating the need for a method to design packaging for a multitude of products, such as foods, drugs, non-foods, durables, etc., which especially includes the steps from designing an image down to the realisation of the packaging. The underestimated complexity of functions of packaging is a reason to analyse the way common design methods work in designing packaging. Although designing packaging need not be as complex as designing a car, it is probably more complex than designing many other products. Safety, for instance, can be of crucial importance in packaging design problems for foods and medicinal drugs. The costs of packaging are restricted in many cases. The time to market of many products is very short. Packaging materials are tested by producing companies in general, but once the material is being used, the produced packaging is in many cases not tested. To change the packaging material of a medicinal drug takes a long time and is obliged to testing programmes because of legislation. In comparison with the packaging of foods, there seems to be a disbalanced situation. Testing of cars, for example, takes months or even longer. This probably asks for a different model of the design process than common design methods use.

An additional, yet by no means less essential, goal of developing a method is to provide a better insight into, and an overview of:

- the functionalities of packaging throughout the entire chain;
- the users that are of consequence in each part of the chain;
- the innovation options;
- the scope of potential reductions in cost and environmental impact;
- the decision-making structure in the packaging design process.

Functions such as designing, producing, filling, informing, storing, transporting, displaying, purchasing, carrying home, using, emptying, recycling, etc., should all be included. Packaging design is a complex, multidisciplinary activity that calls for insight and training because much knowledge on the product to be packed has to be integrated and because the functions of packaging change when the product goes through the entire chain. A packaging design method must include concept development as well as the elaboration of that concept and communication with industrial designers, food technologists, pharmacists, etc., graphic designers, logisticians and several other relevant disciplines.

Packaging is essential in terms of the economy and ecology, at both micro and macro level. The annual turnover in the Dutch packaging industry is in excess of EURO 4.6 billion (figures from 1998), more than 2.4 billion of which is from the packaging of food, more than 1.4 billion from the packaging of non-food products and 0.5 billion from the packaging of miscellaneous goods. The total market size, including the added value generated on packaging lines, is estimated at at least twice to four times as much. An annual turnover of EURO 40 billion is realized in the European Union from the packaging of food (MIP, 1997/1998). An estimation of the total market of packaging in the EC is about EURO 100 billion, and about 500 billion US-Dollar in the world (World Packaging Organisation), which is about 1-2% of the GNP.

A distinction can be made into product categories like: food, drugs, non-food, non-durables - catogories such as hygiene, personal care, detergents, office supplies, do-it-yourself -, durables and industrial packaging or distinguishing packaging materials like wood, paper and carton, plastics, metals and glass. Often, however, it is hard to find accurate and reliable sources. Some studies have been carried out in which the costs or the estimated environmental impact of products are compared with that of the packaging. Keynote figures in different industrial areas and figures, starting with the packaging materials, could add to more insight into the packaging field.

There are several professional groups that could benefit from a packaging design method:
- Packaging designers: by providing an insight into the innovation and design process, an insight into the link with industrial (three-dimensional) and graphic design, food design, etc., the ability to use efficient tools. This makes it possible to deliberate on more rational grounds and facilitates communication with other, essential disciplines.
- Industrial designers: by providing an insight into the specific features of these design processes, an insight into the relationship with packaging designers, the ability to use efficient tools. Here too, this makes deliberation possible on more rational grounds, and facilitates communication.
- Food designers, etc.: more or less the same applies here as for industrial designers.
- Persons in the field of packaging carrying responsibility at the level of product and range of products: by providing insight, supporting decisions, guiding the design process.
- Trainers in packaging and teachers of industrial design engineering, to convey rules of development in this specific profession.

Below are the potential advantages that can be gained from a documented method for packaging design. A clear-cut parallel can be drawn with the proven benefits of design methods for industrial design engineering.

A more efficient design process

A method can be disseminated and thus ensure that the packaging design process is carried out more uniformly and, consequently, more efficiently. It would also help to cut the costs of the packer or other decision-makers in the packaging process. A method also makes the design process more manageable.

Economy versus quality

The first two objectives of packaging are product protection and economy (Kotler, 1980). Costs, plus the environmental impact are, according to most definitions of packaging, major conditions to be taken into consideration. The aspect of the environment is dealt with under the next heading. Hine (1995) claims that the costs of packaging can be reduced. Paine (1991) also mentions the element of cost: *"packaging is ... techno-economic function for optimizing the costs of delivering goods whilst maximizing sales and profits"* (p.5).

Packaging design thus has a major influence on the packers' expenditure. During the development process the cost of the packaging process must be weighed against the benefits from the result: a packaging that protects the product and diminishes transport damage, a packaging with less material, a more efficient filling process, a more highly appreciated product because of the packaging, etc. It is probable that a method will make the costs and benefits of a packaging design proposal more transparent and thus will provide more insight into whether and which packaging is superfluous or a success.

Environmental aspects
The ecological aspects of packaging have been focused on since the early 1970's when more plastics started to be used in packaging (Staudinger, 1974a and 1974b). Especially the durability of plastics was investigated and the use of plastics for non-returnable functions was criticized. Attention has already been paid to ecological aspects in this introduction.

Paine (1991) gives a good picture of the tension that exists between the necessity of packaging and its environmental impact. His view dating from 1991 (p.22) is still up-to-date:

"... To summarize, the main functions of packaging are to prevent damage and hence reduce waste – not only of goods and materials but also of energy and labour. When the package has done its job, it can be used for something else and, when it finally becomes a waste material to be disposed of, it often has already reduced the waste disposal problem by reducing the amount of trim (husks, bone, etc.) appearing in urban waste. Even where the primary function of packaging is not that of conservation – it is designed either to improve sales or to provide convenience – both will lead to better profits and will contribute to improvements in the quality of life.

Packaging will continue to serve mankind by containing, protecting, preserving and identifying the products that are needed. It will contribute to improvements in the quality of life in all countries, from the developing to the most sophisticated, by getting goods in the right quantity, at the right time and in prime condition, to the people who need them, at the minimum overall cost. It will continue to do this. Although the manner in which it does so may well change in a world where the costs of raw materials and of energy are increasing disproportionately."

He also states that no fundamental changes may be expected in the way packaging fulfils its functions. Three trends have been under way for 40 years now, and these will continue, says Paine (p.22):

- Lighter, more economical and convenient packaging for the purposes for which it is needed. Disposal and recycling properties will become increasingly more critical.
- The function of containment, protection and preservation, together with identification, will be necessary for all types of packaging.
- The costs of labour also play a crucial role in the choice of a specific packaging system. This applies in particular to the more flexible packaging materials for food and other domestic goods.

The previously mentioned legislation in the field of packaging and packaging waste has already come into force and businesses are now obliged to work on the aspect of pollution prevention. In other words: they are forced, within the requirements of safety, hygiene, health, etc., to use less packaging material per unit of product sold. A packaging design method for packaging design is able to contribute towards the proper formulation of the requirements in the field of prevention.

Helping less developed countries
In Western countries programmes to reduce the amount of packaging waste have to be set up, while in many less developed countries food has to be thrown away because it stays unpacked or is not properly packed. A documented method for packaging design could help these countries to reduce the amount of spoiled food because of bad or lack of packaging.

Innovation
Buijs (2000) defines innovation as a sudden change of a new product in relation to the past, concerning product, market and technology.

As already stated in the foregoing, so many aspects can change in the case of innovation that using a check list, being an overview of aspects based on current solutions, is no longer adequate. Totally new situations can arise and the check list may not be sufficient. For instance, current developments in the field of ICT that make it possible to follow products from a distance, to automatically book goods in and out by having them pass through a specially designed gate, and even to record where the packaging waste is located at a given time. Other developments, such as bioscience developments in the field of genetic engineering etc., can also call for alternative packaging methods. A method that starts out at a higher level of abstraction can boost the innovation process.

A method focusing not only on the packaging design, but which is also based on the combination of product and packaging can also boost innovation, as was demonstrated in the before-mentioned case of Océ van de Grinten.

A tool for decision-makers
Decisions concerning packaging can be made more transparent when explicit methods are used. Decision-makers lack good tools to support decisions in the field of packaging design. Stern already made mention of this in 1981, a statement which is still to a large extent current. Many incomplete assessments can be found, especially where ecological aspects play a role. A comparison between two different sorts of packaging, to assess the degree of environmental impact of the packaging per packaged unit, does not give a complete picture, even if only because of the different functions that packaging fulfils (the possibility of re-closing, pouring, folding for storage, etc.) and the difference in product shelf life. Kooijman (1995) demonstrates that the steps that must be taken in the packaging chain, and the method of use by the consumer at home related to the packaging, are very important for the final assessment in terms of the environmental impact of the packaging. The product, the method of preserving, the amount of product that is packaged, the heating or cooling method used at the consumer's home, and – last but not least – the residual product which is thrown away, should all be included in the analysis. Legislation splits up the waste of product and package in many cases and insights like these could be a benefit for the environment. Kooijman (1995) gives examples of packaged products that would reduce the impact to the environment if they would be packed with more packaging material.

Initially, this field of research was prompted from the ecological angle: the superfluousness of packaging. It has meanwhile been demonstrated that while packaging is far from superfluous, some superfluous packaging certainly does exist. Reductions of the amount of packaging material are, however, restricted because of several reasons, like economical arguments, cultural aspects, demographic developments and personal incentives of people involved. The view at the start of this study was to conduct a very broad investigation into this field of activity: in addition to the methodical aspects, the ecological and the economic aspects as well. The lack of methods, a definition, a description of functions, etc., was reason to take the basis of three-dimensional packaging design as the first subject of this study. Due to the magnitude of this, several subjects will not be dealt with, that in effect should have been included.

It may be concluded that a packaging design method can make a contribution in various areas, including ecology and economy, and that such a method can be of benefit to a variety of professional groups, including product designers in many different fields. Nevertheless, the step we will make will only be a small one. A description of the functions of packaging in combination with a definition can constitute the first step in setting out exactly what packaging should do. This is the first step on the way to developing a design method. The method itself must offer an opportunity for interaction with product designers and must preferably also fill the gap to graphical design of packaging.

Before going into the research questions a short note on the explanation of three terms: approach, method and methodology. In the first place the idea was to develop a methodology. Methodology means all the methods that are used together. This cannot be reached in the scope and duration of our present study. The difference between approach and method, according to Cobuilds English Dictionary (1995) is that an approach is the way you deal with it, think about it, and a method is a particular way of doing. A method therefore is that what we want to develop.

The research questions that should lead to the development of a method for packaging design are formulated in the next section.

1.8 Research questions

A design method for packaging design which incorporates all or most, possible functions for packaging has, as far as we are aware, not yet been formulated. As is explained in the foregoing, there are sufficient reasons why this could be very beneficial. The main question of this study is therefore:

A. *What method can packaging designers use to design packaging effectively and efficiently, such that it incorporates all the essential functions, and as many of the desired functions as possible?*

The terminology used in the main question is defined as follows:

By '*method*' is meant: a regular, well thought-out way of proceeding or doing something in order to achieve a specific goal (Van Dale, 1997). Packaging designers (the term packaging design will be used for three-dimensional design of packaging) may come from a wide variety of different backgrounds. While product packaging may be their main daily task, it can also be a part of a more extensive set of responsibilities. The designers may be employed by a packing firm or a firm that produces packaging, a design office, the government, etc.

'*Effectively*; means that the solution functions as wanted and 'efficiently' means with the least costs in money, effort and/or time.

'*All essential, and as many of the desired functions as possible*' refer to those functions formulated in advance by the customer(s) or the profession itself, which the packaging must fulfil (essential functions) or preferably, but not essentially, fulfil (desired functions). This means that the technical problems, to produce the packaging and to fill it efficiently on packaging equipment, are involved in the design process. Also attention is paid to the desire to design a good looking packaging, including graphical design. This combined approach should be guided by a method, analogous to the methods in industrial design.

It must be noted that where crucial, the economic aspects have also been included in this study. They have not, however, been regarded as separate subjects of study as referred to in the previous section. As will become apparent later, involving economic aspects more would mean departing too far away from the core questions on method development, would be too comprehensive and too extensive to incorporate in this study.

Sub-questions are formulated on the basis of the main question. The first is about the functions and a definition of a packaging:

A.1 *What are the functions of packaging and what is an adequate definition of packaging?*

Designing is the translation of functions into working solutions. Therefore the focus will be on methods used in three-dimensional packaging design.

A.2 *What method or methods are currently used in (three-dimensional) packaging design and what can be learned from this?*

To answer this question it is only natural to take a look at the practical situation. Design practice, as a collection of product development processes, is hardly documented. Yet packaging is designed by packaging designers as part of their job, and, among other people, by students of several Universities.

We will try to get an overview of the way these practising designers work, what methods they use and what can be learned from this. Research will be done into projects on packaging design of students, to find out what methods they use and to get an idea of the strengths and weaknesses of the used methods.

1.9 Study structure

In Chapter 2 the focus will be on design methods and on research into these methods. Then a look will be taken at design projects on packaging design of students and known mistakes in packaging design projects in practice. A part of the answer to question A.2 will then be given.

Chapter 3 elaborates on the role of the various functions in the design process and the history of the functions of packaging. This will then be used as the basis for drawing up a definition of packaging. The chapter is concluded with an enumeration of potential packaging functions. This answers research question A.1.

Chapter 4 focuses on tools that can facilitate the design of packaging and on any shortcomings that might come to light in the MSc reports studied and in the design projects in practice.

In Chapter 5 a search will be made for a method of approach to demonstrate how in practice packagings are designed. The word 'approach' will be used here consistently so as to prevent any confusion with the (design) method. The word 'approach' is probably somewhat too limited for the procedure, yet for the sake of clarity the choice is made to use it here.

Chapter 6 sets out how the approach described in Chapter 5 can be implemented. The design process is simulated in such a way that conclusions can be drawn about the way people involved in packaging design normally set to work when solving packaging design problems.

The results of using the approach set out in Chapter 6 are presented and interpreted in Chapter 7. This answers research question A.2.

All the results are interpreted in Chapter 8 and a method for the design of packaging, especially concerning the steps from designing an image up to the realisation of the packaging will also be presented here. This chapter answers the main research question, research question A.

Chapter 9 concludes this study by presenting the conclusions and recommendations.

The structure of this study is presented in the form of a diagram.

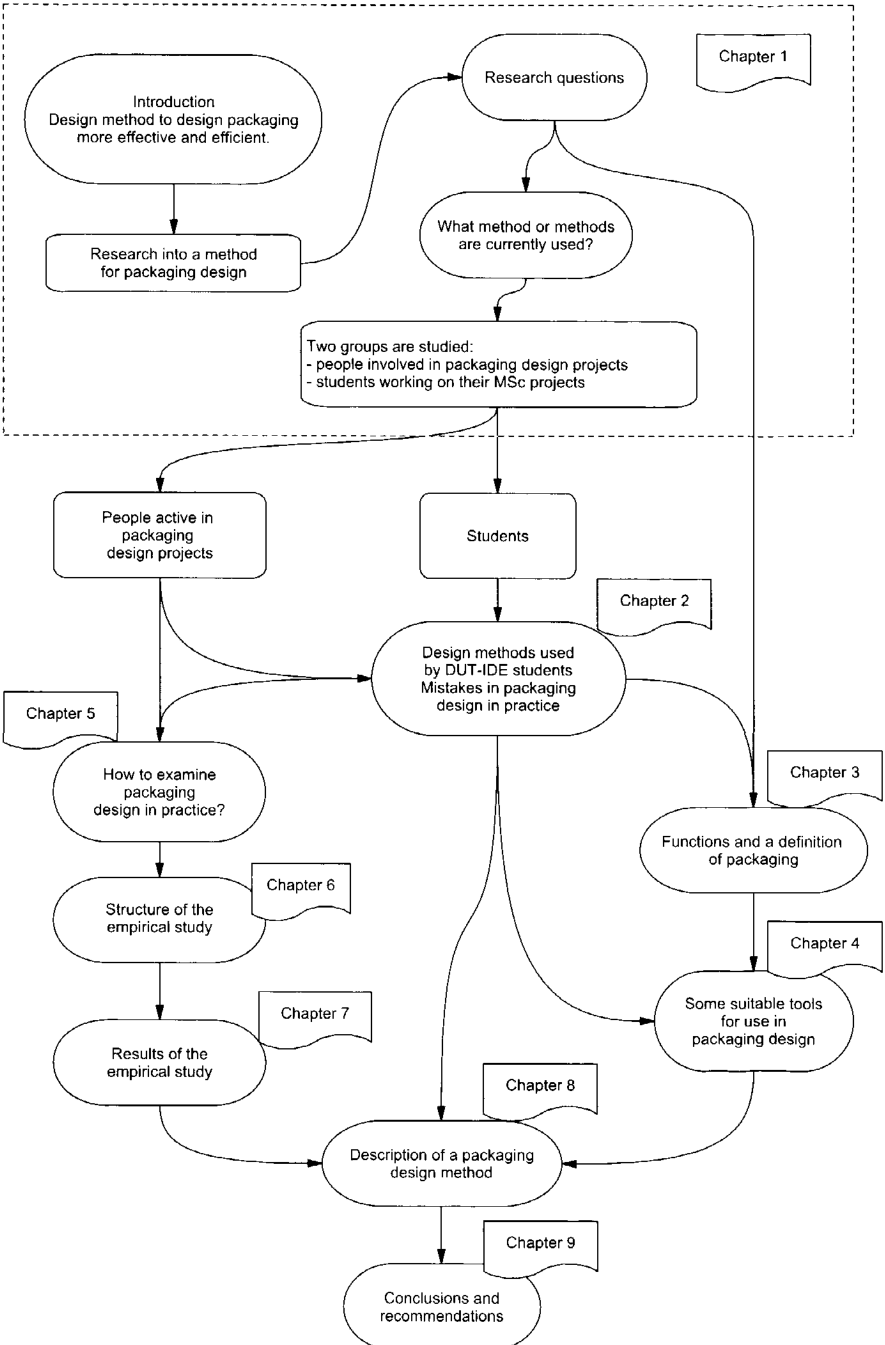

Figure 1.1 Structure of the study

2. *Design methods and packaging design*

Summary

This chapter explains why this study was partly carried out at Delft University of Technology's Subfaculty Industrial Design Engineering. Design methods there are part of two research programmes and many MSc projects concern packaging design and are well documented. These projects are analysed to provide an answer on how students at this subfaculty tackle packaging design. Some background of this analysis will be given by a survey of the field of industrial design engineering and the methods applied. Attention will subsequently be focused on the MSc reports on packaging design. A quantitative analysis will first be made regarding the subjects of these MSc projects. This will be followed by a qualitative analysis. Conclusions are drawn as to how applicable the methods described for industrial design engineering are for packaging design. This analysis is compared with an analysis of a number of design projects outside university, known from our own practice, in which problems occured.

2.1 Introduction

Since a conference on product design methods was held in 1962 (Jones (ed.), 1962), there have been many publications on this subject, among others Jones (1981), Eekels (1982), Pahl and Beitz (1988), Oakley (1990), Delhoofen (1994), Roozenburg and Eekels (1991, 1995), Boddendijk and Sarlemijn (1994), Cross (1984, 1994 and 1996), Pugh (1996), Dorst (1997), Lawson (1997), Buijs (2000), Reymen (2001).

Research into design methods is executed at several universities like Massachusetts Institute of Technology's (MIT) research program Information Flow Modelling, executed by the Center for Innovation in Product Development and projects like the DOME project which concentrates on computer aided data flow and management in complex design projects, at MIT together with Rochester Institute of Technology, University of Detroit-Mercy and Naval Postgraduate School-Monterey. The universities mentioned in Chapter 1 which have packaging amongst their courses, do not have research programmes concerning the design process.

At the Technology Transfer Centre of The University of Sheffield, research is done into the relationship between cognitive decision making and packaging design and the research focuses on bringing together concepts from ergonomics, psychology and engineering, in order to evaluate current methods of opening packagings, and to develop recommendations for the future to reduce injuries caused by packaging.

At the Delft University of Technology, Subfaculty of Industrial Design Engineering (DUT-IDE), research is done into the way designers think (Dorst, 1997) and the integration of ecological aspects in the design process, the latest called eco-design methodology. The Design for Sustainability group is doing research in this latter field and their programme activities comprise three – closely interlinked– research projects, of which Eco-design is one. This programme aims at gaining more insight into successful methodologies, including environmental tools and strategies, for the reduction of environmental impact by existing products. The main target groups are industrial design engineers in companies and design consultancies. This study is part of this research field.

The published manual *Ecodesign, a promising approach to sustainable production and consumption* (Brezet and Van Hemel, 1997) is being used in many research programmes of universities all over the world (for example Sweden, Great Britain, Japan, China, Thailand, Australia, USA).

Dorst (1997) studied the way designers think and compared two paradigms: rational problem solving and reflective practice. His conclusion is that "design can be understood as consisting of 'objective' and 'subjective' interpretative activities" (p.171). The recognition of the distinction between the two kind of design activities, could play an important role in stimulating more accurate descriptions of design activities, eventually bringing design methodology closer to design as it is experienced in practice. Dorst's approach is very interesting for this study and these insights to describe packaging design will also be used.

Many students at DUT-IDE conclude their study by designing a packaging. About 21% of these MSc projects concern environmental strategies. The students' reports of their MSc projects can certainly provide more insight into the methods and tools used. Tools are in this study: schemes, tables, enumerations, etc. which can be used in the design process, to structure the problem, to find requirements, to find solutions or for other purposes. These MSc reports are also able to provide an insight into the results achieved, and probably also into problems that crop up. Hopefully this will give us an impression of the strengthes and weaknesses of the design methods used.

As mentioned in Chapter 1 typical problems occur in packaging design practice. Some insight in the kind of problems, together with the analysis of the MSc projects can help us to formulate requirements which a method for packaging design has to meet.

Because of the research at the DUT-IDE into methodology of design in general and of eco-design in particular, because many students conclude their study by designing a packaging and because package and product are strongly related to each other, the choice is made to combine the research fields.

Since the early 1970's the Subfaculty of Industrial Design Engineering of DUT-IDE has focused attention on how design projects evolve and how they can be succesful. The development and deepening of design methods should ensure that design projects proceed effectively and efficiently (Roozenburg and Eekels, 1991).

Several design methods are taught to DUT-IDE students. The essence of most of these methods is the systematic approach to, and the elaboration of, design problems by using tools. These tools may cover the entire design process, but they can also relate to only a small part of it.

First of all attention will be paid to the methods used by the students. We can then investigate whether these methods are used when designing packaging. The questions that need answering are:

1. What is the specialization of Industrial Design Engineering in terms of content at Delft University of Technology?
2. What methods do the students use in design, and what are the specific features of these methods?
3. How many MSc projects were carried out connected with packaging, and does this give a sufficient broad view of packaging design?
4. Are the same methods used to design packaging that are used for the design of durable goods?
5. Is the packaging design process efficient and effective by using these methods? Are there examples that show an efficient and a less efficient method of approach?
6. Are there any reasons that can be pinpointed for the success and/or failure of separate components or the entire method?
7. Is there a high number of aspects involved in the design project, and how is this complexity dealt with?

After this it is possible to take a look at problems occuring in design practice and compare these problems with the aspects found in the MSc projects.

8. What kind of mistakes occur in packaging design in practice and how do these compare to problems found in the MSc projects?

And finally:

9. What conclusions can be drawn as to the methods used?

This chapter is structured on the basis of the above nine questions. Section 2.2 deals with Industrial Design and Industrial Design Engineering. Section 2.3 looks at Industrial Design Engineering and packaging design at DUT-IDE. The methods currently used at DUT-IDE are explained in section 2.4. Section 2.5 sets out a quantitative and qualitative analysis of MSc packaging projects. The results of the qualitative analysis are given in section 2.6. In section 2.7 attention is paid to mistakes in packaging design in practice. Section 2.8 answers the main questions asked in this chapter: what works well, and what doesn't when following the customary methods for packaging design. Conclusions of the analyses are presented in section 2.9. Demonstrable causes and research representativeness of the research are subsequently discussed in section 2.9. This chapter is concluded with section 2.10, the conclusions.

2.2 Industrial design and industrial design engineering

During the Industrial Revolution, the newly invented technologies of mass production became disconnected from the design of products. The goods concerned were mainly durable goods used in households, farming, general tools used in professional fields, products in public space and transport, etc. The distance from the producer to the user became larger. The disconnection of design from manufacturing signified the start of the industrial design profession. De Wilde (1997) states that the disconnection of functions in the process, as this took place at the Wedgwood factory in 1750, fragmented it and made it difficult to oversee. These aspects gave rise to a new preparatory and integrative activity in the production process, the activity that finally became industrial design engineering.

De Wilde (1997) gives a description of the change of background of the first industrial designers: from artists to arts-craftsmen (19^{th} century), to industrial designers and then to industrial design engineers (20^{th} century). Mass production changed the designing of products from an artistic profession into a creative engineering profession. Production was becoming repetitive with an accuracy that human hand could not match (Heskett, 1980). Producers and designers became aware of the fact that designing products without technical knowledge was very difficult to achieve, as can be concluded from how product design developed in the USA. The first industrial designers who were active in the USA, such as Raymond Loewy, Norman Bell Geddes, Walter Dorwin Teague and Henry Dreyfuss, were called artist-engineers. They worked from different bases, but they all had artistic backgrounds, sometimes combined with engineering jobs. They offered companies the services they had invented and intended to provide: improved looks for a product, superior ergonomics, and increased sales. These designers stated that engineering had to be incorporated into the design, to make sure that the product could be produced (Bayley, 1979).

Procedures to design products were developed. Norman Bell Geddes (1927, in Bayley, 1979) focused attention on the equipment to be used at the client's factory, such as equipment that would improve the quality of life among the working class.

Also Walter Dorwin Teague (1927, in Heskett, 1980) showed a growing regard for technical factors. With this approach he designed very successful products for Eastman Kodak.

The German School of Design, *Bauhaus*, was faced with the problem that several teachers regarded this as an experiment to satisfy higher, for instance societal, objectives, closer to art than to production (Droste, 1990). However, not many producable and marketable products were designed. A major development in the change of the Industrial Design profession was the founding of the *Hochschule für Gestaltung* in Ulm in 1953 by Inge Scholl. Design was seen as a process of intensive and systematic analysis and synthesis of all those aspects that play a fundamental role in the production process.

With this view, industrial design was becoming a multi-disciplinary profession (Lindinger, 1987). Different subjects were introduced into the curriculum for the students at Ulm. The objective was to design products in such a way that the designer could defend his result on the basis of rational knowledge. This new way to design products laid the basis for design methodology.

Archer, a former teacher of the *Hochschule für Gestaltung*, was influenced by the ideas on a systematic approach for solving design problems. The International Congress of Societies of Industrial Design, in which Archer played an important role, adopted the following definition by an industrial designer (Archer, 1974, p.19) in which many aspects are involved:

"One who is qualified by training, technical knowledge, experience and visual sensibility to determine the materials, construction, mechanisms, shape, colour, surface finishes and decoration of objects which are reproduced in quantity by industrial processes. The industrial designer may, at different times, be concerned with all or some of these aspects of an industrially processed object. The industrial designer may also be concerned with the problems of packaging, advertising, exhibiting and marketing when the solution of such problems requires visual appreciation in addition to technical knowledge and experience."

The designer's responsibility for more than aesthetics, or commercial aspects, was adopted by Heskett (1980) in his view of how industrial design had evolved from its origins in early industrial Europe to the present day. He states that "... *the growing industrial design profession finds itself enmeshed in a complex web of problems.*" (p.201). Problems such as the depletion of finite material resources, the increase of environmental pollution, the degradation of the nature of work by mechanization or the displacement of workers by automation, and the gulf between the 'haves' in industrial countries and the 'have-nots' in the so-called 'under-developed countries'.

The development of design methods has led to many publications on this subject giving an account of the tools used with the objective of structuring the design process, making it more understandable (strategic), or allowing parts of the process to run more effectively (better solutions) and more efficiently (time, costs) (see the sources quoted above). A great deal of use is made of design methods in design practice. It can therefore be stated that the chance of success in the market is greater if the design process is structured.

In summary it can be said that an industrial designer is an important link in the development process of many, especially durable, mass-produced industrial products. An industrial designer is in fact, as was already the case at Wedgwood in 1750, still the person who has a complete overview of the most important decisions in the development of consumer goods. To ensure that this process remains manageable, use is made of methods that describe the design process or are able to optimize parts of the design process in terms of effectiveness and efficiency.

2.3 The Five-year Curriculum

The subfaculty of Industrial Design Engineering (IDE) of the Delft University of Technolgy aims to train students as professional product developers of (particularly) serially or mass-produced durable, material products (Delft University of Technology, 1996). The DUT-IDE brochure stresses that the study programme aims to train those engineers who also have a wide knowledge, such as mathematics, mechanics and the theory of the strength of materials. However, a great deal of attention is also devoted to the marketing side of product development and aspects of business economics.

Graduated designers are expected to be able to think in terms of product functions and not only in terms of technical solutions. Hence, producability, functionality and the saleability of a product must be combined with design, ergonomics and environmental aspects. State-of-the-art production and assembly techniques, computer applications, a knowledge of materials and marketing, are all subjects a designer is expected to be familiar with. In short: 'creating products for people' (Oppedijk Van Veen et al. 2001).

In the final two years of the five-year programme, students can choose between two specializations: product design and innovation management. The development of specific three-dimensional products comes first and foremost in product design. The emphasis in innovation management is on product innovation and the management of product development processes in a business environment.

The last assignment in this curriculum is a sort of proficiency test. The student is required to carry out an assignment which is strongly related to design practice. In most cases the assignment is carried out both at and for a specific firm or for a governmental organisation; in a few cases it will be a study carried out at Delft University of Technology. In terms of study load, the time allowed for these assignments is six months; in practice they take some eight to twelve months to complete. The student is required to set out the design process logically in the form of a report. This is necessary to give the supervisors an insight into the decisions that have been made. All the steps of the design process can be found in the report, from the assignment description up to and including the solution(s) found, the conclusions and the recommendations. The diploma of this five year curriculum is a Msc in industrial design engineering.

De Wilde (1997) gives an extensive overview of the fields of activity and the functions within which graduated engineers operate. This list shows that 70% ultimately finds work in the field of product development, and 16% work as independent designers.

2.3.1 Packaging design at DUT-IDE

In the nineteen sixties, when the industrial design course first became established at DUT-IDE, and when packaging started to belong to the course of study, a distinction was still made in terms of packaging durability. For example: the design of durable packaging was accepted (e.g. plastic containers for transport purposes) or the design of packaging for durable goods was allowed. According to the faculty, packaging for non-durables, food for instance, belonged to the Wageningen Agricultural University. Choosing packaging materials on the basis of durability properties, gas barriers, micro-biological aspects, etc., that play a role in the design of packaging for food, did not, according to the faculty, belong in the curriculum of an industrial designer.

At the end of the seventies, quite in line with the views on packaging design, a MSc thesis at Delft focused on a plastic crate for the Dutch Flower Association. The subject of this thesis was not seen as packaging, but rather as a means of transport. After five different MSc thesis projects for the Dutch Flower Association, child-proof closures were the subject of a MSc thesis. Subsequent projects carried out on packaging were a one-way gas canister and a sleeve for margarine. It is not completely clear why at a certain point the criterion of durability was withdrawn from the approval procedure of the projects. According to Marinissen, the professor who taught the main subjects for the projects on the child-proof closure and the gas canister, several aspects probably played a role. It is quite possible that the departmental board, that had to approve the projects and test them against the objectives, had overlooked the aspect of durability. It is also feasible that the student had already been engaged on the project for some time when the board came to test the assignment, a situation that arose many times, and that the board members had decided not to call the student to order. Another possibility is that the assignment was deliberately approved in order to allow other professors more scope when searching for subject matter. Another aspect is the lack of a definition for packaging. Crates and boxes can be defined as a means of transport, the child-proof closures as durable goods to protect children, the gas canister as a temporary means of storing gas, etc.

It is also highly plausible that the professors had the insight that the general design methods could also be used for many different sorts of packaging.

The subject of packaging was included in a discussion held in February 1997 on potential subjects for the design curriculum. Packaging subsequently became an elective part of the curriculum.

2.4 Currently used methods at the DUT-IDE

During their study, students are presented with a wide range of methods that can be used systematically in design processes. Some methods are for a specific part of the design process only. This section focuses on the methods taught to all students. Subsequently, attention is given to eco-design, a design approach in which environmental improvement comes first and foremost. The eco-design method of approach is a recent addition to the methods used today and in quite short time has earned itself a permanent place in standard design methodology and the associated handbooks (Remmerswaal, 1999). Legislation on packaging and on packaging waste as will be dealt with in section 4.6, but also the social pressure on packaging, plus the fact that the reason for many design projects carried out at DUT-IDE in recent years was the environmental aspect, justifies incorporation of the eco-design approach in our study. An analysis of all MSc projects in the field of packaging shows that the grounds for 21 of the 61 projects carried out between 1991 and 1996 (34.4%) were the environment and that tools had been used which now belong under the heading of the eco-design approach.

2.4.1 The basic design cycle

The recurrent theme running through the design process as taught at DUT-IDE is the basic design cycle referred to by Roozenburg and Eekels (1991, p.79). Buijs (2000) mentions that this method is sometimes called the 'Delft Method'. This basic cycle comprises the following steps, starting with an assignment, usually formulated as a goal (also referred to as the function):

- analysis: what is the problem;
  this produces the criteria: what the solution must satisfy;
- synthesis: the search for potential solutions;
  this leads to solutions which will, or will not meet the criteria;
- simulation: determine whether the proposed solutions will satisfy the specified criteria;
  this will explain the properties that can be expected of the design;
- evaluation: find out the extent to which the goals have been achieved;
  an assessment is in fact made of the proposed solution(s);
- decision: whether to go ahead or not;
  an acceptable design should ultimately emerge from the process.

Such a design can be described as a plan that shows what a solution for the problem will look like. The following items (not necessarily all of them) may be present in such a design: the functions that must be fulfilled have been defined; the materials have been selected in combination with production techniques, shapes have been specified; the decision has been made regarding quantity; the tools for manufacturing have been taken into consideration; the assembly of the product components has been established; a prototype has been constructed; the cost prices are known; a plan for distribution and sales has been drawn up; attention has been given to the diversity of the products to be produced and to the components and/or product variations; in certain cases test runs will have resulted in optimization activities, and market surveys will sometimes have been carried out.

The design process is generally not linear but iterative, i.e. it can involve large amounts of feedback and, consequently, the process is carried out in loops, some parts of the process occasionally being gone through repeatedly.

Roozenburg and Eekels see the cycle described as the most fundamental model of designing. They state: "*Someone who claims to have solved a design problem has gone through this cycle at least once.*" (1995, p.89).

This procedure can be found in numerous accounts of methods. Cross (1994) gives a short overview of some descriptive and prescriptive design processes. The descriptive accounts tend to lean towards development processes, i.e. consistently following enumerated design activities. On the other hand, the prescriptive approach is more algorithmic, generally referred to as design methodology (p.24). Cross (1994) presents an outline of the development of systematic design methodology (in: Jones, Archer, Pahl and Beitz) in accordance with the detailed models of the German Engineering Society (VDI 1973 and 1986) which describe in great detail the many, many steps that should be taken (pp.24-28).

Roozenburg and Eekels stress the holistic approach as Archer did too (1974). This is an approach in which it is seen as essential to bring together all the potential aspects that might possibly play a role in solving design problems. Nijhuis (1980) developed tools for this purpose, based on a product's life cycle. A product goes through several processes that can be set out hierarchically, thus providing us with a 'process tree' of its life cycle. A description of the life cycle of a product consists of the following phases: manufacturing, distribution, use and termination. On the basis of the processes enumerated in the process tree it becomes possible to impose requirements and wishes on the (future) solution.

The requirements and wishes imposed on the solution are brought together in a so-called programme of requirements. This programme of requirements plays an important role in the further design process. A great deal of attention is devoted to this programme of requirements in the publications of Roozenburg and Eekels. The way in which requirements are formulated is extremely important when selecting solutions. Over the past few years the necessity has been argued of building up an idea of both the product and the context before drawing up the relevant requirements (Dirken, 1999). This idea can be in the form of a brief, qualitative description that may include sketches and drawings, giving a rough and initial picture of what is expected of the outcome. Functional aspects play an important role here. Today, on the basis of the Design for Sustainability research programme on eco-efficient product and service combinations, arguments are even expressed in certain cases favouring the initial designing of 'a business' before moving on to the product idea and its design (Brezet et al, 2001). A logical follow-up to the attention Roozenburg and Eekels devote to the requirements is the attention given to selecting the best solutions from several design proposals. These two authors deal with several different methods of how to best assess a design proposal (Roozenburg and Eekels, 1991). The testability of the requirements is important when drawing up the programme of requirements. A distinction is made according to standards (to which the solution must comply, imposed externally), specifications (determined by the design), requirements (to be met by the solution for it to be acceptable; this can be either a qualitative or a quantitative criterion) and wishes (which, if at all possible, the solution must meet; a qualitative criterion). Six criteria are named for a good programme of requirements (1991, p.126), in order to maximize chances that a solution is able to meet the objective:

- the validity of each criterion individually (the aspect, as a component, must reflect the objective adequately);
- the objective must be covered by the criteria collectively (the objective must be accomplished);
- the criteria must be operational (objectivity);
- non-redundancy (the aspects may not be included several times);
- the number of criteria must be the least possible, but must be complete (the programme of requirements must be manageable);
- accessibility (the degree of predictability must be such that a design proposal can be tested).

A procedure is presented for drawing up a programme of requirements. This procedure includes the following three steps (1991, p.132):

1. drawing up the criteria (processes, wishes, demands, needs);
2. analyzing the criteria (all aspects are unambiguously present, goal-means hierarchy, completeness and consistency);
3. editing (not yet specifying solutions, operationalization of the requirements).

An overview is also presented of the techniques that can be used to generate ideas. The most well-known – brainstorming – is only one of a long list of options. New techniques are constantly being introduced. An overview of practicable creativity techniques is given by Walravens (1997) and Buijs (2000), and Melis (1991) also pays attention to creativity and innovation on packaging. Many other scources can be found about creative techniques.

Considering the wish to be as complete as possible when designing products, it may be assumed that packaging will also be included. After all, packaging is a useful part of a product's life cycle. Archer (1974) referred to packaging as a subject for which an industrial designer can be called in when designing a product, especially when design and technical expertise are essential. Cross (1994) makes use of several design problems in which packaging plays a role (a feed delivery system, p.69; packing carpet squares, p.71) as examples when dealing with design methods or tools used in a specific part of the design process to make that part of the process more effective and efficient. Nevertheless, he fails to mention an integral approach for packaging design.

Design methods are heuristics, i.e. An aid to solving design problems, but the use thereof does not automatically lead to a solution. This means that the field of design methods will be dynamic. There will be a continuous attempt to solve certain problems more effectively and more efficiently and to re-scale the methods found for use in other sorts of design problems. A few examples of design methods or of tools that have been used frequently in recent years are: design for assembly, design for disassembly, failure mode effect analysis, quality function deployment, statistic process control, computer aided design, computer aided engineering, concurrent engineering, customization design, etc. A clearly visible, specific trend is that designing is an activity which is becoming less of an isolated activity. It is not only concerned with making the product worthy of production, but other aspects also play a role, such as the supply of parts, combining parts or components with other products, combining the production of different parts, the routing in the company as a result of the design, etc. For more complex products consisting of many parts, designers are more frequently included in an ever-growing interdisciplinary team of experts who work together to develop new products. Most developments using design methods lead to an efficient process or ensure a higher quality of the end result.

Dorst (1997) explains that the basic design cycle is an abstract way to solve all kinds of problems and is part of the theory of human problem solving. To explain the science of design he uses the model of Simon to describe rational problem solving. The design process is defined as a rational search process, in the way of the basic design cycle. The other way of design Dorst examined is 'reflective practice' in which the design process is seen as a reflective conversation. Subjective interpretation is involved in almost all design projects, especially in the development of the design concept (Dorst, 1997; p.169). This means that in the development of a method to design packaging, it has to be taken into account that the design process cannot be described only by rational search steps.

2.4.2 Eco-design

In response to the environmental design problems that had been raised in society after the early 1970's an increasing amount of attention was given to the ecological aspects of design in the early nineties. This was in line with Heskett's views on industrial design. Several methods have since been developed to integrate ecology into industrial design. Several tools have been developed, both strategic and operational. These tools can be integrated in the design process and it is up to the designer, the design team or the client to take action.

Several demonstration programmes, supported financially by the Dutch Government, showed that the integration of environmental aspects is indeed profitable. These demonstration programmes were called Eco-design. 'Eco' stands for both ecology and economy. The results of the projects were analysed and tools developed for integration in the design process.

Attention is paid to this approach because, as will be seen in section 2.5.1, about one-fifth of the MSc projects on packaging was started from the viewpoint of eco-design.

One of the tools, developed by Van Hemel (1998) in the demonstration programme Eco-design, is called Lifecycle Design Strategies. The title suggests that the method is on the strategic level, but that depends on the way it is used. Eight directions are listed as potential dimensions in the Lifecycle Design Strategies for the purpose of examining possible improvements, in order to achieve a more sustainable development. The directions are:

- *New concept development*: an alternative way of fulfilling the functions can result in less harm being done to the environment; dematerialization, shared use of the product, integration of functions, functional optimization of the product (components).

- *Selection of low-impact materials*: choose the materials with the least impact on the environment; clean materials, renewable materials. low energy content of materials, recycled or recyclable materials.
- *Reduction of material usage*: fulfilling the same functions with less material is less harmful to the environment; reduction in mass, reduction in (transport) volume.
- *Optimization of production techniques*: choose those production techniques with the least harmful emissions: alternative production techniques, fewer production steps, low/clean energy consumption, less production of waste, less/clean production of consumables.
- *Optimization of the distribution system*: as many products or as much product per transported volume and the least possible number of transhipments: less or reusable packaging, energy-efficient mode of transport, energy-efficient logistics.
- *Reduction of the user impact (such as products which need energy or water to function) that can cause substantial pollution by the use of the product*: low energy consumption, clean energy source, reduction of high-need consumables, clean consumables, no wastage of energy/consumables.
- *Optimization of initial lifetime*: longer lifetime avoids the need for new products; reliability and durability, easy maintenance and repair, modular product structure, classic design, strong and lasting product-user relation.
- *Optimization of end-of-life system*: reuse of product or of material spares new materials, production steps and waste managing activities; reuse of product, remanufacturing/refurbishing, recycling of materials, safe incineration.

Attention is given to how these strategies can be integrated into the design process and to the degree of intervention in the design process.

Integration of theories and models from product design and innovation methodology, technology assessment, design engineering and environmental sciences creates the basis for above's program's approach. An interdisplinairy, product life cycle orientation is followed, since sustainability demands an insight integrated in the environmental consequences during all phases of the product life cycle and involves many disciplines. Special focus is on emerging strategies and technologies that can help to reduce the environmental impact of products by dematerialization.

Due to the relative newness of eco-design for industrial design engineers, the development of practical tools and the testing and experimentation in a business context are considered important elements in the Design for Sustainability programme of DUT-IDE, to be balanced with more fundamental research into and explanation of sustainability as a theoretical concept. Although the main focus of the program is on optimisation of the environmental aspects of products and the technologies involved in their life cycle, other aspects of the "sustainability concept", such as economics, social acceptance and cultural implications are also taken into account.

Other tools are also developed and presented in the Eco-design Manual (Brezet et al., 1994), later on published in English with additional information (Brezet et al., 1997). More projects on 'environmental design', in addition to the Eco-design projects, were analysed for this manual. One tool that should be mentioned is the MET matrix

(Material, Energy, Toxicity), a qualitative tool, used for finding aspects which need to be given more attention from the point of view of ecology.

Bakker (1995) concluded that an industrial designer needs simpler tools and quantitative information to judge design concepts during the design process. A first step in this direction has been taken since the beginning of the nineteen nineties. Consultancies, universities and commercial institutes have developed qualitative tools and software tools for life cycle analysis (LCA), to measure the environmental load in ecopoints, in financial units or by several scores on specific ecological problem areas. An overview of LCA software tools is given by the UNEP, IE, and lists 47 different tools and is presented in the English Eco-design Manual (Brezet et al., 1997, p.199).

The before-mentioned quantitative and qualitative tools do not change the methodology of the design process. The methodology of Eekels and Roozenburg is accepted as the starting point, although different views are being published (Brezet et al, 2001). The difference between the normally used methods of Eekels and Roozenburg and eco-design is that environmental requirements are included or even placed in the foreground, and that a system-based approach is more explicitly used. This means that the complete chain of production, distribution and use is taken into account more completely. For example, a comparison shows that an ecological examination is more than mere cost-price calculation. The residue inside a food packaging after use has only seldom (Kooijman, 1995) been an aspect in cost-calculations of the packaging or product-package combination. When environmental aspects are integrated in the design process, the waste that remains at the end of the lifecycle has to be taken into account. In fact, it can be stated that only a part of the real costs of products and packaging has been calculated in the past and this omission tends to continue, also because of the approach of legislation in which products and packaging are not integrated. If a packaging is difficult to empty, the amount of waste increases, and at the end the costs incurred by society to dispose of that waste increase too. Some (Brezet et al, 2001) go so far as to claim that the idea, that the environment (packaging waste and pollution from packaging) is the same as money, has led to more life cycle costing tools being developed in eco-design within a five-year period than in the other industrial design professions over 25 years. This claim implies the proposition that eco-design not only leads to a greater environmental merit but also to more attentive designing in general.

It can be concluded that environmental analysis forces industrial design engineers to broaden their scope. As can be seen in the book on the Eco-design programme (Te Riele, 1994), this does not limit but rather exhorts the finding of interesting and creative solutions.

2.5 MSc packaging projects

This section deals with MSc projects carried out at DUT-IDE in which the assignment was to design a packaging. First of all a quantitative overview of the design projects is given. This explains the sort of packaging that has been designed, which is useful when making the qualitative analysis. Subsequently, the method the students used to tackle the projects, and how they progressed, is then discussed.

2.5.1 Quantitative analysis

By November 1996 a total of 109 MSc projects had been executed on packaging over the preceding 20 years at DUT-IDE. Two projects from other Universities of Technology were also included. The first project on packaging was executed in 1977, project number 62. From that time on there was a steady growth in the number of projects on the subject of packaging until the figure stabilized at 7% in 1991. This percentage remained at 7 up to 1996. The first project on packaging in which the environment played an important role was carried out in 1987. From 1991 to 1996 the annual percentage of packaging design projects in which the environment played an important role grew from 6 to 19 and remained stable over the last three years of this period. Projects that started after 1996 have not been taken into consideration.

Not all reports give details as to the amount of time spent on the projects. Projects are usually completed within a period of 8 to12 months. This is confirmed by those reports stating the time taken to complete the project.

The projects were divided into different categories. The division is based on several aspects:

- kind of packaging
  - primary packaging[1]
  - secondary packaging
  - primary/secondary packaging; this signifies that it is difficult to make a distinction. The packaging is usually the first layer, or a combination of layers; on the other hand it can also satisfy the description of a secondary packaging. Most packaging used for televisions is, for example, categorized as primary/secondary packaging.
  - projects sometimes concern primary packaging as well as secondary packaging. These are also categorized here.
- kind of products to be packed

  The division of products has been made on the basis of Kotler's division of products (1980).
  - food and drugs
    - food
    - beverages
    - drugs

[1] *Chapter 4 explains 'primary' and 'secondary' packaging.*

- non-food (non-durable)
  - do it yourself (DIY) articles (non-durable), leisure articles
  - articles for personal care & personal hygiene, cosmetics
  - horticultural goods
  - detergents
- durables
  - electronic equipment
  - electronic components
- durable tools
  - furniture
  - other durables

• packaging is sometimes developed for a group of products, or the packaging can function for different products. This packaging is categorized as follows:
  - industrial packaging; intended for large quantities of (amorphous) products
  - transport packaging; intended for small amounts of (mostly rigid) products, equal to a secondary packaging
  - display packaging; having the special function of displaying the products

• additional components, specific methods and packaging equipment are sometimes designed too. Because the design of these products or systems influence the design of the packaging, these projects are also included, categorized as follows:
  - auxiliaries
  - equipment; to bring together product and packaging
  - methods on specific aspects

• two projects were difficult to categorize and are therefore called:
  - other

The division of products is presented in Table 2.1.

Category:	Food & drugs	Non-food Non- durables	Durables	Packaging itself	Additional to packaging	Other	Total
Number of projects	45	24	10	13	15	2	**109**
% of total	41%	22%	9%	12%	14%	2%	**100%**
of which on environment (number)	9	6	3	4	1	1	**24**
% of category	20%	25%	30%	31%	7%	50%	**22%**

Table 2.1 Division of MSc projects on packaging design

	Food & drugs	Non-food	Durables	Total
primary	36	11	1	48
secondary	4	3	2	9
prim./sec.	5	10	7	22
subtotal				79
industrial				6
transport				3
display				4
subtotal				13
additional to packaging and other				17
total				109

Table 2.2 Division of projects on packaging design by kind of packaging

About 1/3 of the projects were executed between 1977 and 1990.The remaining 2/3 were executed after 1990. Environmental considerations in design projects became common after 1990.

2.5.2 Qualitative analysis

This section gives the qualitative analysis.This analysis is carried out to get an impression about the strengths and weaknesses of the used method(s). It should be clear that this examination is not meant to give a scientific evaluation on the validity of the methods used or the results.The projects are executed over a period of almost thirty years, at different companies, with different partners.

A schedule of each project has been made in which the major steps are enumerated; how the requirements are set up, which tools are used (cheklists, brainstorm sessions, function models, etc.), how a selection is made of concepts, which requirements are used (all of them or just a selection), etc.

Considering the characteristics of the methods taught for solving design problems the aspects to be specified are the following:

- taxonomy in the design process;
- the basic design cycle as the recurrent theme;
- a variety of tools that can be used in each design stage;
- it is customary to stress the programme of requirements, completeness of aspects (common tools are process trees), creativity techniques and techniques for evaluating the design proposals;
- specific or non-specific methods for the design of packaging;
- the eco-design approach (taught since 1992/1993 as an optional subject, and as a compulsory subject since 1995/1996).

The projects were analysed to answer the following questions:

- Has the DUT-IDE method been applied?
- Were many aspects involved in the design process?
- If the current DUT-IDE method was not used, in which part was it not used, and what procedures were followed for that part instead?
- What went well – measured in terms of effectiveness and efficiency – when using the methods?
- What went not so well – measured in terms of effectiveness and efficiency – when using the methods?

The answers to the first three questions can be estimated reasonably objectively and therefore a short list of the facts found should be sufficient. The answers to the last two questions are partly subjective. It is for this reason that examples taken from the MSc projects are given, in order to support our impressions.

2.6 Qualitative analysis of the MSc projects on packaging design

It became evident that substantial differences occured among many of the projects in which use was made of DUT-IDE methods. Eekels and Roozenburg's methods give a lot of freedom, and this made it difficult to assess the projects. In a few cases the use of an approach that differs from the usual one, can be seen. The conclusions of the analysis of the MSc projects are given in section 2.8.1.

2.6.1 The use of DUT-IDE methods

DUT-IDE methods were used without exception in all 107 projects analysed; (taxonomy, basic cycle, tools, etc.).

- Frequent use was made of tools. The process trees, for example, were used almost without exception. Check lists were added to the aspects taken from the process trees in a few cases. In only very few cases, process trees were not used at all, only the check lists.
- The number of requirements brought into the projects was generally high, varying from at least 20 to more than 100.

When considering the number of tools available to the students in each stage, it became clear that each project was carried out in a different way. This was because of the difference in assignment (objective, starting point), the different companies where the projects were carried out and obviously because of the student's individual viewpoint. The design methods used allow for this freedom. This was particularly evident from the way the programme of requirements was handled, as well as in the selection of ideas and concepts. Several of the different methods of approach are shown in figure 2.1.

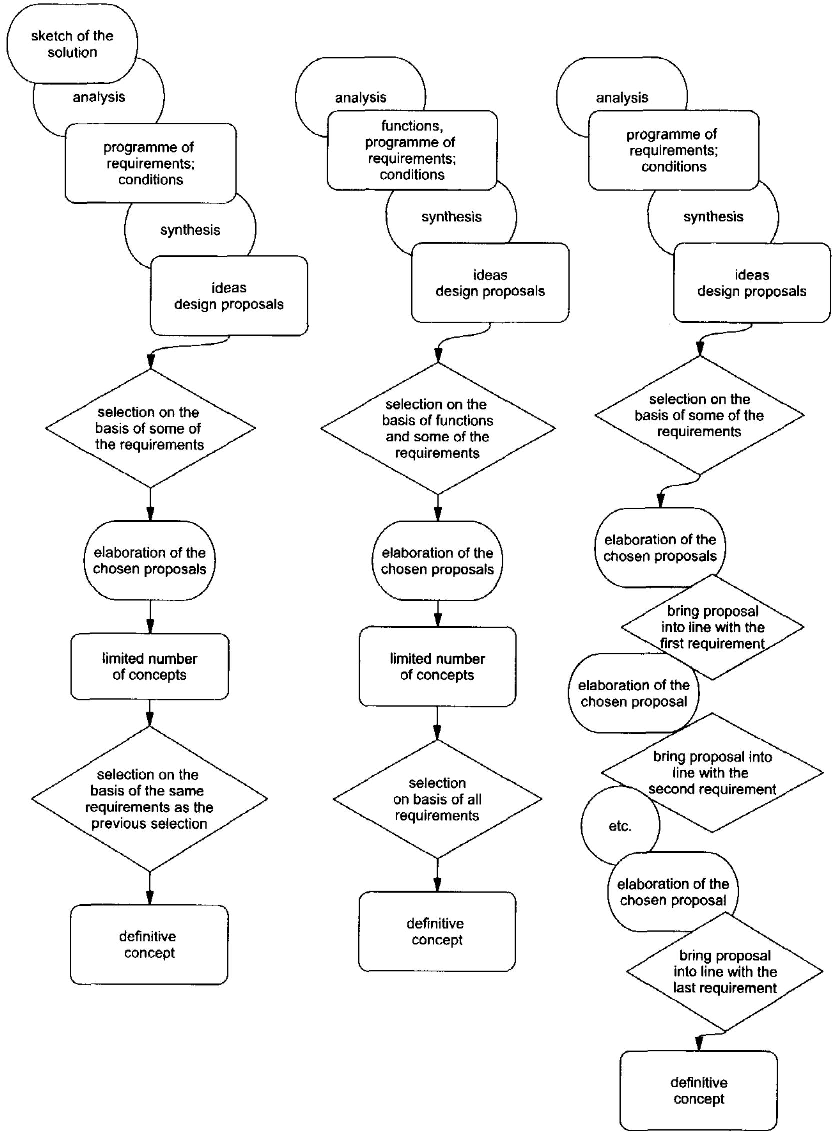

Figure 2.1 Examples of the different ways of working with the various methods

2.6.2 Unclear aspects in the projects

Although the MSc projects show that the students used the methods described by Roozenburg and Eekels (1991 and 1995) as the starting point for their projects, decisions are often made which are not clear or not mentioned or explained. This is generally the case when drawing up and dealing with the programme of requirements. Several salient aspects that were evident from the analysis are given below.

Decisions difficult to understand

Frequent use is made of attributing weighing factors to requirements when testing the concepts against the programme of requirements. The concepts are subsequently examined against the requirements. The reason for attributing a certain weight to a requirement is often left partly or fully unexplained.

To be able to use a manageable programme of requirements, concepts are regularly tested against a selection of the requirements. These requirements are then referred to as the principal requirements. Why these specific requirements are selected as the principal requirements, is in many cases not explained.

This method of approach makes it difficult to assess the decisions that have been made and goes against the objective of being able to form the best possible value judgement of design proposals.

Selection and use of principal requirements

When using principal requirements, the way a requirement is formulated does not always explain it unambiguously. The following example was taken from a project in which the following two requirements were among the principal requirements against which the concepts were tested:

- the packaging must protect the product;
- the packaging must offer protection from moisture.

Is the moisture barrier also included in the first requirement as product protection, or does the first requirement refer to something entirely different? When the concepts are tested, it is not clear as to what the concepts are being tested on. Both requirements count in the final consideration and both score the same for each concept. Although the omission of one of the requirements does not affect the choice, it certainly does change the differences between the concepts. The first requirement is not objectified. As pointed out, requirements must be able to be interpreted unambiguously, and aspects may not be counted twice (redundancy) in the final judgement, in order to increase the value judgement. This is not the case in this example.

The use of non-discriminatory requirements

Concepts are tested repeatedly against requirements that are not discriminatory. This sometimes concerns more than half of the requirements. It is therefore obvious that the distinctive aspects have not been analysed.

Not separating the requirements from the starting point

If the assignment is to design a packaging made from glass (a jar for soup), or a packaging for twelve dragées (packaging for chewing gum), it is superfluous to test the concepts against these starting points as if they were requirements. After all, it would make little sense to design a plastic packaging for a glass producing factory, or to make a sketch of a packaging for twenty dragées while the assignment specifically states twelve.

The assignment, specifications and standards have no place in a programme of requirements. This does not, however, mean that certain aspects should not be considered discriminatingly, but they certainly do not belong in the programme of requirements.

The unclear facts indicated above are omissions and are probably not specific for packaging design. A short investigation of other projects affirms this, but this is not of great importance in this study.

2.6.3 Remarkable ways of using the DUT-IDE design methods

Methods of approach were occasionally detected that were different from the usual DUT-IDE methods. These are explained below.

The use of functions to prevent double requirements
A method of approach is occasionally taken, in which of a list of functions is used instead of process trees, for instance in the design of a packaging for paint. The explanation given was that the use of process trees would lead to double requirements, i.e. that requirements made in the various stages of the life cycle of the packaging would then be placed in the programme of requirements several times. This method – using the functions and the goal-means-hierarchy – differs from the usual one. Obviously it can be claimed that the result, the programme of requirements, need not be substantially different, if the basis chosen is the process that the packaging goes through. Had this been the case, then a well carried out analysis of the requirements would have ensured that none of the requirements had been duplicated. However, it can be concluded in this respect that the use of process trees can lead to double requirements, and thus to a lower level of efficiency in the design process. On the other hand, it can also be claimed that for each function, all the different circumstances that could possibly arise must be looked at in order to quantify a requirement. If the function of the packaging is to offer protection from mechanical influences, then exactly what those mechanical influences are, how big they are, and what requirement can be drawn from them, must be investigated. It is inefficient to run through the life cycle for each function.

Starting points, requirements and wishes
Separating starting points, requirements and wishes apparently made things clear in several cases, for instance for the design of a cluster pack for beer. A starting point cannot be compared with a specification or a standard. The programme of requirements does not stipulate any starting points. If the solutions fail to meet the objective totally, then a result can be achieved which is more in line with the objective by modifying the starting point.

Designing an 'image' first
In one of the projects, namely the positioning and design of a packaging for a flower variety, the first move was to make sketches; a selection was made on the basis of interviews. The sketch chosen was then elaborated on. To this end a programme of

requirements was drawn up by using process trees. The usual method only started to be followed after a concept shape had been designed.

Drawing up a programme of requirements is much easier if it is preceded by a brief, qualitative product image to provide insight and coherence. It can sometimes be wise to start by making sketches instead of drawing up the requirements and formulating the actual problem, especially in projects requiring the design of something totally new, or if there is the wish to break away from an existing image.

Decision hierarchy

In one project, the design of a modular packaging system for medicinal drugs, a solution was first of all worked out which met the requirements drawn up on the basis of the aspects of product protection and distribution. A second design phase was then started up to be able to present the information that needed to be either on the packaging or accompany it. How the necessary, as well as the desired information would be printed on the packaging or included in it, or with it, could only be specified after other choices had been made, such as materials and dimensions.

DUT-IDE methods aim to assess the design on as many relevant aspects as possible. First of all the design is put to a general test, to see whether it meets the requirements, after which the requirements are set out in greater detail and then testing becomes more specific. In the project for the modular packaging system for medicinal drugs, several of the functions were worked out, ranging from rough to detailed; other functions were subsequently worked out in the same way. This is a process that seems to be steered by a goal-means-hierarchy which, in this particular case, worked well.

2.7 Packaging design in practice

In this section attention is paid to illustrations of packaging design in practice, outside projects by students. As mentioned in Chapter 1, the term packaging design is often used for graphical design. This means that in many occasions only the graphical design is changed. Sometimes another packaging is chosen out of the standards to highlight the product.

Koopmans (2001) warns designers in changing the shape of the packaging to avoid technical problems. Nevertheless, many projects described in publications show that packaging designers who design three-dimensional packagings, come up with an image first and then start the technical realisation of the design. This is in line with the approach of Dirken (1999), as mentioned in section 2.4.1.

Still many problems occured in packaging design projects. A short list of project descriptions or mistakes, as we noticed over the last years in our own practice, follows hereafter and attention will be paid to the nature of the mistakes.

Caps of shampoo bottles which could not be unscrambled
A shampoo bottle was designed to optimize the appearance of the bottle on the shelves in the shops. The shape of the cap was designed in such a way that is not possible to unscramble the caps mechanically in a hopper, which means that many caps enter the filling equipment up-side-down. Another (new) hopper could not solve the problem. In the end the design of the caps had to be changed which meant that new moulds for injection moulding had to be manufactured.

Cause of the problem: The design office which designed the caps refused to pay attention to requirements set by filling equipment. They have never been in the filling hall and their opinion is that technical problems can be and have to be solved by changing the equipment. In their opinion the design of the bottles is more important than problems and costs caused by changing equipment.

Conclusion: A lack of integration of design aspects is the cause of this problem.

Spicy peanut sauce in a sachet that opens by itself
This problem occured twice. The sauce is brought into sachets by vertical form-fill-seal equipment. The company chose to use a laminate of PET and LDPE. PET for the stiffness of the sachet and printability and LDPE to seal it easily with a high seal-integrity. The seals opened and the sauce came out.

Cause of the problem: The sauce contained natural oils. LDPE and many oils do not go together very well. Many oils diffundate inside LDPE. The oil creeps in the spaces between the two layers in the seal and breaks it.

Conclusion: This problem occured because of a lack of knowledge of material properties in relation to product properties.

Rollers on glass jars that came off during use
A company decided to fill a product (against insect bites) in glass jars, with a roller on the top. The rollers are known for their use for lipp gloss. The roller ball is inside a plastic device that is placed on top of the jar. The device wedges inside the neck of the glass jar. The roller is protected by a plastic cap which is screwed on a thread on the glass jar. During use the complete plastic device came off and the contents of the jar came out all at once.

Firstly, the people involved thought that the problem occured because of dimensional problems of the different parts. The glass jars and the plastic devices were measured and no problems were found.

Cause of the problem: The recipe of the product is based on 'Haarlemmer' oil. The device of the roller ball that is wedged in the glass jar, is made of LDPE. If the oil comes into contact with the plastic device, it absorbes the oil and expands. The oil also comes in between the device and the glass and functions as a lubricant. Because of this combination the device comes off slowly up to a certain point and then it comes off entirely. The company tested the combination only superficially and not in conditions of use.

Conclusion: This problem occured by a lack of knowledge of material properties in relation to the properties of the product.

Labels that come off

A combination of aspects, like the design of the label, the kind of paper used, the glue used, etc. causes many labels to come off just after labeling. This problem occurs on glass as well as on plastic and metal packaging, with self adhesive labels as well as with labels glued with wet glue.

Cause of the problem: Mostly the problem is caused by a combination of properties of the packaging to be labled, the label material, the glue, the equipment and the circumstances. Sometimes the shape of the label is the problem.

Conclusion: Labeling is a complex process with many parameters. A solution has to be found and tested and all the variables have to be specified and controlled. Besides that, graphical designers are mostly not aware of the critical aspects of labeling on existing equipment and should cooperate more with technicians who understand these problems.

Labels on glass bottles

Glass bottles are often labeled with front, back and neck labels. In one example a graphical design of new labels was set up and the designers decided to put the neck and front label exactly in line. Because of the use of graphical components on the neck and on the front label, small deviations between these two became very clear.

Cause of the problem: To label the bottles with a specification of neck label and front label within one millimeter, means that this specification is within the tolerances of the *cilindrical* shape of the bottle. To find an acceptable position of the labels, it takes about six hours of adjustment on the equipment, in stead of half an hour normally. The graphical designers did not have any knowledge of the tolerances in the glass bottles and the difficulty of adjustments of labeling equipment.

Conclusion: This problem occured by a lack of knowledge of the graphical designers of glass bottles and labeling equipment and/or the management of the design process.

Graphical design for a transwrap sachet

A graphical design was made to fit on the front of a sachet to be filled on vertical form-fill-seal equipment. The design fits exactly on the front of the sachet. Probably these dimensions had been copied from some other sachets. Deviations, however, could not be tolerated. Many sachets are produced with the design not exactly on the front. To produce the sachets as specified, the speed of the equipment had to be lowered by 30% and the waste still then increased with 15%.

Cause of the problem: The problem which occurs is that the equipment has a tolerance of about 3 mm to produce the sachets. This tolerance has to do with material properties and with filling speed.

Conclusion: The graphical designers did not have knowledge of the tolerances of the equipment and/or bad management of the design project (nobody told them).

Colorpaste with xylene in PE-bottle

A colorpaste, which is normally packed in a metal can, was packed in a thickwalled PE-bottle. After some months the bottles slighly collapsed to the inside.

Cause of the problem: The xylene (probably) reacts with oxygen which is inside the headspace of the bottle and because of this an underpressure inside the bottle occurs. Because the walls of the packaging are quite thick, not enough oxygen diffundates into the bottle to compensate the loss of oxygen that has reacted with xylene.

Conclusion: Because of a lack of knowledge of material properties this problem occured.

PETP for saladbowl

An artist designed china bowls for salads. The salads are placed in PETP bowls that are highly transparant. The PETP bowls are placed inside the china bowls. The dimensions of the bowls were chosen on base of the designs of the artist. On a tray of 40 x 60 cm, the normally used transport tray, only two bowls can be placed and about 50% of the space is vacant.

Cause of the problem: The artist has not been instructed properly and there were no requirements set by distribution.

Conclusion: A lack of knowledge and communication is the cause of this problem.

Delamination of a foil by components of the product packed

A liquid product was packed in a laminate with an aluminium layer and a PE layer. The latter is to seal the packaging. After filling, the layers of the laminate became seperaten and the packaging tore too fast.

Cause of the problem: Components of the product diffundate through the PE innerlayer and react with the glue of the laminate. Because of this the layer delaminates.

Conclusion: The problem is caused by a lack of knowledge of product properties and material properties.

Lids that come off buckets

In buckets with a content of 5 litre a sauce of high temperature was being filled. The buckets are used in snackbars. The buckets are sealed on the top with a plastic film.

To protect the film and to make the buckets stackable, lids are put on top of the buckets. After destacking the lids came off.

Cause of the problem: The sauce shrinks when it cools down. The rim of the bucket is pulled to the inside of the bucket by the film which makes the lids come off.

Conclusion: A lack of insight in the consequences of cooling down is the cause of this problem.

Plastic cheese tub
A plastic tub was designed using requirements set by a product manager. The tub and lid are produced by different production techniques and problems occured because of different tolerances. These problems could be solved and then the real problem arose: the dimensions set by the product manager were too small to pack the wanted, and in retail usual, amount of cheese.

Cause of the problem: The project manager did not know that angles are needed to get the plastic packaging out of the mould and therefore wrong outside dimensions were chosen. A lack of insight in packaging production requirements is the cause of this problem.

Conclusion: requirements set by production techniques can limit the solutions and should be taken into account in time.

Plastic cap for glass bottle of coffee creamer
A plastic cap for a glass bottle of coffee creamer with a pouring function was designed. The cap had to stay on the bottle during sterilisation of the creamer. Many caps opened during sterilisation, others could not be opened afterwards without using tools. The specification of the cap was examined and changed many times. No solution could be found.

Cause of the problem: The level of filling of the creamer in the bottle can be described by a Gaussian distribution. The pressure inside the bottle during sterilisation is influenced strongly by the deviations of the filling level. Under normal conditions the pressure causes a pre-stretch of the plastic cap, so it can be opened easily. If the pressure is too high, the cap opens during sterilisation. If the pressure is too low, the cap is not pre-stretched and the cap cannot be opened by hand without using tools.

The colour blue also had influence on the force needed for opening the cap. If too much pigment of this colour is used, this could result in crystallisation of the plastic during sterilisation. In that case almost all the caps will open during sterilisation.

In table 2.3 an overview of kind of problems is presented.

Main cause of the problem	number	percentage
Properties of packaging material and of the product packed	3	25%
(Graphical) designers and production technique	4	33%
Material properties	1	8%
Distribution	1	8%
Physical process	2	17%
Production technique	1	8%
Total	12	100%

Table 2.3 Overview of the kind of problems occuring in design practice

We should be careful in drawing general conclusions out of these examples of mistakes in packaging design projects. It may be concluded, however, that in many projects technical aspects are not integrated and/or the knowledge is missing and/or the management is not as it should be. The consequences of the described problems are that costs rise and/or that the introduction in the market is retarded and/or that the goals of the project have to be changed.

2.8 Conclusions of the analyses

In this section some conclusions are drawn on the methods used, on what seems to work well and what seems not to work so well in packaging design and on the problems that occured in examples of packaging design practice.

2.8.1 Conclusions on the MSc design projects on packaging

Regarding the methods followed by the students:

- students have been taught to work systematically when solving design problems, in order to ensure that the design process is as effective and as efficient as possible;
- Roozenburg and Eekels' basic design cycle is the recurrent theme running throughout the entire design process;
- many tools are available for each design stage, for analysis, synthesis, simulation and for evaluation;
- the emphases are on the programme of requirements, aspect completeness, creativity techniques and techniques to ensure the best possible evaluation of the design proposals;
- the eco-design approach is a more recent, supplementary approach which offers opportunities to come up with creative, interesting solutions which have a lower impact on the environment; several tools are also available for finding solutions that have a lower environmental impact.

2.8.2 The strengths of DUT-IDE methods

The many different ways in which DUT-IDE methodology can be and is used constitute, maybe, the most important strength. This freedom in the methods used in the MSc projects also makes it difficult to judge the projects. We tried to obtain a good idea of how the packaging design projects were carried out.

Our assessment is as follows:

- The taxonomy used and the use of tools, such as process trees and check lists, lead to very extensive lists of aspects that must be considered in the design process for example projects of packaging for television (3x), beer (3x), paint (3x).
- The method, including all potentially useable tools, leads to creative solutions, which in a number of cases are worthy of production, such as the projects concerning a margarine wrapper, packaging for electrical components, packaging for flowers.
- Attention given to the environment leads to a reduction in the environmental impact, and thereby a reduction in cost can also be obtained, for instance the design of a reusable packaging for televisions, presentation and packaging of non-food products.
- There is seldom a lack of ideas when solving problems. Many tools are put to use and there is a wide diversity in the solutions put forward, also in projects. Ideas vary from rough sketches, via the application of existing principles, to the use of standard solutions.

2.8.3 The weaknesses of DUT-IDE methods

- Black boxes: The grounds for taking a decision are not always explained, nor what the aspects listed were derived from; it sometimes resembles a black box. There is no structure, enumeration or check list supported by DUT-IDE for packaging design. Such a structure could be used when designing packaging, for instance for glue, paint, soup, yoghurt, etc. Nor does the DUT-IDE methodology specify how to solve the problem in part, and subsequently move on to another part of the problem, as seen in the MSc project for medicinal drugs. This methodology specifies assessment of the total design on the basis of *all* the requirements or a selection thereof.
- The basic design cycle starts with functions, but a way to make a tree of functions is not presented.
- The design of impractical solutions.
  In many cases all aspects are deemed to be equally important. This can lead to problems. For instance: if the assignment specifies that the packaging must be made more ecologically sound, then sometimes the environment is considered as being more than product protection. The definitive solution can apparently be impractical when subjected to the final test.
- Inefficient approach
  An inefficient method was used in one project for the redesign of a tube for

hydrocarbon-based glue. The programme of requirements that should be decisive for selecting the most appropriate material includes the following:
- the packaging must be squeezable;
- the packaging must have deadfold properties, i.e. if the packaging becomes distorted due to external pressure (e.g. during its use), the packaging must yield to that pressure and retain that new shape until it is subjected to external pressure again;
- the packaging must present a barrier against hydrocarbons;
- the packaging must be ecologically sound.

The first requirement can only be accomplished by using flexible packaging materials such as plastics, paper, metal foils, etc., i.e. no rigid plastics, no metal cans, no glass, no wood, etc.
The second requirement can be accomplished by using metal foils, cast plastic films or films with additives and a few different sorts of paper.
The third requirement can be accomplished by using metal or glass.
The only material able to meet this requirement is metal foil, specifically aluminium foil.
In his approach, the student selected the most suitable material from the point of view of the environment and decided to design a new tube using that material. When testing the concepts against the requirements it soon became apparent that none of the concepts were adequate. This resulted in a lengthy period of time before the tests showed that the solution failed to meet the requirements of protection. In this particular case it would undoubtedly have been far more efficient to have selected a suitable material first of all on the basis of the required properties.

- Design of the packaging only
  The assignment to design packaging generally focuses on the packaging only. Designing a combination of product and packaging is sometimes indicated by the students as an option for finding optimum solutions in which an integral approach is chosen. In the case of designing a packaging for ice cream, the dimensions of the starting point – the ice cream – were changed in order to achieve better logistics. In this case, the project was clearly undertaken in the way described in Chapter 1 in the case of the photocopier. An approach, which keeps in mind both the goal of the packaging and the nature of the packaged product, can lead to a better solution. This would seem to be in line with the eco-design approach: a more system-oriented approach.

It must also be pointed out that not everyone is knowledgeable about specific packaging regarding the mass technology of filling, logistics, barrier functions, etc. Examples in this respect are: sealable applications using materials that can only be sealed under very specific circumstances, the stackability of crates that cannot be realized, materials without barrier properties for barrier applications, etc. Initially, this would not seem to be methodical but the next example illustrates how a lack of knowledge and insight can lead to methodical problems.

The assignment for an MSc project was to design an ecologically sound packaging for glue with the requirement that the glue is diluted on a hydrocarbon basis and that the packaging must be squeezable. If glue is diluted with hydrocarbons, there are very few materials that will offer optimum protection.The most efficient and effective method of approach in this case was, as set out in the foregoing, to first select an appropriate material and to then make a design on the basis of that material. A lack of understanding of the glue's vulnerability and the required material properties to protect the glue, resulted in it taking a long time before the conclusion was reached that there was no suitable design possible because the wrong material had been chosen. Choosing materials on the basis of environmental impact was in this case inefficient and non-effective.

In comparison with design processes of many products, it seems that designers of packaging have to confront many unexpected aspects.This partly explains the complexity of packaging design.

2.8.4 Demonstrable causes

Consistent with the above analysis, the following causes can be given as a reason for the poor functioning or the non-functioning of DUT-IDE methods.

- The students as well as many designers in practice fail to dictate a hierarchical structure of functions for adequately dealing with the requirements. A way to set such a tree of functions is not presented.
- The procedure of specifying a design in part for certain functions, and then to start a new design cycle, is not common in the DUT-IDE method.This results in little or no steering of the requirements on the basis of prior choices.
- The projects do not always provide the opportunity to design a combination of product and packaging.The result is the design of the packaging only. Eekels and Roozenburg's methods do not indicate how changes in the starting points of a project must be dealt with. In a large number of cases it will be customary to design the product and the packaging separately, and there will be a lack of insight into the innovative options available, if the two are designed simultaneously and interactively. Although it could be defended that the basic design cycle is still being followed, students are not taught to change the starting points of a project.

The following must be pointed out regarding the lack of knowledge:

- Specific packaging knowledge is lacking; this relates particularly to filling, logistics and the specific barriers that packaging materials must offer, such as barriers against hydrocarbons, oxygen, UV light, etc., the interaction between material properties and properties of the product.These are subjects given little or no attention to in the curriculum and are subjects not known by many designers in practice.

2.8.5 Examples of problems in the industrial practice of packaging design

The described projects out of our own design practice show problems which look quite similar to the students projects showed. Material properties of the packaging in relation to the properties of the packed product cause many problems. It seems that packaging problems are more physically and/or chemically restricted than design problems like for example the design of a chair. Thicker walls, other plastics, do not solve the problem in many cases as in other design projects than packaging they probably will. The restrictions are set by the product in many occasions and therefore packaging design more often means designing with restrictions. This would ask for an approach which splits up the problem in logical parts in such a way that rational problem solving parts are followed by reflective practice.

Functions play a crucial role when selecting a suitable solution. If a function can be fulfilled by different materials, then there is always room for making a selection from the materials on the basis of other properties too, the environmental impact for instance. The example of the packaging for glue also shows that systematics are steered by knowledge and understanding. If the material or potential materials are known, then it is also known which production techniques can be used, what the feasible shapes and dimensions are, and what the options are for applying the required information.

It may be concluded that the lack of specific packaging knowledge and the lack of understanding of packaging matters, results in adopting a procedure which is not, as effective or efficient as wished for, students as well as for designers in practice. The systematic recording of such knowledge and understanding can therefore be of great value for a designer of products and packaging.

2.9 General conclusions

It may be concluded that a customary design method is taught at DUT-IDE. This consists of placing emphasis on the programme of requirements, aiming towards completeness of aspects (a common tool for this is the process tree), the deployment of creativity techniques and techniques for evaluating design proposals. There is a great deal of freedom of use regarding design methods and design tools. The recurrent theme is generally the basic design cycle.

Many different sorts of design problems can be dealt with. Considering the fact that product functions are subject to constant change (see also Chapter 3), and that new applications emerge and new materials are being developed, it may be stated that the continuous evolution of methods is essential and, fortunately, does take place. Designers think in a way that can be described as a combination of rational problem solving and reflective practice. Eco-design is an addition to the existing methods in so far that it is a system approach; an approach which has been improved upon by looking at whether a market demand can also be satisfied by providing a service, or by finding out what kind of business could be set up to meet that market demand.

To develop a method for packaging design, strengths and weaknesses taken from the analysis of MSc reports and from projects out of our own practice can be combined.

The requirements are:

- designers of packaging must set to work in a welll-thought-out systematic way, preferably in accordance with a set of methods and techniques that constitute a method;
- the basic design cycle must be a recurrent theme;
- tools must be available, especially concerning knowledge in the field of packaging and the role of material properties;
- a system approach must be possible, and preferably used;
- it must be possible to draw up a hierarchical structure of the functions;
- it should allow the steering of design proposals on previously made choices; including iterations;
- it must be possible to design the product and packaging in combination;
- the method should be a combination of rational problem solving and reflective practice.

This has answered a part of research question

A.2: What method or methods are currently used in packaging design and what can be learned from this?

The next chapter devotes attention to the functions of packaging and also focuses on a definition of packaging. In Chapter 4 tools will be developed: packaging insights, properties of packaging materials and packaging legislation. Chapter 5 continues to find out how people involved in packaging design processes set to work.

3. The functionalities and functions of packaging

Summary

This chapter sets out the functions of packaging as asked in research question A.1: What are the functions of packaging and what is an adequate definition of packaging? In literature there is confusion regarding terminology on this subject. We inspired our way to work on the lines of the procedure set out by Dirken *(1999). This procedure is based on 'product functionality' and 'use functionality'. Product functionality is more on the strategic level and is indicative of how the use functionality is interpreted. Use functionality presumes the intention of the user, that which is expected of the fulfiller of the function.*

The background of the fulfiller of the function can give a good idea of the structure of the functions, hence the reason for looking at the history of the packaging functions. That history is then used to define three main groups of use functionalities: preservation/protection, distribution and information. Then a look is taken at the product functionalities and potential users/appliers/persons concerned in the relatively long and functionally heterogeneous life chain of packagings.

Subsequently, a definition of packaging is formulated. By elaborating on this definition an enumeration of possible packaging functions is set up as a tool for packaging designers.

3.1 Introduction

This Chapter will answer research question

A.1: What are the functions of packaging and what is an adequate definition of packaging?

The functions of packaging will be dealt with aided by a brief historic overview of packaging. Before doing this the terms 'function' and 'functionality' must be explained. If the functions of packaging are described, it becomes possible to formulate a definition and a list of potential functions can be drawn up. Section 3.2 deals with functions and functionalities. Section 3.3 gives a short explanation of the history of packaging functions before a definition of packaging is formulated in section 3.4. The potential functions of packaging are set out in section 3.5.

3.2 Functionalities and functions and the hierarchical presentation of functions

There is absolutely no unequivocalness in the design literature with regard to the terms of function, functionality, principal requirement, detailed requirement and sub-requirement. Therefore, a look is taken at the terms of 'function', 'functionality' and 'to function'. The other terms of principle, detailed and sub-requirement are regarded as subsequent to the above terms.

The Dutch Van Dale Dictionary (12th Revised Edition, 1992) gives as a definition of function (third explanation) special working and action (the functions of the various parts of our body; the function of a capacitor; perform the function, fulfil a ...; to work as such). Functionality is explained as (sense 1): consistent with the function, synonym for efficacy. To function (sense 2) is described thus: his function, performing his work: the engine ignition is not functioning properly; his kidneys are functioning normally.

A packaging is expected to fulfil its specific function: that it protects the product, that it provides the haulier, the boy employed to fill the shop shelves and the buyer with information in the way wanted, that it has a beneficial effect on sales, that it explains how the product should be used. The functions of packaging can therefore be referred to as all the functions that may be expected of the packaging. Functionality is not only concerned with the functioning of the packaging, but also with the way in which that functioning is fulfilled; the efficiency and the effectiveness.

3.2.1 Functionalities

More use is made of the term 'functions' than the term 'functionality' in the literature on design and the methodological solution of problems. Both Cordia (1996) and Dirken (1999) use the term 'functionality'.

Cordia (1996) works on the basis of seven principal requirements which she refers to as functionalities, divided into main functions (p.100ff.).

According to Cordia, a main function leads to a principal requirement which, if necessary, can be broken down into sub-requirements, which in turn can be divided into detailed requirements. The division of functionalities as defined by Cordia is not unambiguous. For instance, economic aspects are mentioned several times (consumer price, lifespan and the environment) and therefore fail to give an unambiguous description of product functionalities. It is more of an extensive check list of functions that can be drawn up for the purpose of determining the requirements. Dirken's description of functionalities is more unambiguous and apparently more comprehensive because of its logical structure. We have therefore chosen to use the description Dirken has set up.

Dirken (1999) defines functionality as the fulfilment of an effective action, and explains that the intention and expectations of the user co-determines the functionality. In addition to this extremely essential functionality (after all, the user also determines the quality of the object that fulfils the function), Dirken distinguishes yet other functionalities. These functionalities apply to each quality of use and therefore to all objects that fulfil a function and can be regarded as a sort of archetype of (consumer) goods (p.418ff.):

- the user's intention and expectations: in addition to the desired, primary functions, more abstract functions can be distinguished, such as the need for rest, achieving or maintaining a good condition, etc.;
- aesthetic product functionality: the significance is individual but also more general, cultural; does the product look well-balanced, is it attractive, is the shape appropriate for the sort of product;
- technical product functionality: the technical significance is that it works, preferably cleverly and with a high level of cost-effectiveness; do the choices of material, mechanisms, composition and manufacturing process present a comparatively good solution for the technical output to be achieved;
- business management product functionality: the significance here is business continuity; employment, the link with market demands.

Dirken also distinguishes several product functionalities at a higher and more abstract level in which societal interests are also at stake, but which need not be applied to each use quality:

- psychological product functionality: this is concerned with supporting a person's ego, creating an impression, showing one's social role or status in society, etc.;
- political product functionality: this relates to cohesion in a community, or security;
- regional or global product functionality: this is concerned with the continuity of employment or of sustainability, as is the case with eco-design.

A product fulfils the desired functions satisfactorily if the four ergonomic qualities of use of: usefulness, efficiency, comfort and safety, are met.

The meanings of these four qualities are explained as follows.

Usefulness is expressed by the following aspects whereby usefulness increases along with the weight of the aspect, i.e. the larger the weight, the more important the aspect, etc.: urgency, duration of use, frequency of use, lifespan, number of users and pleasure. Usefulness decreases along with the weight of the following aspects: effort required before, during and after use, the value of time, one's own money and space.

Efficiency is the extent of efficacy and, in addition to the elements of efficiency and effectiveness, also takes cost into account.

The dictionary defines comfort as a state of ease or well-being, while in ergonomics the preferred definition is 'the absence of bodily and mentally discomfort'.

Safety means that injuries will not be sustained by persons, and also that the product and its surroundings will not be damaged.

The aesthetic product functionality is very close to the psychological product functionality. Observing a shape, and deducing from it that it is in line with the product's functioning, is to a large extent a psychological process. And yet the choice is made to regard this functionality separately because the modelling of form is a designer activity that differs considerably from the activity of thinking about the psychological aspects that a user may or may not be able to see in a product. For instance, for many a product its status is derived from the price and not from the use functionality. Driving a Porsche is far more demanding than driving many other car brands; it is not always easy to tell the time on a Rolex. Product functionalities are currently brought into one and the same category. It would probably help to clarify matters if a breakdown was made into the choices made by a company itself, and the choices a company makes because they are forced by the outside world. Target group, price, sort of status, etc., are all examples of choices a company can make itself; legislation, political decisions, public opinion, are examples of choices a company has to make because it can be forced to it.

It should be noted that Dirken's model insufficiently pay attention to necessary infrastructure to realise new product concepts. If a product has been designed, for example, that needs a returning system which does not exist yet, Dirken's model would probably suggest to put this aspect under the economic functionality. Another functionality, the infrastructure functionality could overcome this conflict.

3.2.2 Functions

Most sources describe the concept of functions in detail. Roozenburg and Eekels (1991) make a distinction between different sorts of functions: technical, ergonomic, aesthetic, functions of a business economic nature, societal, etc. They explain that functions play an important role in designing: changing function into form is regarded as the core of the designing process. This is an enumeration of that which may be expected of a product: the functions. Yet it is highly probable that by this – similar to the way in which the functions are fulfilled – the functionalities are meant.

Heskett (1980) also uses functions in his definition of designing. He explains that designers see their work as *"an autonomous activity concerned with refining and advancing defined forms and functions"* (p.201). He feels that the process of elaborating functions is part of a designer's work. Heskett also states that it is wrong to define designers *as "institutional functionaries"*. They take the aspect of social awareness into account in the products they design. In fact he says that regional, global and use functionalities, as defined by Dirken, are taken into account by designers in the considerations they make when working on a design. Function and functionality are not mentioned, and Heskett apparently sees the two as being interwoven.

In the design literature, more use is evidently made of functions in the sense of providing overviews of what the object that fulfils the function must be able to do. The next section deals with the hierarchical presentation of functions.

3.2.3 The hierarchical presentation of functions

Delhoofen (1994) sees the function as the goal of the object to be designed, making a distinction between the main function (that which is of primary importance), sub-function (that which is desired), supplementary function (that which is not essential but *is* present), unwanted function (that which is detrimental), and the unnecessary function (that which is present but not requested).

Different terminology is used to present functions hierarchically in the literature. Delhoofen (1994) speaks of a division into main functions, supplementary functions and detailed functions, Reinders (1996) of a hierarchical structure of functions with main functions and sub-functions and a function tree, Roozenburg and Eekels (1991) of a functions structure. In the German VDI design model, VDI 2221 (1986) and VDI 2222 (1973), a great deal of attention is devoted to the construction of a structure of functions. It is pointed out that a functions structure can be constructed from a limited number of elementary or general functions. The reason is that this can then be used in combination with catalogues to search for a solution, an approach that is similar to the one presented by Archer in the days of the *Hochschule für Gestaltung* in Ulm (see Chapter 2). Roozenburg and Eekels (1991, p.178) regard the functions structure as a tool to help determine how a product can meet the specified goals. Reinders (1996, p.44) explains that 'function description' can be distinguished from 'function detailing'. Function description makes a progressive breakdown of the functions, while in function detailing, the requirements that the object must fulfil are specified in greater detail.

Cross (1994) points out that when designing an object, frequent use is made of a decision structure. Several solutions are put forward for a certain function, and a choice is then made from those solutions; the same is then done for the sub-functions in progressively more detailed steps. On this subject he says (p.14): *"The hierarchical 'top-down' approach to design is quite common, although a 'bottom-up' approach is used, starting with the lowest level details and building up to a complete overall solution concept."*

3.2.4 Functions change over the years

Definitions of products and services change through time just as Esse (in Harckham, 1989) explains for packaging: *"packaging has and is changing dramatically as a function of what is happening in the marketplace"* (p.109). Over the years, packaging fulfils an ever-increasing number of functions. This evolution is still under way (e.g. Dirken, 2000). A description of this evolution provides insight into the hierarchy of functions: which function springs out from the viewpoint of the designer. Illustrative of this is the function tree of a car that was drawn up by Reinders (1996). According to Reinders, current car designs reflect the realisation of functions over a hundred years. He claims that describing functions can often be carried out as a 'postnatal' activity (p.42). This view can also be applied quite well to describing the functions of packaging. The solution chosen for a certain problem steers the definition of the object that must fulfil the function. In order to make transportation by car possible, the first and foremost requirement for a car is that it can be steered, that it has a driving mechanism and that it can be braked; functions that have become no more than obvious over the years. Looking at the significance of the word 'automobile', a self-propelled road vehicle, a solution was chosen that rides, one that has wheels. A designer will generally base his ideas on a car as usually having four wheels for it to function (three wheels is also possible). Had the hover principle been chosen in the past, like a hovercraft, then the definition of a car would be totally different. Today, a car is not only expected to ride, but also that it is safe and comfortable, and that it has a low environmental impact.

In other words: functions explain the genesis and in fact define an object. The object fulfils a function. In a design process this decision-making process can be important.

Eger (1989 and 1999) maintains that the functions fulfilled by a product category during its economic life cycle, change. In the initial stage, the product is introduced on the market as a new product that fulfils a primary function, the product only does that for which it was purchased and/or is intended for, no more and no less. The primary functions are optimized in the next stage, and functions are subsequently added in order to distinguish the product from rival products. In the next stage, the products are designed in such a way as to make them appropriate for a specific target group, the market is thus segmented. In the final stage, products are designed in such a way that the consumer himself is able to determine the outward appearance of the product or how it will be used. According to this view, a product category goes through five stages: that of fulfilling the primary function, optimizing, detailing, segmentation and individualization.

It is important to realize that, according to Eger, the number of functions a product fulfils increases during its economic life. This implies that a product's history presents a picture of how the functions evolve and multiply, starting with the primary functions. This view, combined with Reinders' reflection of 100 years of fulfilling functions, gave rise to the idea of drawing up a description of functions on the basis of a historic overview of packaging. This is also in line with the insights of Fodor (1998) and Marconi (1997) on definitions as discussed in Chapter 1: defining what is a good and what is a moderate design, or in other words: objects that fulfil a function well or moderately well within the definition, are known but not often reported. The description of the functions is therefore indicative of the limitations of what can and what cannot be categorized as packaging.

The functionalities of use are elaborated in the next section, inspired by the approach of Dirken, on the basis of a brief description of packaging history. This implies that the use functionalities will be explained by the functions packaging fulfilled in the past and still fulfill nowadays. These functions have become part of some common (not written) definition of packaging as is presented in the sections 3.3.1, 3.3.2 and 3.3.3. Subsequently, the functionalities referred to by Dirken are dealt with: the aesthetic, technical, technology and management, psychological, political and regional/global product functionalites, respectively the sections 3.3.4 to 3.3.9.

It must be stressed that the starting point of this approach is still: the production of the product and packaging in combination and, with the purpose of serving the individual users. Being able to use the product is therefore one of the conditions for a successful design, measured in terms of the qualities of use of: usefulness, efficiency, comfort and safety.

3.3 A brief outline of the history of packaging functions

Packaging has been in existence for thousands of years and in past times it has played a particularly important role in the preservation and transportation of food. Even today, excavated objects can be found that give an idea of how people lived in the past, and how they were able to preserve food. A detailed description that goes back thousands of years to the oldest packages would be far too comprehensive for our goal: to describe the functions of packaging. Our study focuses on industrial packaging, a way of packaging that was born in the period immediately before the Industrial Revolution. This is portrayed perfectly in the book *'De oudheid verpakt'* [Packaged Antiquity], (Topa Holding, 1997). Bottles with a slender neck, sealed with cone-shaped corks, were used for champagne which was invented in 1700 (Baudet, 1986). A French chef, Nicolas Appert, discovered that food could be preserved longer if it was first heated and then hermetically sealed off from its surroundings. This was the introduction of a technique the army and navy had been searching for since time immemorial (Baudet, 1986). Techniques which had until then been customary for preserving food, such as smoking, drying, pickling and conserving, had the disadvantage that they changed the taste and/or the composition of the food. The usefulness, and probably also the aspect of safety, was important enough to continue this trend. Appert, who presented his ideas in 1810, was awarded a prize put up by the French *Directoire* of 12,000 FF, which he used to start up the world's first food preserving company. Canned food was an invention of a London merchant, Peter Durand, who was in possession of the patent dating from 1810. Dinkin, Hall & Gamble, the firm that took over the patent, became the permanent supplier of canned meats for the British Navy. Because of the poor quality of canned foods (tin-plated steel plate was only invented in 1839) and because of the impermeability of glass, Appert chiefly used glass. In 1863 Pasteur laid the theoretical basis for Appert and Durand's processes in a publication in 1863: the killing or the long-term elimination of bacteria by means of heating. His ideas were brought into practice by a brewery in Copenhagen in 1870 (Moody, 1963) where beer was pasteurized for the very first time. In all probability, the canned foods of Appert and Durand were not sterilized. The packages do not look as if they would have been able to withstand high pressure. Pasteurization temperatures sufficient to eliminate micro-organisms for a long period of time were hardly achieved (Moody, 1963).

Another method of preserving food was to bottle it. This process (called *'wekken'* in the Netherlands after the German manufacturer of the jars used for this purpose, Weck) was also introduced in the 19^{th} Century and became a frequently used method for bottling vegetables and fruit, mainly in the domestic sector (Baudet, 1986). It was a relatively simple, safe method which was very useful. Bottling is a method still used today, but the introduction of the freezer has reduced its use to a very small scale only.

Pictures of the first generation of cans (Baudet, 1986, p.106) show a metal body welded to the can bottom and a lid (in his book a picture of a can from 1850 is showed). A ring is attached to the centre of the lid for the purpose of carrying the can. The can displays a hand-written label. It is obvious that there is no question of the packaging having been optimized for the purpose of distribution because it would seem impossible to stack these cans. The main purpose of the packaging was to contain the product, to keep it together, conform the explanation of the term 'packaging' given in Chapter 1. The packaging must also display its contents, otherwise this can only be found out by destroying the package. Packaging in the earliest periods was already provided with text or symbols to indicate the contents (Topa Holding, 1997). It would only seem logical to include a statement of the contents of the packaging if they were not visible. Today, this is compulsory by law. We shall return to this subject later.

3.3.1 Use functionality of preserving

The first industrially manufactured jars and cans for packaging food were for the purpose of preserving food. The most important functions were to allow the product to 'bridge time and distance' before the food was eventually consumed. This is still the case in today's preserved food industry. The packaging must serve to contain and preserve the food and thus allow it to bridge time and distance without too much loss of quality so that the food can eventually be consumed.

The following activities must take place before the food is protected: bringing together, keeping together, shaping, dividing into portions and delivering or using as a specific unit. This obviously applies in the case of amorphous products such as liquids, powders and granules. Whatever is used to achieve this, is called packaging. Packaging therefore derives its reason for existence primarily as an object of containment, an object that provides a form, an object that brings the product together. Debates as to which of the two functions was first attributed to the term 'packaging' is of no interest here. In the definition of the word 'packaging' these concepts must at least be included given that they form the basis for packaging. We shall return to this subject later.

All lists of packaging functions include the word 'protection'. As is evident from Paine, 1991, p.3, packaging must above all offer protection: "*... preserves farm- or processor fresh quality or prevents physical damage*"; Melis, 1991, p.3: "*to protect the product, to preserve its quality*"; Kooijman, 1996, p.73: "*distributing, protecting and identifying products*"; Briston, 1992, p.111: "*to protect against deterioration mechanisms*"; Hine, 1995, p.3: "*Packages lead multiple lives. They preserve and protect, ... etc.*", Esse, (in Harckham), 1996, p.108: "*The first consideration is obviously the protection of the product*". All these functions can be summed up under the concept: guaranteeing a certain or specified quality of the product, defined as preserving. The product must be protected from the environment and from the effects of time. This applies to many food, medicinal drugs, and also products such as glue, ink and paint which have to be diluted before use. The opposite is also possible: the environment must be protected from the product because it is a potential danger or nuisance, as is the case with substances that are hazardous to the environment or mankind. For instance, radioactive material and waste, toxic substances, hazardous solvents, etc. A combination of the two is also possible: some types of glue contain hazardous solvents, and without those solvents the glue would be unusable; certain sorts of cheese must be protected from external influences, while the environment must also be protected from the effects, in this case the odour, of the cheese.

Effects on the product of a totally different nature are those that result from moving and transporting the product: putting it down, picking it up, transporting the product, etc. The associated loads are mechanical: static forces, shock and vibration. Many products are sensitive to such loads, both in the category of food and non-food: preserved or fresh vegetables or fruit, candy-bars, chocolate, dried spaghetti, and vulnerable products like electrical and electronic equipment. The way distance can be bridged co-determines the circumstances in which the packaged product ends up. This must be taken into account when making an analysis of the functions a packaging must fulfil, and when specifying the requirements.

The term 'to protect' can also be mentioned instead of the term 'to preserve'. The latter is defined as *guarding* against deterioration and decay, while 'to protect' is defined as *preserving* the quality as it was at the time of packaging. However, whether influenced or not by their immediate surroundings, many products undergo change during their packaged period due to entropy. The term 'to protect' would therefore be too restrictive. It can be pointed out that in common usage, the term 'to preserve' is strongly associated with canned products and consequently with food, while 'to protect' conjures up connotations of vulnerable, durable goods. While the two terms will be used throughout this study, the combination of 'to preserve/protect' will also be used frequently.

Changing a packaged product as a result of its thermodynamic property, the enthalpy, can be beneficial, for instance in the case of wines and spirits. Whereas it is less desirable for many products, for many others the way in which the qualities change and the extent of the change, can be influenced by packaging the products in a special atmosphere, as is done in the case of bananas, meat products and nuts: modified atmosphere packaging (MAP). Packaging firms are able to retain a certain product quality by using this technology.

As referred to in Chapter 1, in the example of the photocopier, packaging is an economic activity. This not only applies to durable goods but also to food. The recipe will in many cases be adapted in order to make the product less vulnerable and thus to offer a less expensive market-product combination. Yoghurt-based drinks are an example. The so-called single-tastes, made exclusively from one sort of fruit, are more sensitive to taste deviations than the cocktails produced from a mixture of different fruits; the taste is less defined.The single-taste drinks consequently need to be either packed better or preserved differently.

Hine (1995, p.19) states that: "*The protective function of packaging is often taken for granted, but it is in fact a very powerful set of technologies with life and death consequences.*" This is a technology which is still developing, and even today involves very complex systems. Incorrect packaging in the food, medicinal drugs and medical aids can certainly have fatal consequences. Examples of these complex systems are the previously mentioned modified atmosphere packaging which is identified in the Netherlands from the mandatory text: "packaged under protective atmosphere", bag-in-box packaging with double-walled bags for wines and water, aerosols that work on the basis of air brought up to pressure by the user himself, packaging with components that change colour if the product has absorbed too much energy and thus warn of deteriorating quality.

The extent to which the product quality can be guaranteed improves every year.This is reported in the many publications on the subject and in packaging journals. It is difficult to forecast whether there is a future for such technologies, considering the trend of gamma-radiation of food, a highly promising technique which has only so far captured niches in the market. Developments in the food technology market, the use of a variety of supplements, developments in the field of genetic engineering, will in the near future undoubtedly result in an increase in the technology of product protection.The increasing use of intelligent sensors, to identify and indicate product deviations on future packaging, will probably prove a useful development.

3.3.2 Use functionality of distributing

The evolution of packaging runs parallel with that of the industrial production of food and goods (Hine, 1995).The Industrial Revolution saw the beginning of mass production and the adoption of packaging on a large scale.The combination of developments and discoveries in the field of food production, medicinal drugs, physics and engineering, resulted in population growth.The need for manpower led to higher incomes for the working population as well as to the simultaneous demand for a wider range of luxury foods with a higher quality.

There were a dozen or so small firms engaged in preserving food around 1850 in the Netherlands.Twenty five years later there were at least another dozen larger and smaller ones (Baudet, 1986, p.106). Packaged food was mainly used on ships, in the colonies and probably in the army (Baudet, 1986).Typical of this situation are the histories of new instruments for packaging used by the end user: can openers and corkscrews.The oldest can opener found to date is from 1875 (Baudet. 1986), according to Hine (1995) the oldest can opener dates from 1865.Various patents on corkscrews date from about the same date and it is assumed that these would be the oldest corkscrews. Nevertheless, the principle of a more complex corkscrew can be derived directly from Leonardo da Vinci's auger (Ten Klooster, 1986). Around 1875 there was evidently a large enough demand for instruments to facilitate the opening of difficult packaging. Hine (1995, p.72) describes the emergence of the canning industry in the USA, establishing a link between the ability to manufacture thinner steel plate, Pasteur's teachings, the mechanization of labour, the growth of the fishing fleet and the growth of the population, and thus all the ingredients for the introduction of a can opener were present.

Baudet (1986, p.104) states that, initially, the supplier himself opened the purchased cans (these had a thicker wall) in the shop. It should be pointed out that this is quite odd considering the ultimate goal of this packaging: use or consumption of its contents. Baudet rightly points out that the packaging industry has learnt very little over a period of more than 100 years if the number of difficult-to-open packages is taken into account. Paine (1991, see Chapter 1) referred to *"convenience in shape, size and weight for handling and storage"* as functions of packaging. Knowledge and an understanding of ergonomics, even today, seem to be seldom used if a look is taken at the many packages that simply cannot be opened by elderly people and the weaker members of society. (A series of articles on this issue is published in the Dutch magazine Pakblad by Daams and Stephan in 2001 and 2002 and also by Cramer, 1998a and 1998b.) One possible reason for this was put forward in Chapter 1: packaging designers generally originate the graphic design profession. In recent years, more structural attention has been given to "design for all" (members of society): both elderly persons and weaker young people. The ageing populations in many European countries require the packaging industry to do just that: to design with everyone in mind. Elderly people now represent more than twenty five percent of the population, while the purchasing power of this group, particularly in West European countries, is rising sharply and represents a wealth of much more than this quart.

Dutch people have shown an emotional conservatism towards preserved foods. The major breakthrough was only achieved in the nineteen sixties when freezers came onto the scene. Higher incomes also played a role. Considering the evolution of packaging in glass jars and bottles we can speak of the industrial production of packaging commencing as early as the 19th Century (Moody, 1963). The first semi-automatic bottle manufacturing machine was invented in 1880. The crown cap ('cork' nowadays) was invented by William Painter in 1892, who said: "The happiest life is that of a crown cap, always a full bottle under you." and the first fully automatic bottle manufacturing machine in 1903 by Michael Owens. The Owens firm is still one of the leading bottle manufacturers and bottle machine manufacturers in the world, although smaller firms, such as Heye Glass in Germany, also manufacture bottles and machines for blowing bottles. Milk was bottled and pasteurized in bottles as far back as 1894.

A typical consequence of production on a larger scale is the greater distance between the producer and the buyer or user. The transport of goods has become a necessity. The effectiveness and efficiency of transport systems is therefore becoming increasingly important.

The First World War, the economic recession in the nineteen twenties, and the Second World War blocked progress in industrial evolution and consequently of packaging too. The reconstruction activities after World War II raised the packaging industry to a high-grade technological industry. Several trends have had an enormous influence on the sale of products. One of these trends was the introduction of self-service shops, this was in 1948 in the Netherlands (Rutte, 1998 and Organisation for European Economic Cooperation, 1960). Hine (1995) also mentions the introduction of the television into our homes, and thus a substantial increase in packaging exposure. Exposure, frequent display, is an important factor that brought about a change in packaging; more about this later.

As already stated, spending power grew and western society saw a period of prosperity in the nineteen sixties and early nineteen seventies. Despite several periods of economic recession, the volume of goods produced, the greater part of which is packaged, underwent constant growth. New professions have since emerged that focus on the most effective and efficient transport and transhipment of all these goods: logistics management. The distribution of goods has grown into an industry which the Netherlands, a country with several sea ports and a major airport, uses to profile itself: the Netherlands, Distribution Country. Logistics management was defined by Van Goor (1996 and 1998) as the integral management of the flow of goods, and covers subjects like physical supply, material management, physical distribution and reverse logistics (devoting attention to the return flow of all goods and packaging in connection with environmental legislation, as well as to achieve savings in cost).

A logistical concept in today's world is indispensable for the distribution of a product. According to Van Goor et al., (1998) such a concept consists of four different levels:

- *The basic structure*
  This is the method of transporting the goods throughout the chain. In the most ideal situation pipelines are used with no branches. In less ideal situations the goods are supplied in units which are often transhipped. Of importance are the commercial and the logistical distribution structure.
- *Control system*
  The control system is determined on the basis of predictability of delivery. A distinction is made between complete pull, in which work is carried out to order – and this is unpredictable – and in which systems to replenish stocks and data requirement planning are necessary, and complete push, in which deliveries are totally predictable.
- *Information system*
  This relates to the method used for data exchange. A distinction is made here according to manual exchange, island automation, exchange and electronic data interchange (EDI). Digital technologies and electronic communication play a major role.
- *Organization*
  What kind of organization will be used to achieve product distribution: centralized, decentralized, decision-making by staff or in the line.

The concept currently used by many supermarket chains can be described as follows:

Packaging is provided with a so-called EAN Code (European Article Number Code), sometimes referred to as the external barcode. If the barcode is scanned at the check-out desk, an article is written off from the stocklist in the computer. The supermarket automatically places an order at the distribution centre via electronic media and data are then passed on to the supplier. Some chains even place the responsibility for the stock with the supplier who is able to keep an eye on stocks by using electronic media. The aim is to ensure that stocks are replenished within a period of 18 hours (Ahold's Today for Tomorrow system and Schuitema's Today for Today system). The result is that the average time that stock finds itself in the chain has been reduced over the years from 104 days in 1985 to 43 days in 1995, and this is expected to be brought down to 30 days in 2005 (Van Goor, 1996). For the delivery of goods it is becoming more important that the goods are delivered at the right time, Just-in-Time, a system based on Japanese management concepts and introduced by the Americans in the nineteen fifties and sixties. The consequence of this system is the large amounts of stock on the road, and lorries are required to make deliveries while they are not full to capacity. The distribution centres only have a limited amount of space and use the cross-docking system more and more: full pallets come in which are not subsequently used for order-picking; orders are made up of one or more units of a certain product and go directly to the retailer without being divided up.

In order to manage transport space as efficiently as possible, the so-called packaging module system, named 'Collomodule', was introduced in the Netherlands in the nineteen eighties. The revised road width led to amended legislation governing the width of lorries and axle load. This made it possible to construct lorries that had an internal width of 2.44 metres. This dimension was used to standardize the dimensions of pallets to a width of 1,200 mm so that two pallets could be placed side-by-side on the lorry floor. The lengths are 800, 1,000, 1,600 and 1,800 mm (pallets of 800 x 1,000 mm are also made). Current names are Europallet (800 x 1,200), Chep-pallet (named after a firm that runs a pallet pool for paying participants), Block Pallet, NEN Pallet or Industry Pallet (all of which are 1,000 x 1,200) and Stevedorspallet (1,200 x 1,800). Many national and international standards have been established (NEN, ISO, DIN; TNO Centre for Packaging Research) for the purpose of standardization.

Roller containers used by distribution centres and supermarkets have a loadable surface of 600 x 800 mm and dollies, also used to stock shops, have a floor surface of 400 x 600 mm.

Assuming a dimension of 400 x 600 mm for a transport packaging or secondary packaging, a box, crate, tray, etc., also referred to simply as packages, the pallets referred to above can all, with the exception of the 800 x 1,000 mm one, be loaded to the full 100%.

Smaller dimensions, fitting in with the standard dimensions of 400 x 600 mm, are allowed in the packaging module system. Examples are the plastic crates for glasses and plastic bottles, the majority of which are 300 x 400 mm in the Netherlands. Transport containers for the food industry are generally 400 x 600 mm.

The introduction of this system has proved to be an enormous success. The organization set up for the purpose of introducing this packaging module system was disbanded in 1997 after it had achieved its goal. Germany and other countries are now considering to adopt this system.

This dimension-based system also governs shelf space and also influences shop space.

For the selling of plants and flowers trollies, are being used to transport the products from the grower to the auction. In the past more than a million of the so called Danish trollies were produced to be used in Europe. They have a dimension system different from the above mentioned 'collomodule' system. In practice this means that in this sector somewhere in the chain the loadable area is not fully used.

The optimum loading of pallets is important for the total cost, particularly with regard to food. The turnover per transported volume is relatively low when compared with other sectors. It is easy to understand that the costs of packaging materials, are consequently, proportionately higher for food than for non-food. An efficient distribution system is therefore of crucial importance when transporting food.

A variety of different sources maintains that the consumer will be less dependent on the retail trade in the future. A Procter & Gamble manager stated to expect that 10% of all sales will directly be delivered to the consumer before 2003. This expectation is based on the fact that consumers are easily able to communicate with producers without the need for mediation by the distribution chain and the trade, mainly through the Internet. For the time being, however, the effect this will have on packaging will be only limited; the requirements set by the distribution industry for the delivery of goods must still be met: efficient loading and participation in electronic data interchange. Supermarket chains also publish their requirements regarding the outward appearance of packaging in frequently changing guidelines (e.g. Albert Heijn, 1995 and 1998; Dirken, 2000).

Also in terms of functionality packaging must be seen as an economic activity. Should it appear that a packaged product can only be transported by sacrificing space, then consideration can be given to packing the product differently (components packed separately, product on its side, etc.) or changing the dimensions. Obviously this will depend on the sort of product and market demand.

A general description of the basic structure of the logistics of the total packaging chain can be seen as the following sequence of phases:

- manufacturer of the raw materials;
- manufacturer of packaging materials, packaging components, etc.;
- packaging producer;
- packer;
- storage, transport;
- storage, transhipment, distribution;
- transport;

- storage, transhipment, distribution (the latter two possibly a second time);
- display, sales, delivery;
- transport, storage;
- use, storage;
- disposal;
- transport, storage;
- cleaning and reuse, material recycling, landfill.

The above list can be used as the starting point for determining the chain that is of relevance in a given case; the requirements regarding the information system and dimensions and weights that can be used efficiently can be stated for each step.

It can be concluded that for the purpose of distribution a package must meet a large number of requirements otherwise the links in the distribution chain will be faced with handling problems. The functionality of packaging can be defined as: to ensure that the product, of a specified quality, is able to reach the specified destination at a specified time and having a specified quality; the functionality of distributing is consequently an essential part of this.

3.3.3 Use functionality of informing

If a product can be examined only by removing it from its packaging, often by effort or even by taking destructive action, methods will be sought to ensure that the packaging contains information about its contents. It is assumed that in past years the choice of the most suitable packaging for a certain product was based on the nature of the product itself, the distance it would need to travel and the method of transportation (Topa Holding, 1997). Because the different product groups used the same packaging shapes, such as the people of ancient Rome used an amphora for wine, oil, grain and occasionally water, it was essential to indicate what the packaging contained. Excavations made along former trading routes in the Arab countries show that signs were used on the outside of earthenware packaging to indicate whether it contained beer or wine. Food cans from the early 19th Century were provided with a (handwritten) label that was used for the purpose of information, stating the contents. Here too was it necessary to indicate the contents given that the same sort of packaging was used for a variety of products. The provision of information is therefore stated by many as being one of the most important functions besides product protection. For instance Melis, 1991, speaks of the *Silent Salesman* and Paine, 1991 (p.4), says: *"All retail packages must communicate, for not only do they have to identify the contents, but they must also assist in selling. The unit load and/or the shipping container must inform the carrier about the destination, provide any instruction about the handling and stowage of goods, and perhaps inform the user as to the method of opening the package and assembling the contents.".* Hine, 1995, even states that the communicative function of packaging is so strong that lawyers in the USA, with varying degrees of success, fought to have them categorized as educational tools. The packaging informs

the buyer as to the amounts of essential ingredients he/she will consume with this specific food, and thus also on what that food is deficient in.

Initially, when hearing the concept of 'information', the tendency is to think in terms of text and possibly a logo, while the shape and colour of the packaging certainly play an equally important role. This can be illustrated by the dairy products sold in the Netherlands, in which colour coding distinguishes between low-fat milk and full-cream milk, buttermilk, different custards and yoghurt. Design can also be seen as information, particularly in those instances where the shape is an identifying element (Coca Cola and Perrier), but can also be regarded as product functionality. It is therefore wise to first of all give attention to the various sorts of information the combination of product and packaging can provide as seen nowadays. Seven life stages of packaging have been chosen to this end: production, filling, distribution, purchase, use of product, use of packaging, disposal.

Life stage	Information content	Sort of information
Production	how to carry out certain actions, information regarding quality control such as register marks, the ability to trace the tools used in the production, such as mould numbers	alpha-numeric, barcodes, colour, icons, embossing, graphical elements
Filling	control codes for filling machines such as sensor surfaces, bar codes, marks for filling such as filling height, filling volume	alpha-numeric, barcodes, colour, icons, embossing, graphical elements
Distribution	amount, weight, distribution codes, tracking and tracing data, dimensions, how to transport, spatial orientation, hazard classification, origin, legal aspects	alpha-numeric, barcodes, colour, icons, recesses
Purchase	identification, attracting attention, sort of product, quality, type, model, amount, origin, composition, sell-by-date, price, legal aspects'	shape, colour, alpha-numeric, artwork such as photographs and drawings, recesses, transparency
Use of packaging	taking away, putting away, opening, closing, emptying, holding, using, conserving, how not to use, potential danger, service methods, legal aspects	alpha-numeric, colour, icons, drawings, graphical elements such as arrows and lines, artwork such as photographs and drawings
Use of product	volume, amount, brand, sort, quality, parts constituents, date, how to use, how not to use, how to conserve, potential danger	alpha-numeric, colour, icons, drawings, graphical elements such as arrows and lines, artwork such as photographs and drawings
Disposal	how to make smaller, where to take, to dispose of in which circuit, legal aspects	alpha-numeric, icons

Table 3.1 An overview of the seven phases in the life cycle of the combination of product and packaging, and the information of relevance in each one as seen nowadays

Despite the large amount of different sorts of information, there is still packaging that displays the contents and furnishes either no or very little information. This, for instance, is the case with regard to products in the group of furniture. A sticker with the barcode and article number is used for the logistics trajectory, possibly a window in the packaging to display the product so that the purchaser knows what he is buying in terms of type, colour, etc. The packaged products are generally stacked in the vicinity of the displayed product and show the model number to give the consumer certainty in this respect if the model cannot be observed through the window in the packaging. Examples here are boxes containing laminate strips, cupboards, tables, picture frames, table legs, etc.

Two trends that have been very important for the functions fulfilled by packaging have been mentioned already: the introduction of self service shops and the introduction of televisions in households.

The introduction of self service shops resulted in packaging taking over the role of the person of the grocer of informing, recommending and weighing. The packaging had to sell itself, and once the product has been sold, the packaging constantly advertises the product and brand. Packaging is consequently referred to as the silent salesman by different sources (Pilditch, in Riezebos 1996; Judd, Aalders, Melis, 1989). Visser (in Riezebos, 1996), however, reports that this *"is a narrow view on the communicative role of packaging"* (p.166). Research apparently shows that 80% of purchasing decisions are made in the shop. Later on he qualifies this by stating that these decisions mainly relate to impulse purchases and purchases in a pre-determined category but not for a pre-determined brand, where packaging is mainly for recognition. Packaging will, for the time being, continue to fulfil the role of the silent salesman. With the tighter legislation regarding brand protection, and with producers in countries where it is difficult to tackle them legally, the establishment and maintenance of a brand calls for caution (Terwindt, in Pakblad 1, 1998).

Several brand names have already been mentioned and Franzen and Holzhauer (1989) and Riezebos (1996), and others, state that the presence of a brand is very important for sales. Kotler (1980, p.366) defines 'brand' *as "a name, term, sign, symbol or design, or a combination of them which is intended to identify the goods or services of one seller or a group of sellers and to differentiate them from those of competitors"*. He defines 'brand name' as *"that part of the brand that can be vocalized"*, and brand mark as *"the design (letter font, shape, color, etc.) by which the brand distinguishes itself"*. A trademark is a brand or part of the brand which is legally protected against abuse from third parties. Branding consists of the activities of designing, affixing, distributing, promoting and protecting the brand, the brand name and the trademark.

Four feasible functions of branding are mentioned: the identification of goals to simplify handling and tracing, the protection of unique features (emphasizing a certain level of quality), the facilitation of product tracing and finally, making price differentiation possible. Several of these functions could therefore be categorized as the use functionality of informing.

There are many different reasons why packaging should communicate information. Depending on the product, the packer is obliged to furnish certain information on the packaging, to make the packaging in accordance with certain guidelines, and to exercise care when choosing materials. The next chapter will give an outline of most relevant legislation. To determine the functionalities and functions of packaging, it is important to know that a package must comply with legislation on a variety of aspects: the safety of man and his environment, hazardous substances, packaging waste, fair trading, the provision of information, transportation of goods, the transnational transport of (perishable) goods, packaging design, brand names, product, type or sort, liability for damage caused, working principles recorded in patents, etc.

Optimum economic division of functions between the product and the packaging can also be found in the functionality of informing. For instance, a choice can be made between showing the actual product, or seperately showing a picture of the product or a description of the product on the outside of the packaging. Alternatively furnishing certain data on the product itself or on the packaging, or even on both, such as required voltage, an indication of the positive and the negative terminal on small, electrical appliances.

It may be concluded that packaging can be used to communicate a wide variety of information for a wide variety of users, from manufacturer to waste processor: providing information on the functionality of informing on package, contents and their combination.

3.3.4 Design product functionality

That the outward appearance is appropriate for the product in question is not only important for the product but also for the packaging. The balance between the different dimensions, the shape, the use of colour, graphics, roundings, design details, etc., all determine the outward appearance. As stated in Chapter 1, in this field a great deal of attention is focused on the packaging, for instance the 'Handbook of Package Design Research' by Stern (1981) and, *inter alia*, by Riezebos (1996) and more recent by Koopmans (2001). The attractiveness of the outward appearance is often of immense importance for the purchase of a product, especially for those products sold on the basis of what the package displays, mainly supermarket articles, and particularly for impulse purchases (Riezebos, 1996). This will apply less to products sold on the basis of their technical features.

A separate category is the packaging of cosmetic goods, particularly odours: perfume, eau de toilette and after shave. It would appear that there are no upper limits on how these packages are designed.

With regard to food, design is often used to evocate a certain atmosphere. High-grade laminates are used as old-fashioned kraft paper, paper that is beige/brown and sometimes decorated with light and dark stripes to create a nostalgic, traditional and even an environmentally-friendly impression. One example here is Albert Heijn coffee, special blends packed in a plastic laminate with aluminium, printed to look like kraft paper. Sometimes recycled corrugated cardboard is coloured to make it look like kraft paper, projecting an image of higher quality but with a higher impact on the environment.

Illustrative examples of the design of packaging are the Coca Cola bottles designed in 1915 by Alex Samuelson and T. Clyde Edwards (Sudjic, 1985) and redesigned (slenderized) by Raymond Loewy in 1955 (Bayley, 1979), and the shape of the Perrier bottle. Coca Cola claims that its bottle is recognized by 90% of the world population (Bayley, 1979), thus showing the importance of packaging design. In a survey held in four Amer-ican cities in 1987, 71% of the respondents gave Coca Cola as the answer to the question which product could be identified by the colour red (Hine, 1995). Kodak has become known for its yellow boxes in the past and, outside the Netherlands, Heineken for its green bottle. In addition to identification, colour also plays a role in aspects of assessment such as quality, taste and the naturalness of the packaged products (Favre, 1969).

Visser (in Riezebos, 1996) states that 'beautiful' or 'ugly' are not the only criteria used by the purchaser when selecting a product, referring to brand and non-verbal aspects such as shape and colour.

3.3.5 Technical product functionality

The packaging has to do its job, it must fulfil its purpose. This means that barriers against oxygen must be in place for products which are sensitive to oxygen; that the packaging must provide a suitable buffer to absorb energy for products sensitive to shock and vibration. The packaging industry has many examples of clever technical solutions with a high return: Metal cans with a honeycomb structure allowing the wall thickness to be kept as thin as possible. Plastic bottle and metal can shapes that are able to resist the internal pressure resulting from pasteurization or sterilization. Stackable plastic crates constructed with a minimum amount of material which can be made in the shortest process time possible, such as some beer crates for glass bottles. Plastic laminates comprising seven layers of material offering optimum protection using a minimum of material and the possibility to include information, such as the foil used for bags of crisps, foils used for coffee packs. Glass bottles constructed on the basis of maximum strength to withstand internal pressure, and a minimum amount of material such as 'stubby' bottles; and dozens of other examples. All users benefit from the technical function, but a technical solution that is both clever and has a high profit as well, benefits the manufacturer or filler and the (end) user in particular. Solutions concerning distribution obviously benefit the distributors in particular. A user who is aware of the technical function can also make 'use' of it a second time by telling an interesting story.

3.3.6 Product functionality in economical and management aspects

As was already stated in Chapter 1, the packaging industry is very important for a country's economy. All companies wish to guarantee their continuity and hope, to a greater or lesser extent, to make profit. Competition between different sorts of materials and types of packaging ensure the constant improvement of packaging. Competing areas are e.g. solid board and corrugated board, thanks to the introduction of a reduction in flute height by the corrugated board industry; plastic and glass compete in the soft-drinks, the spirits and the beer market; plastic, wood and cardboard compete in the market for transport packaging, for vegetables, fruit, foods, etc; polypropene (PP) as opposed to polyethene teraphthalate (PET) for foils with gas and liquid barriers.

To achieve its goal a company can search for ways to boost its sales. Each use functionality can be translated in such a way as to ensure the most profitable situation for the company.

Detachable or separately included premiums, etc., only play a marginal role in designing packages and are therefore not taken into consideration in this study. The effect of premiums on sales can however be enormous as seen from the 'flippo' campaign run in 1996/1997 by Smith (Lay's nowadays), the crisps company. This particular campaign achieved a temporary growth in Smith's market share of more than 20%.

The economic aspects are given little consideration in this study and are only mentioned where they are of special relevance, as set out in Chapter 1. It seems that many businesses still make too little use of the marketing and management aspects and opportunities of packaging. Too much attention is focused on the cost aspect solely. Projects to achieve cuts in the field of packaging have been introduced over the past few years by many packers. Several trends have illustrated that a different packaging, which may be more expensive, can nevertheless achieve higher profits. A package costing twenty-five cents more can bring in several euros more in extra income, e.g. the long-necked bottle introduced by Heineken as an exclusive bottle in the Netherlands. Other examples are the packaging for Telfort telephones based on the milk carton design, Heineken's shaped cans, Albert Heijn's plastic bottles for washing detergents, etc.

The entire user chain, up to and including the end user, and even the waste processor, all may benefit from the product functionality in economical and management aspects.

3.3.7 Psychological product functionality

The psychological product functionality can be looked at from two different angles; from the tradesman's point of view, and from the buyer's point of view.

The tradesman will, generally, do everything in his power to sell as many of his goods as possible and will use his knowledge of psychology to achieve this. The design production functionality concerns the aesthetic value, the way in which the packaging influences the consumer's purchasing and his decision-making behaviour. What role does colour play, what associations are evocated by different letters, what is the effect of shape, how does the name, the sort and type of the brand sound, etc. This is a major area of research which has only been tackled systematically for packaging in recent years. How a package should be handled is also important. Beer, a product that conjures up an image of male sturdiness, should not be contained by a pack that can be opened with a light unscrewing movement, needing the use of two fingers only; nor can a robust, ridged screw cap be used for a bottle of perfume. The movement needed to hold, open, close, pour, dose, etc., must be in line with the image of the product, brand, type, etc. (Ten Klooster, 1987). This field of research is called design semiotics.

The purchaser can attribute psychological values to the purchase of a certain product, for instance by identifying himself with the target group shown in television commercials. Other psychological values can be the status, self-image or the social role of the consumer (Dirken, 1999). While the latter values are systematically ignored in studies carried out by consumer organizations, they are still used explicitly in, for instance, studies carried out by the motorcar industry, because status plays an important role in the purchases made in this sector.

Grolsch, as an A-brand beer producer, always shows its unique swing-stoppered bottle in its commercials because it reflects the image of beer and thus allows the packaging to give added value. Robijn fabric softener made its packaging smaller, but it also changed the appearance of its bear mascotte to make it look slightly more macho, otherwise the look would have been too "soft". The economy size of the packaging of Zwitsal baby shampoo was given a more robust shape than the regular size packaging, because many adults also use this shampoo, particularly the package with a larger content.

This product functionality applies mainly to the selling party and the end user and less to the preceding phases of the chain.

3.3.8 Product functionality in political aspects

The government or certain user groups can benefit from the production of a certain packaging, to boost employment for instance. Examples are the former production of strawboard in the North of the Netherlands, the production of sacks for the transport of sugar from Cuba to Russia. Scandinavian countries have up to this day always strongly encouraged the sale of wood pulp by carrying out a great deal of research and development in this field including packaging applications. The introduction of cardboard packaging for beverages was the result of this R&D. The Scandinavian countries and Austria keep warning for 'forest suffocation', because western nations use too little new pulp, i.e. the level of recycling is too high and, consequently, the forests are thinned out far less than was planned.

3.3.9 Product functionality in regional/global aspects

The product functionality in regional or global aspects mainly concerns the environment and therefore everyone is directly or indirectly user of this function. Eco-design as a design activity was explained in Chapter 2 and many MSc packaging design projects at Delft University of Technology demonstrated that the environment was an important starting point. On the basis of the analysis carried out in the graduation reports, as described in Chapter 2, several functions were made more explicit and can be brought under the heading of regional/global aspects of product functionality. Some specific solutions for eco-design of packaging are illustrated in the following.

Allocating second-life functions to packaging
A second-life function prevents waste. Mustard was packaged in the Netherlands for many years in a beer glass, and the packaging for hazelnut spread (Nutella) is still in the form of a soft drinks glass. Instead of the entire packaging, part of the packaging can also be designed in such a way that it can be used for second-life functions such as construction kits from folding boxes (McDonalds), memory games (Festina box for ice creams), plastic treasure chests filled with ice cream (Ola's Max ice-cream). A variety of biscuit packaging made from folding boxes (Bolletje) that can be used to make doll's houses etc. This is particularly for products intended for children. With regard to products for older people, cigar cases were used in days gone by as boxes in which a variety of small household items were saved.

A distinction can be made between different sorts of parts of packaging: the packaging obtained from a part that contributes to its construction, a part that is added to the package without it contributing to structural aspects, parts that can be detached from the package, and parts that are supplied separately from the package. The latter two are generally premiums.

Making empty packages smaller
Waste volume is important for transport, for processing and temporary or permanent storage (landfill sites). Thus packaging that contains a large amount of air can, in a number of cases, be reduced in size once it has been emptied. The cardboard packages of today are much easier to flatten than before. PET bottles for soft drinks can be fitted with weakening ridges so that they can be crushed or twisted to reduce their size. If the cap is then screwed back on to the bottle it is prevented from returning to its original shape (AA-drink, Eau-vital, and many other PET bottles).

Preparing packaging for recycling
Packaging can be constructed from a single material, and any additional components of other materials, can simply be omitted or substituted. Examples in this respect are: the omission of plastic sealing tape on boxes, substituting anti-slip hotmelt on the top sides of boxes with thinner coatings, substituting PE liners in paper, etc.

Using recycled materials

It is continually attempted to use the highest possible percentage of recycled material. Recycled material can be used in an intermediate layer (containers of engine oil, disposable coffee beakers) by applying co-extrusion in the extrusion blowing process, for instance, when producing plastic bottles. Plastic from beer and soft drink crates has been reused for more than ten years now in new crates or returnable plastic pallets. Glass, paper and cardboard and metals from packaging are also reused on a large scale.

Increasing the packaged volume

Increasing the packaging size results in an increase in volume by a power of three, while the surface increases by a power of two. This means that the amount of packaging material used per unit of product is advantageous for greater volumes. This measure reduces packaging waste. It is hard to imagine that the amount packed will only be changed because of environmental reasons. Competitive advantages will play an important role.

Adapting the packaging to meet the amount consumed

The amount of product thrown away because of ageing or decay generally causes far more environmental pollution than the amount of packaging material thrown away. The amount of product packaged should consequently be in line with the amount that is usually eaten or used (Kooijman, 1996).

Optimizing the construction of the packaging

Many packagings can be optimized with engineering rules based on placing the material in an optimal way were it is used. It is possible to simulate many kinds of loads with software and to optimize the construction of packaging as Van Dijk shows (2001).

It may be concluded that packaging when added to the product, contains the product, bundles it, makes it suitable for transportation or protects it, and that three main use functionalities of packaging can be distinguished: preserving, distributing and informing. Product functionalities can also be distinguished, all of which can play an important role.

Depending on the sort of packaging, attention may be focused on a certain functionality and it is also feasible that only little attention is devoted to certain functionalities. We will return to this later.

The functionalities are set out in the following diagram.

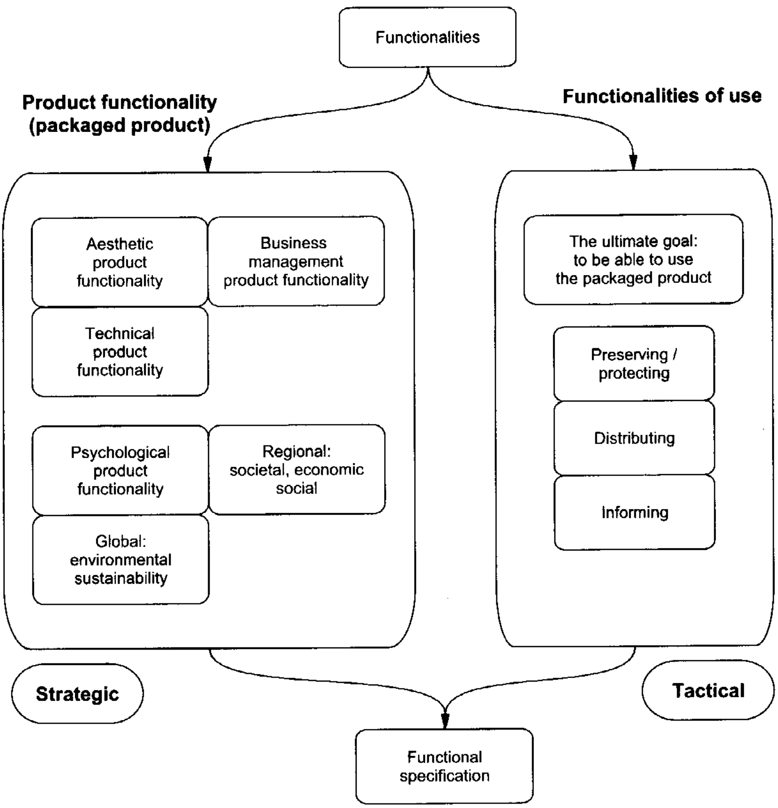

Figure 3.1 The functionalities of packaging

3.4 The definition of packaging

It was concluded in Chapter 1 that a good, comprehensive definition of packaging, which includes most or all the multidisciplinary aspects, can probably provide some clarity as to the term 'packaging', as well as deny or nuance the alleged superfluousness of packaging. An insight into the basic terminology has already been given in the previous sections.

Also in Chapter 1 it was concluded that a number of different functions must be distinguished. Thereupon we have tried to present and analyze a rather complete set of the functionalities of packaging. The final goal of packaging is using the product, unwrapping, dosing, etc.

Further more it should be stressed that functions can change when the packed product is going through the chain, also that sometimes functions are realized by means that usually would not be defined as packagings.

It is a combination of functions that determines whether the fulfiller of a function is or is not a package. This again leads to the field of study of Fodor and Marconi (see Chapter 1); many people sense the boundaries concerning a definition of a fulfiller of a function, yet the actual definition itself is extremely difficult to formulate. There is packaging that does not bundle something together, or does not offer protection or does not distribute the product efficiently or inform, yet which will still be regarded as packaging. Examples of packaging that does not offer all three main functionalities (preserving/protecting, distributing, informing) are:

- the net bags used for oranges: this bundles, separates into portions, provides information on a label, is a means of distribution for the buyer, is a convenient means of distribution for the retailer by means of transport packaging, but it does not protect the oranges from drying out or from mechanical load;
- last-minute-packages such as paper bags for fresh vegetables mainly have a bundling function and do not protect the products well from e.g. mechanical load;
- harmonica carton wrappers around glass products such as wine glasses, glass tea cups and ovenware inform, portion and bundle the products (or product) but only offer a limited amount of protection from mechanical load;
- a foil to protect magazines from soiling may also provide a bundling function e.g. if samples are supplemented or just to keep the label with name and adress in its place, but usually does not provide information or contribute towards distribution (magazines packed in foil even tend to slide off one another more easily);
- cardboard boxes for table legs bundle, protect and distribute them but sometimes offer no information.

Is there a minimum number of these before-mentioned functions that must be met to be referred to as packaging, and if so, which combination of functions?

An article that only serves to bundle the product or products, such as an elastic band, is only seldom referred to as packaging. Another factor which is important concerns size. Whereas a transport container for cargo ships and lorries could be referred to as packaging, because of the bundling and protection of goods during their transport, most people will not bring such containers under the heading of packaging. At the other end of scaling: a bucky ball containing a specific atom or molecule is outside the scope of our study too.

Nor will an article intended solely for the protection of a product inevitably be defined as packaging, articles such as the plastic corner-pieces of a quick-change picture frame. The same applies to the other consumer functionalities; only distributing or only informing. This leads to the conclusion that an article that bundles a product, as well as enveloping it, will generally be defined as packaging. An article that fulfils only one functionality of use will not as a rule be defined as packaging. A combination of at least two functionalities of use, or a combination of bundling and enveloping, together with one of the three functionalities of use (protecting, distributing, informing) apparently determines the limitations as to what is and what is not seen as packaging. Nor may it be forgotten that fulfilling the combination of these functionalities is temporary and that this influences how packaging is defined. A box for compact discs is referred to as packaging as long as it is in the chain, and as a durable means for storing the CD in after its purchase. The table shows which combinations are defined as packaging on the basis of the approach used.

Packaging functions:				Regarded as packaging:
Bundling, enveloping, shaping.	Protecting / preserving	Distributing	Informing	
×				generally
	×			usually not
		×		usually not
			×	usually not
×	×			generally
×		×		generally
×			×	generally
×	×	×		always
×		×	×	always
×	×		×	always
×	×	×	×	always
	×	×		exceptionally
	×		×	exceptionally
		×	×	exceptionally
	×	×	×	exceptionally

Table 3.2 Function combinations that roughly determine what is and what is not regarded to be packaging

The following description of packaging is based on the above functions and potential combinations of functions to be able to use the product. In order to keep the formulation manageable, a definition is given first, followed by detailed explanation.

Definition of packaging

Packaging is the fulfiller of functions that is added to a product to bridge the aspects of time and distance at acceptable cost and acceptable environmental impact, ensuring acceptable quality of the product for the end user.

The following points are explained. Packaging:
is an additional element or seperate elements, connected in such a way that it can be disconnected from the packed product;

- with the objective of enabling or aiding the product to reach the user; so it can be unwrapped and used;
- which can consist of several layers;
- with a temporary combination of functions related to the product;
- which is industrially manufactured and combined with the product industrially or on a small-scale, i.e. by hand;
- and which contains, holds or envelops a – usually predetermined – amount of product(s);

- for the purpose of carrying it safely through the chosen or specially-developed distribution channel, to the specified destination at the specified time;
- needs to guarantee a certain quality at the moment of use/consumption;
- which is an economical tool in the commercial chain;
- in which the parameters of time and distance play a major role, and, if necessary, delay the decrease of quality by entropy, external or other influences;
- needs to give necessary, obligatory and value-adding information;
- and which usually can boost the sale of the product by virtue of its particular design in order to communicate its identity and attractiveness;
- which can be joined by several means (auxiliaries) to effectuate its functioning, especially during end-use;
- which can be re-used, recycled or disposed of in an acceptable fashion;
- and which usually also realizes and integrates several other functionalities of psychological, technical, commercial, political and ecological nature.

3.5 Enumeration of the functions of packaging

An extensive list of aspects has been drawn up that can lead to functions that a packaging must or can fulfil on the basis of the aspects enumerated in the definition. This list can be used as a checklist for a packaging designer and in principal underlies design methods of which at least one is intended to be developed in this study.

An additional element consisting out of one or more seperate parts, connected in such a way that it can be disconnected from the packed product:

- Joining product and packaging:
  all the functions in the chain, in which product and packaging are united, can be fulfilled either in whole or in part by the packaging: during producing, transporting, forming, filling, joining, closing, preserving, labeling, bundling, stacking, palletizing, storing, distributing.
- Separation of product and packaging:
  all the functions needed to be able to use the product: opening, holding, pouring, spraying, dropping, shaking, drinking, smelling, using, closing, putting away, cleaning, taking back.

The purpose of reaching the user:

- Ergonomic aspects such as: dimensions, weight, the way of using, handling, holding, positioning, method of opening and closing and the force required, storing, dosing.

Which can consist of several layers; primary, secondary, tertiary:

- Packaging layers:
  packaging can be engineered in several layers: primary, secondary, tertiary; the (main) function(s) of each layer must be defined and the combination of functions between the layers must be taken into account.

A temporary combination of functions related to the product:

- There must be harmony between the functions of the product, the required preservation and protection and the functioning of the packaging.
- The objective of the packaging is the use of the product;
  ergonomic aspects are of importance; legislation on safety and health for instance, human care, transport, fair trading, the need to provide information, presenting information; legislation on the use of aerosols, pressurized packages, etc.

That contains, holds or envelops a – usually predetermined – amount of product(s):

- Functions in this respect can be: containing, holding, enveloping, keeping together, keeping external influences out and internal influences inside; legislation; keeping out external influences such as dirt, dust, odours, gasses, micro-organisms and rodents; keeping inside such internal influences as grease, odour, micro-organisms.
- Portioning, product quantity or of seperate elements/sub-units must be determined.
- Internal separation, some products function by joining two components at the moment of use.

To carry it safely through the chosen or specially-developed distribution channel, to the specified destination at the specified time:

- Legislation and standardization on transport and exports is of importance in this respect.
- The logistic concept, consisting of the product delivery route, the management system, the information system and the organization, must be defined.
- Distribution aspects such as sequence, physical process, dimensions, handling methods are of importance in this respect.
- The packaging must be designed to suit the dimensions of the place where the product is to be sold and or consumed.

Essential or desired quality, in terms of containment:

- Defining the required quality of both product and packaging.
- Containment; the packaging should keep unwanted elements out and/or desirable elements in.

Functions related to preservation, determined by the parameters of time and distance:

- Time, many aspects can be named:
  because of the nature of the product: entropy, maturation, controlled change, preservation;
  the biological processes that may cause illness, secretion of toxic matter that causes fermentation, growth of fungi;
  the biochemical processes caused by the presence of enzymes;
  the chemical and physical processes of the product such as oxidation, UV light, freezing, evaporation, absorption of alien gasses or odours, enthalpy, boiling, condensation, osmosis, migration, pressure, radiation, magnetism, electricity, static charge, drying, pressure, humidity during the total transport chain and storage;
  mechanical influences (see influences of distance below);
  accidental influences of the weather, like rain, snow, cold or heat, or by leakage,

theft, tampering, rodents, insects, etc.;
chemical or physical reactions between the packed product and the packaging material;
open systems, i.e. packages which are not closed;
half-open systems i.e. permeable packages;
closed systems, i.e. closed packages; systems to preserve contents that have undergone pasteurization, sterilization by heat, radiation, by gasses such as ethylene oxide, by pressure or electricity, or other techniques.

- Distance:
  Transport;
  (storage: i.e. time; see above)
  transhipment and distribution;
  mechanical influences such as shock, vibration, acceleration, slowing down, centrifugal forces, collision;
  contact with other articles or products or with sharp edges;
  chemical influences such as oxidation of product and packaging;
  reactions between packaging material and product;
  reaction with matter that diffuses through the package;
  vulnerability of the product, of the packaging and auxiliary equipment.

Informing about necessary, obligatory and value-added aspects:

- Legislation on safety, fair trading, etc.;
- About contents, quantity, producer, ingredients, etc.;
- About those aspects of which the producer must control the quality;
- About those aspects the filler needs to work faster on and maintain the quality thereof;
- Distribution codes and other distribution information;
- About final use of the product, like how the product must be used, opened, closed, stored, disposed of, etc.;
- About the environmental impact and end-of-life handling of the product-packaging combination;
- Branding, (registered) trademarks, type of product;
- Service, possibilities for inquiries;
- Promotion.

Styling:

- One of the functions of packaging is to look in a visually balanced and a recognizable way that helps identification as belonging to a group of products, of users, environments or life-styles: by colour, shape, graphic design, dimensions, logos, material, texture, shine, etc.

Features

- Premiums and give-aways can be added; collecting systems can be integrated; adding extra functions during or after use; using images/portraits (comic heroes, 'stars', celebrities, Disney characters), the relationship with commercials can be strong, for example the sound of opening, the way of handling or using.

This enumeration brings this chapter to a close. It has answered research question

A.1: What are the functions of the packaging and what is an adequate definition of packaging.

The study showed that this question could only be answered with an extensive description and that packaging calls for a very wide definition.

The next chapter looks at packaging properties and the associated functions of materials. It is meant to give some insight into the reasons why certain materials are used for certain products, to show possibilities and limitations of materials and to show the limited choice of packaging materials to pack certain products.

Thereafter attention is also given to legislation and regulations in the field of packaging since they have a strong influence on packaging design.

4 Packaging insights, properties of packaging materials and packaging legislation

Summary

In this chapter we will, to offer some background and contents for the design method to be developed, provide knowledge of and insights in packaging and packaging facts and give a description of the role of material properties in the design of packaging; this background itself can also be a 'tool' for design projects. Packaging layers, bringing together and separating of product and packaging and the packaging chain will be described. After that attention is paid to product vulnerabilities, which are finally set out in the form of tables. To achieve optimum packaging, the basis is the product's vulnerability and a search must be made for that material, or combination of materials, that is expected to counteract that vulnerability. Hence the most essential properties of the packaging materials are specified. These are also summarized in a table. Subsequently, attention is focused on the influence of the amount of product to be packaged, the absolute and the relative dimensions of a package, and the influence of the package shape on the amount of material used. Legislation can be very coercive on how packaging is produced and on the process used to pack the product. This chapter also contains an overview of various, relevant facets and laws which apply in the Netherlands. The functional grounds make it possible to weigh the consequences of this legislation, and also of legislation in other countries. Especially, during the last decade legislation has had a major influence on packaging activities in terms of packaging and the environment. In order to harmonize the various regulations governing packaging and packaging waste within the European Community (EC), regulations were adopted in 1994 by the EC which have priority over the national legislation of the Member States. Attention is focused on this in general; the characteristic way in which the individual nations have translated EC legislation is focused on in particular.

4.1 Introduction

In Chapter 2 the conclusion is drawn that for a method to design there should be among other things, sufficient knowledge of and insight in packaging facts. This chapter tries to partly fill this gap. Important information is gathered in this chapter and an attempt will be made to present this in such a way that it is easy to access. This can result in tools that may be useful for packaging design. As was illustrated in Chapter 2, the lack of factual packaging knowledge, among those product designers who do not have a great deal of experience in packaging design, frequently leads to wrong decisions and less effective and less efficient processes. It is essential that the designers of packaging for a wide variety of products, and/or those persons in decision-making positions, have ample knowledge of the possibilities and the limitations of packaging materials, the specific vulnerabilities of certain products, and how these two aspects interrelate.

Material processing techniques can have an effect on the packaging process and, where relevant, can be included in the description.

It is also essential for packaging designers to have an insight into products vulnerabilities. The ultimate goal of packaging design is to find the weakest link in the product's vulnerability chain and to design a packaging for that product along the lines of, for instance, the design approach taken by the French Ministery of Environmental Affairs (*Ministère de l'Environnement,* 1999).

It is important that a designer is aware of the fact that packaging dimensions can have a considerable effect on how far the quality of the packed product deteriorates and on the amount of material used. A brief annotation explains this.

Legislation can have a considerable effect regarding the freedom of choice when designing packaging. It is for this reason that at the end of this chapter an overview is given of actual (2001) legislation of relevance to packaging designers.

The chapter starts by explaining matters which are specific to the packaging world, such as the constructing of packaging in layers, and the joining and separating of product and packaging. These are two crucial events that are typical of the packaging chain.

4.2 Packaging layers, the skins of a product

'Primary', 'secondary' and 'tertiary' packaging are frequently used terms in the world of packaging, usually referring to the first, second and third 'skins' of a product. However, each of the skins themselves can consist of several layers. This is why the significance of the three skins is discussed briefly, by using the definitions given in the 'Materials Technology, packaging design and the environment' study conducted by the Congress of the United States Office of Technology Assessment (1991, p.4).

Attention is also given to the method of defining packaging or a packaging layer on the basis of the fulfiller of the function.

Primary packaging

The primary packaging is the packaging that comes into direct contact with the product. Given that packaging can be built up of different layers, and because it often occurs that several primary packages are bundled for sale, the term is used in a wider sense. Primary packaging here means primarily the sales unit. The outward appearance and the attention-getting value of the packaging are of importance in this respect. A chewing gum package can serve as an example. Sportlife chewing gum in the Netherlands is packed in a push through strip. The strip protects the chewing gum from unwanted effects and thus guarantees its quality. The strips are packed in sleeves made from folding cardboard, which displays the producer's required and desired information. Three strips are bundled in a three-pack packaging made from folding cardboard that can be hung up in retail stores. In other words: three skins that form the primary packaging.

Secondary packaging

The secondary package is the packaging that facilitates the bundling of the products, makes them easier to handle, and makes distribution possible: group packaging. In practice, this means cardboard boxes and trays, plastic crates, containers, plastic films, etc. In some product groups it is quite possible for a secondary packaging to be the first layer in which the product is packed, as can be the case for durable goods: machine components on a tray in shrink-film, for instance. Nevertheless, in such a case we still usually refer to secondary packaging. While in the publication issued by the Office of Technology Assessment referred to above, the term 'exterior packaging' is used when the primary and the secondary packaging is the same, it is also explained that this is not a commonly used term.

Tertiary packaging

Tertiary packaging serves to bundle a large number of products for long-distance transport. Examples are cardboard boxes (Square bins, Octabins), stackable containers, pallet films such as shrink-wrap, and pallets. A pallet is an object that facilitates the storage and transportation of a number of (possibly, different) products at the same time; the transport package.

Auxiliary items

The EC has defined packaging as "all products made of any materials .... from the producer to the user or the consumer" (EC, 1994) (see Chapter 1).

From the viewpoint of the EC, which is responsible for drawing up legislation and regulations in the field of packaging waste, it is only logical that all the auxiliary items used to ensure that the product bridges distance, with the exception of the means of transport itself, are included in a definition of packaging. Functions in the field of protection, distribution and the communication of information are fulfilled by a variety of different means. It would be taking things too far to refer to a piece of tape, string or an elastic band for the purpose of binding together, or a pallet, as packaging, although in the packaging world these items are normally seen as packaging. This probably has to do with the fact that such auxiliary items do play a significant role in how the package fulfils its functions. Without these items, packaging would need to be constructed or designed differently and, consequently, they must be taken into consideration in economic or environmental analyses. Designers must be aware of the possibilities and limitations of such (auxiliary) items.

Another approach is to name the package or packaging layer after the fulfiller of the function. For instance: Unilever makes a distinction according to consumer unit: packaging in which the consumer buys the product, in the form of a combipack, multipack and single consumer unit,These are packed in a traded unit: packaging, in the way it is distributed from producer to retailer, in the form of a single case, crate, tray, display boxes in cases, small cases inside larger cases, and occasionally as a display (Storm, 1998). In the pharmaceutical industry the interaction between material and drug plays a significant role in the search for the most appropriate packaging material. It is for this reason that firms in this business like Organon uses the term of primary packaging consistently for the first layer that comes into contact with the product, secondary packaging for the second material layer and so on.

Terminology that assumes packaging layers and terminology based on the functionality of the package composition, can both be explanatory and will therefore further be used for the sake of clarity in this study. A designer must make clear firstly what to design, which layer or layers and what the termininology of the ordering party is.The limitations of the order must also become clear. If a certain layer of/around a product already exists, the designer must try to clarify whether the starting points may be altered.

4.3 Joining and separating product and packaging

There are two steps in the chain a packaging travels through that must be given particular attention: the joining and separation of product and packaging.The packaging chain will be illustrated in Figure 4.1 in section 4.3.3 after both steps have first been explained.

4.3.1 The joining and separation of product and packaging

Bringing the product together with the packaging is usually referred to as the packaging process.This process can be carried out in many different ways. For example, the packaging can be wrapped around the product or the product can be inserted into the packaging, it can flow into the packaging, be dropped or pushed into the packaging.

Many packages are formed on the packaging line itself. Flexible packaging in particular is folded and glued or sealed while on the line, usually from rolls of flexible material, but loose sheets can also be used. Boxes are erected from pre-cut, pre-folded and glued cardboard (blanks); they can also be erected from blanks on the packaging line itself.There are dozens of options that can be described in this respect and in the following therefore some overview will be given of the steps usually involved in the packaging process, illustrated on the basis of relevant methods.The variables that can be used to describe a packaging line are also set out.

Process steps

The steps in the packaging line consist of the supply of product and packaging or packaging material (input), filling, and then closing (these three steps can be referred

to jointly as the throughput), the final packaging (secondary and tertiary packaging) and out-feed (output). Activities that can take place between these three steps are:
- cleaning, washing, rinsing;
- pasteurization or sterilization of packaging or packaging material;
- preservation of the product, either before or after being placed inside the packaging;
- inspection activities, e.g. inspection for dirt or alien substances or particles, inspection in terms of content, packaging damage, etc.;
- the affixing of information materials, package printing, either in whole or in part;
- the unscrambling of packaging or packaging components; i.e. ensuring that components delivered in bulk, closing devices, for instance, are fed into the machine one by one;
- affixing or attaching a closing device;
- controling and checking the contents;
- sealing transport packaging, bundling,
- stacking on pallets, application of tertiary packaging elements to the pallet;
- affixing information to the tertiary packaging;
- filling containers;
- loading into lorries, etc.

Basically, each activity can be followed up with a check, as is done for instance in the pharmaceutical industry: a check as to the presence of labels, caps, contents, that the process of bundling has been carried out properly. A mandatory check which is in force in the food industry concerns the presence of metal particles. Wherever work is carried out using metal machines or metal parts, particles from such machinery or parts can end up in the packaging. For instance, the numerous detachable parts and metal chips which, at last theoretically, can come loose. The reports drawn up by the Inspectorate for Consumer Goods show that this, unfortunately, occasionally does happen in practice. This can be the result of checks not being carried out, or because checks are difficult to carry out because the packaging concerned is made of metal, or simply because the checks are inadequate.

Packaging line variables

A packaging line can be described in several different ways. For food shelf life is an important factor for the procedures and instructions for packaging lines. A short shelf life can mean that it is unnecessary to focus a great deal of attention on the aspect of hygiene, given that there is insufficient time for the micro-organisms to develop before the shelf life period has expired. On the other hand, a long shelf life can demand extreme meticulousness with regard to hygiene. The nature of the micro-organisms that (can) develop, and the consequences for the product and any person that has consumed the product, is also a determinative factor in terms of procedure.

Technical methods of approach, for instance, describe packaging lines according to operating procedures: intermittent or continuous, in line or rotational. The direction in which activities are carried out determine whether packaging machines are named horizontal or vertical. This is especially relevant when processing flexible packaging material. For example, a package can be formed from one or two rolls of film, folded and glued small boxes can be erected, etc., this too is often reflected in the name of the machine. Machines that pack boxes are the so-called case-packers; machines that use films from rolls, form, fill and seal (FFS), and horizontal processes are called flow-packers (for biscuits, chewing gum, sanitary towels, etc.), while vertically operating machines are called trans-wrappers, and are used particularly for sachets.

Dosing methods also influence the packaging system choice. Which system is the most appropriate depends on the sort of product and the amount to be packed.

Packaging as an industrial activity is based on the packing of pre-determined quantities of product. There are applications whereby this is difficult to achieve, such as several fish fillets together in a pack should weigh 500 grammes ±10; or when slicing and packing cheese when the package is weighed after it has been filled. Manual packing can also take place, also within certain limits, for both pre-determined and varying quantities. Point-of-sale packing, as is done at the grocery shop, etc., (this used to be done in paper bags), is an example of packing large numbers of different quantities in many different forms, as is usually the case in non-self-service shops. Examples are butcher's shops, baker's shops, greengrocer's shops, shops for sweets, clothing, books, jewellery, etc.

Examples can be given of packaging used for both industrial and manual packing, whereby little can be designed by a packaging designer. This is because the shape is either pre-determined or cannot be pre-determined. Sometimes, however, a great deal of design work is needed. Examples of packaging needing little design work, with the exception of graphical aspects, are shrink film or wrapping film, stick-packs (long, narrow packages) for industrial packing and wrapping paper for manual packing. Examples of packaging that involves a great deal of design effort are, for industrial packaging: plastic bottles or crates, for instance, and for manual packaging: small plastic containers for salads and fruit, etc.

Because the investments in packaging lines are high, there is an obvious reluctance to modify a packaging machine or packaging line. In practice this means that once a packaging line is in place, it is generally left as it is for a long time. This imposes restrictions on quick changes to a packaging, and can also set strict requirements on the design of new packaging. It can be a hefty challenge to modernize packaging by making minor changes only.

These investments are usually insignificant when set against the actual value of the packaging materials or packages that pass through the machines after start-up. In the past it was argued that investment costs should be included as variable costs (Janssen, in *Verpakken*, No. 6, 1989).

Other aspects that play a role in the procurement and/or modernization of a packaging line are capacity, operating method, ergonomic and safety aspects, minimum and maximum dimensions, the number of workers required per line, the correlative functioning of different machines, etc. Attention can also be focused on reliability, maintenance, training, operators, lay out, warranty, etc. The financial consequences will usually be the determining factors.

The product's specific characteristics are of immense importance for the ultimate specification of a packaging line. The elementary form of the substance is the first variable to be looked at: liquid, highly viscous, solid, granulate, powder, etc. Other factors then come into play when setting up a packaging line, such as procedures in connection with potential microbiological aspects, with the product's chemical, physical and mechanical vulnerability. Last but not least, the processing aspects must be taken into consideration. Choices must be made in connection with dosing and transport for systems in which it is important to know whether a product is sticky or attracts moisture, whether it has a high or low viscosity, whether it is sensitive to temperature, etc.

The trend seen over the past few years is for machinery either to be adjustable, so that it can be used for a wide range of products and/or packaging, or engineered specifically for a certain packaging with the intention of processing a high number of packages within a relatively short time. Electronics play an ever-increasing role in packaging lines. Programmable Logic Controls (PLCs) will replace electronic circuits and servomotors within the foreseeable future. This will make it easier to carry out statistical analyses and to trace back data, in order to process and optimize variables and thus facilitate operation within pre-determined, strict limits: statistical process control (for example Does et al., 1997).

4.3.2 Separating the product from its packaging (unpacking)

The separation of product and packaging, or unpacking, is the other link in the packaging chain that calls for extra attention. When the packaging and the product must be separated, the packaging loses its function and will in most cases become useless. This is a remarkable step in the packaging chain: from a complex fulfiller of a function to a useless object or piece of material. It then becomes the target of environmentalist movements (Schoonman, 1991).

A distinction can be drawn between products that are taken out of their packaging as a whole the first time the packaging is opened, and products whereby, after being opened, the packaging must provide either the same or modified functions of protection.

Packaging is a link in a complex process of meeting demands. Kooijman analysed this in terms of energy and environmental aspects in a case study (1996, pp.185-188). The total volume of waste generated, as a result of packaging in meeting the demand for, e.g. green peas, is only a part of the total amount of waste. Product losses at the consumers home are apparently very high too, yet this is not taken into account in many analyses. The amount of energy used to produce the packaging, including the energy content of the materials, varies from 10 to 75% of the total amount of energy consumed. A considerable improvement can be achieved, both in terms of quantity of waste and consumed energy by the consumer's more complete use of the product.

The benefits achieved from more complete use was apparently higher in seven of the nine product-packaging combinations investigated than the benefits achieved from the processing of packaging waste. Life cycle costing (LCC) is used far too seldom. Analyses are apparently too narrow.

It is only realistic to admit that many consumers generate waste for different reasons, such as lack of space, convenience, fear of decay. This fear is abused in some cases by shortening the consumer's use-by date on the packaging.

In a rough assessment of the chain, Kooijman demonstrated that, regarding bread packaging, it is more sensible to make sure that less bread is thrown away than it is to improve the packaging. A study shows that 15% of all the packaged bread sold in the Netherlands is thrown away, and that this is 15 times the total weight of its packaging waste (p.185). A comparison of the environmental aspects of only two or more packages would therefore be pointless. Here too the product and the packaging are strongly interrelated and form part of a complex chain.

The packaging designer should take notice of the way of using the packaging and product and also of the generated waste of the packaging and the product together.

4.3.3 The packaging chain

The term 'packaging chain' is used frequently and it refers to all the links that play a role in the marketing of a packaged product, packaging being the main, recurrent element. The route followed by the packaging after its use also belongs to this chain.

Basically it is quite easy to explain this chain, yet it is made complex because of the many options available within the individual steps of the chain, and because of the potential loops involved in connection with the reuse of certain packaging or packaging components. A simple chain consists of the various steps: the production of packaging, filling the packaging with the product, distributing to the point of sale, the purchase of the product, its use and its disposal.

The main lines will usually be based on a reasonably well-known and frequently occurring situation such as is the case for the majority of 'supermarket products'. Figure 4.1 shows an overview of how the modal and most feasible chain could be visualized.

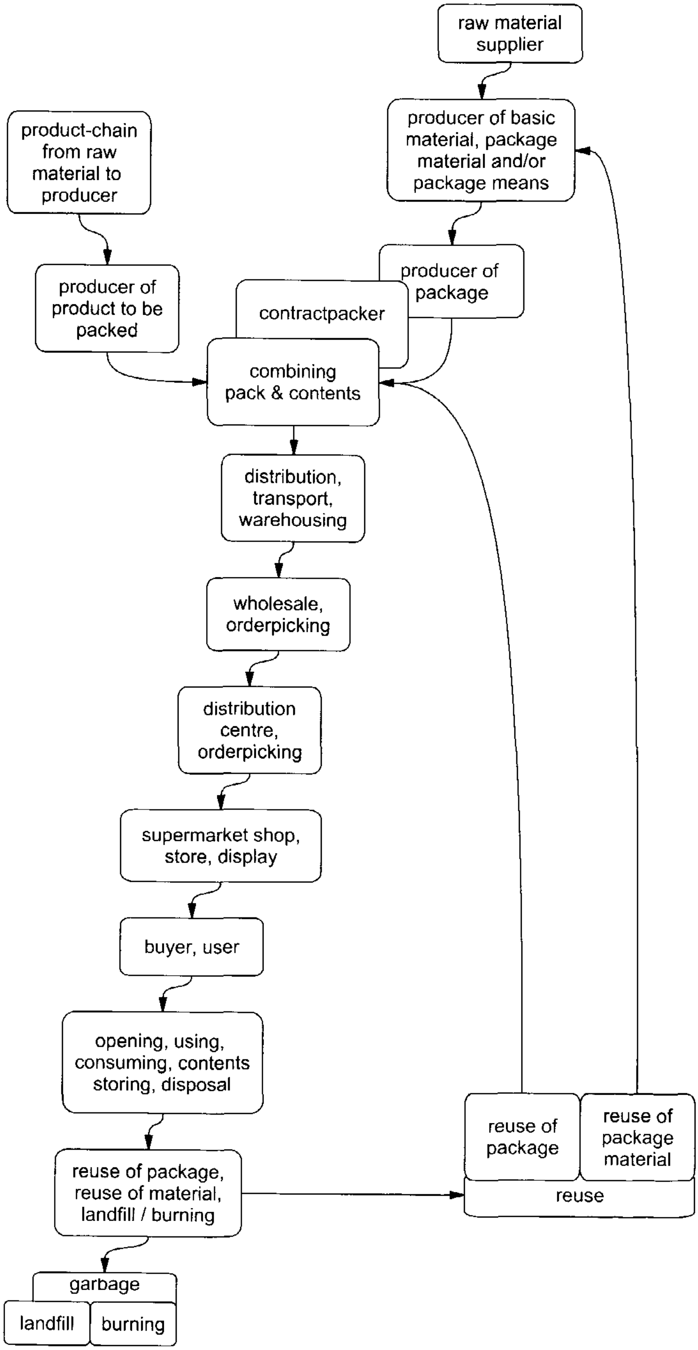

Figure 4.1 The packaging chain, as it can occur

To find all the necessary requirements it is advisable that the packaging designer makes a schedule of the chain as occuring in the specific case.

4.4 Product vulnerabilities

The products to be packaged can be divided into five product groups; and the main vulnerabilities can be set out for each group. That the packaging must be able to help eliminate the cause of a decline in quality, and also help to reduce any unwelcome effects that lead to a decline in quality, applies to each product group. The five groups are: food, drugs, fast-moving consumer non-food goods, durables and industrial goods. Food and drugs are generally regarded as products that impose the heaviest demands on packaging.

4.4.1 Food

About half of all packed products is food (for the USA: Briston, 1994; for Europe: MIP 1997/1998). The foods group is by far the largest among the users and consumers of packaging and packaging materials.

The biological nature of foods causes many different sorts of loss in quality. The most important ones, i.e. those most frequently seen, are the growth of micro-organisms, reactions with oxygen, whether or not combined with UV light, moisture absorption and moisture loss (dehydration), the absorption of alien substances, the impossibility to absorb oxygen, maturation, the loss of alcohol, carbon dioxide, aroma and flavouring, and interactions with the packaging material itself. It can also be necessary to protect the immediate vicinity from the product, from the odour of certain cheeses for instance, or the transmission of flavour from one product to another. One example is cheese with a garlic content that should not be placed alongside packs of dairy products like yoghurt or custard in the supermarket.

Because of the vulnerability for micro-organisms stabilization processes are used. See for instance Kooijman (1996) or Robertson (1993). Especially the heating of the product after filling, or filling the packaging with heated product, imposes extra demands on the packaging and on the material concerning temperature and pressure resistance.

The loss of quality in food is in many cases easy to detect from the change in taste or smell, the lack of carbon dioxide (soft drinks, beer, sparkling wines), a change in colour or the presence of mould. In some other cases, like the presence of salmonella in products containing fresh eggs, it is not easy to detect.

There are several typical ingredients and typical qualities that to a large extent determine the vulnerability of food. Attention will be focused here on the most important ones: ingredients susceptible to oxidation, dry and moist products, products in which certain natural processes are still under way, such as ripening and enzymatic processes, UV-sensitive products, products that contain carbon dioxide, the presence of micro-organisms and products that deteriorate because of change of temperature. In practice it is mostly a combination and chain of reasons why a product deteriorates.

Table 4.1 gives an indication of the most hazardous components and essential aspects the designer has to reckon with.

Food			
Sort of vulnerability	**Hazardous component + examples**	**Essential to maintain quality**	**Remarks**
dry	absorption of moisture causes a decline in quality (salt, liquorice, hygroscopic powders like milk powder or instant soup, biscuits, etc.) or gives rise to micro-organisms	moisture barrier and oxygen barrier	process is reversible, but quality will possibly decrease; the maximum amount of moist to absorb is given as a percentage of weight; there is a relation with oxygen
moist	drying out causes a decline in quality (cake, pastry, meat products, etc.)	moisture barrier and oxygen barrier	process is reversible, but quality will possibly decrease; the maximum amount of moist to lose is given as a percentage of weight; there is a relation with oxygen
with processes still in progress	enzymatic processes or ripening (fresh meat, fresh vegetables and fruit)	appropriate ambient conditions; complex to calculate; choice for half-open systems	composition of ambient gasses is often used: modified atmosphere packaging (MAP)
sensitive to oxidation	edible fats and oils, fatty acids, vitamins A, C and E, colorants, aromas, flavouring, etc. (such as used in dairy products, beer, nuts, coffee, fruit juices, etc.)	oxygen barrier and a humid barrier; choice for closed, half-open or open system	the amount of oxygen is given in part per milion (ppm, weight share); there is a relation with humidity and UV-light; in practice use is made of MAP in many pack agings
sensitive to UV light	degeneration of vitamin C and B2, and discoloration (in e.g. vegetables, fruit, dairy products and grain products)	UV barrier and oxygen barrier	in many cases accelerated reaction with oxygen (beer, dairy products); the part of the spectrum of the UV light is important
acidic products or products containing acidic components	acid can dissolve metals	steel and aluminium must be coated	common coatings are under discussion because of migration of com ponents like softeners
under pressure (gas or liquid)	loss of carbon dioxide (in sparkling drinks, in food and in aerosols); loss of pressure in aerosols	barrier against gasses, pressure-resistant packaging	attention to explosion safety (legis lation)

micro-organisms	products with a 'water activity' higher than 0.6; subjected to an increasing amount of moisture, first mould or fungi, then yeast strains and finally (w.a. > 0.9) bacteria	eliminate or render harmless any micro-organism	presence of oxygen and humidity is essential for growth of (aerobic) micro-organisms
temperature	many products have to be kept under certain temperature conditions; in practice cooling equipment will, in some cases the packaging is important	in some cases the packaging must have the function of temperature isolation (fish in a box with ice for example)	the packaging is also important if products are heated remaining inside the packaging (time and temperature of the process)

Table 4.1 Indication of vulnerabilities of food

Common remarks

The term 'water activity' means the relation between the partial water vapour pressure of the moisture in the product and the water vapour pressure in the free space at the same temperature. Micro-organisms will not easily develop in products with a water activity less than 0.6. In connection with a safety margin to allow for the absorption of a certain amount of moisture, dry products are in many cases defined as those in which the water activity is less than 0.4. Enzymatic processes start to develop at a water activity higher than 0.6.

In literature formulas can be found to make calculations of the mentioned processes to determine the number of days, the amount of moisture, oxygen, etc. Kooijman (1996) demonstrates that the "refreshment rate of a product", i.e. the degree to which a product is able to renew affected parts with unimpaired parts, is important to correctly calculate material requirements such as surface, thickness, relation to the contents, etc.

Different kind of calculations can be made to define the optimum quality of the material, but calculations are only an estimation because the processes that cause the decline of quality are strongly interrelated. For calculating the amount of gas that passes through a plastic film rules of thumb can be used (see Appendix A). Other calculations concern, for example, transport of heat through products and packaging materials, the amount of UV-light going through a material in a certain time, the number of micro-organisms that will be reduced after heating the product a certain time. Temperature plays an important role in all processes mentioned. It is certainly recommended to test if the behaviour of the product is unknown.

Many sources can be found in literature that deal extensively with product characteristics, including vulnerabilities: Robertson, 1993; Briston, 1994; Kooijman, 1995; Paine, 1992, Hicks, 1990 (fruit juices or soft drinks); UNCTAD manual, 1988 (fresh fruit and vegetables), Footitt and Lewis, 1995 (canning of fish and meat), etc.

4.4.2 Medicinal drugs and medical products

Medicines (pharmaceutics, drugs) are products intended for the purpose of curing, improving or maintaining the health of people and animals. They can be taken orally, injected etc. or applied externally. Medical, non-durable products are those products used in medical practice in a wide range, such as cotton wool, spatula, scalpels, surgical gloves and garments.

Medicinal drugs can have the same vulnerabilities as food, although their distinguishing features need not be biological.

It is more difficult for people to detect a decline in quality in drugs than in food; there are generally no or less recognizable characteristics of decay.

The packaging of medicinal drugs and medical non-durable products can be regarded as a separate product group, because faulty packaging can mean a health threat and even lead to the death of a user or a patient. This necessitates meticulous procedures. Generally speaking, as said before, all actions carried out on a packaging line in the pharmaceutical industry are thoroughly checked.

Because sterile conditions are often essential, many products are sterilized after packaging. Customary processes are heating, the use of ethyleneoxide and gamma rays. This also imposes extra demands on the packaging. There are also user requirements that are specific for the market of medicinal products, such as pipettes (for eyes or ears), nasal sprays, etc. Specific attention must also be given to the aspect of safety. Children must not be able to open the packaging and although the packaging must be child-resistant, it must allow to be opened by frail or weak patients, and in practice this frequently leads to solutions that frustrate weak people (Daams, 1998).

The amount of information that must be provided when selling medicinal drugs is so extensive that in many cases the surface of the packaging is insufficient. Hence, many packages contain instructions for use: printed on light-weight paper which is folded and included in the packaging.

Table 4.2 gives an indication of hazardous components and essential aspects the designer has to take into account.

Medicinal drugs and medical non-durables			
Sort of vulnerability	**Hazardous component**	**Essential to maintain quality**	**Remarks**
medicinal drugs	see under food for vulnerabilities; requirements can be more critical than food	identification essential, also shelf life, dosing (contra) indications, etc.; see also under food	decline in quality is not usually perceivable; risks from faulty packaging are high (can even be lethal)
medical non-durables	dependent on application: presence of micro-organisms, dirt, dust, etc.	eliminate or render harmless any micro-organisms, keep out dirt and dust	errors can involve high risks
pharmaceutical products	presence of micro-organisms	eliminate or render harmless any micro-organisms	errors can involve high risks

Table 4.2 Inidication of vulnerabilities of medicinal drugs and medical non-durables

Briston (1994, pp.125-134) gives an extensive list of the different forms of these products: solids, semi-solids, liquids and healthcare packaging, the materials used and the sorts of packaging. According to Briston, a great deal of the primary packaging used, in the nineteen nineties made from metal and glass such as aluminium tubes and glass bottles, have since been replaced by plastic. The expectation is that this substitution will continue. The primary packaging is usually packed inside a folding box which also contains the instructions for use.

Sources that deal specifically with the packaging of pharmaceuticals are Dean (1983 and 1990) and Briston (1994).

4.4.3 Non-food non-durables

The product group of non-food non-durables is also extensive. It is a product group that sometimes is named as fast-moving consumer goods and comprises cosmetic products, hygiene products, household chemicals (cleansing agents, detergents, solvents, pesticides), do-it-yourself (DIY) products (paint, wood, hardware, etc.), writing materials and office articles, hobby products (for drawing and painting, etc., haberdashery, etc.), flowers and plants.

The vulnerability of these products and product groups is very varied. Biological degradation can occur in moist products, including most detergents and in cosmetic products, or in products that become moist unintentionally, e.g. paper. In the case of products in which the growth of micro-organisms can occur, a preservative can be used or the pH-grade of the product can be optimized. Chemical processes such as oxidation can, for instance, occur in hardware, but in practice this form of quality deterioration is uncommon. There are several physical processes that can occur:

- the absorption or the giving off of moisture by hygroscopic, dry or moist products;
- the evaporation of volatile substances from solvents, for instance, in paints and adhesives;

- discoloration caused by UV light, as occurs in the case of paper, wood and certain colouring agents.

Chemical processes that can occur are oxidation, and rusting of metals.

Mechanical influences can also damage products in this product group: due to acceleration, bumping, collision, vibration or contact with sharp objects, etc.

Packages under pressure are a separate category. These include aerosols and gas containers. Special regulations are in force for these products because of the risk and danger of explosion.

Next to vegetables and fruit, a very specific product category is formed by flowers and plants (whether edible or not). Further growth and/or ripening must either be allowed to continue or be slowed down, during transport and storage and at the point of sale. This implies the presence of adequate quantities of water and that the ambient conditions, such as amount of carbon dioxide, oxygen and temperature, must be optimum. Flowers and plants are easily damaged by mechanical load: sprigs and flowers can easily break off, and leaves can become damaged. One source that deals with the packaging of cut flowers and plants is UNCTAD (1993).

In table 4.3 an overview of this category is presented.

Non-foods non-durables			
Sort of vulnerability	**Hazardous component + examples**	**Essential to maintain quality**	**Remarks**
micro-organisms	cleansing agents, detergents and personal care articles, etc.	addition of preservatives to the product, pH grade of the product	is of little or no relevance for the packaging, but must be given attention regarding cosmetic products, etc.
oxidizing	iron: rusting, partly as a result of moisture, aluminium oxide film	barrier against humidity and/or oxygen	dependent upon ambient conditions
products containing volatile substances	evaporation of volatile substances (paints, adhesives, etc.)	barrier against volatile substances	also a safety issue but application of hydrocarbons is decreasing
hazardous substances	protect the surroundings from substances: various chemicals	keep the substances contained at all times, provide a barrier	legislation is important
flowers and plants	optimum conditions for the ripening or growth, or conversely, deceleration of ripening or growth: carbon dioxide, oxygen and moisture barriers; withstand mechanical load	mechanical buffers and barriers against oxygen, carbon dioxide and moisture, or conversely, to allow these gasses to pass through	depending on the requirements; either allow the flowers and plants to ripen or decelerate their growth
general / miscellaneous	mechanical load, discoloration due to UV light, scratching, bumping, etc.,	provide a variety of buffers and barriers	products such as stationery, hobby articles, etc., may not become damaged and/or discoloured

Table 4.3 An indication of vulnerabilities of non-food non-durable products

4.4.4 Durables

Durables are products which are only purchased once in a while and generally have a long life. They are usually bought after a conscious choice has been made. Examples are white goods, e.g. washing machines, refrigerators, microwave ovens, etc., brown goods, e.g. stereo equipment such as amplifiers, tuners, CD players, speakers, etc., electronic equipment, computer equipment, photographic equipment, furniture, etc. The main vulnerabilities of durables are mechanical: shocks, bumps, vibrations and contact with sharp objects, etc.

A great deal of today's equipment also contains electronic components which are sensitive to weak electrical impulses. These can become charged with static electricity, such as caused by many synthetic materials. Equipment such as switch boxes for tele-

phone installations and components for computers, such as hard disks and plug-in cards with electronic circuits, are always packed in anti-static packaging.

Moisture can be a problem for electronic products as it can result in the oxidation of electrical contacts. It is therefore essential that these products are protected from becoming moist. Plastic bags are usually used which also protect these goods from dust.

Also extremely specific requirements may be in place for the packaging of durable goods. For instance, some televisions may not be placed in their packaging with the heavy cathode-ray-tube facing downwards (Heesemans, 1995). And yet packing them in this way would be advantageous in terms of storage stability, given that in conventional packaging the CRT places the mass centroid at the front. If the CRT is placed facing downwards, any dust that might be present in the interior of the tube could descend onto the luminescent surface and, when used, cause the tube to malfunction (Heesemans, 1995).

To calculate shock loads, mainly as a result of falling, use is generally made of the slowing down effect of the product as it falls. One of the requirements, for example, for a television is that it can undergo a maximum G force of 30 G (9.8 m/s^2). Standard tests carried out on packaged products involve dropping the packaging onto its base and onto one of the packaging corners. The height of falling is generally based on the practical situation, for instance, table height and height of a lorry loading platform: 75cm or 1 m. The packaging must be able to absorb the energy from the fall and preferably reduce it linearly and slowly to zero. In practice there is no buffer material or buffer construction used in the packaging world which is able to absorb the energy linearly. The degree and way of energy absorption of the properties of most buffer materials are known and can be found in literature or in documentation of producers.

Another form of load is from vibration. During transport it is always possible that the product or packaging may be subjected to a vibration which is the same as its own frequency (in practice this is between 1 and 300 Hz). This can result in the product vibrating to such an extent that it becomes damaged (Chapter 1 gives an example of an Océ photocopier). This is taken into account when calculating the required buffer material. Other aspects that play a role in determining the most appropriate buffer are the extent of impress in the buffer under static load, the creep of plastic, if subjected to long-term storage and the stability of the packed product (if the product rests on too much buffer material it becomes unstable). A step-by-step plan for determining buffers is given in Appendix B.

In table 4.4 an indication of the vulnerabilities of durables is presented.

Durables			
Sort of vulnerability	**Hazardous component; common requirements**	**Essential to maintain quality**	**Remarks**
white goods (refrigerators, washing machines, etc.)	exterior damage, loss or breakage of components; dirt and dust in general	buffers to absorb the energy and to offer protection from sharp objects	many sizeable packages, difficult to handle, are delivered by or at the assignment of the seller; smaller products are packed and taken away by the consumer
brown goods and electronic equipment (stereo and hi-fi equipment, televisions, printers and office equipment such as computers and photocopiers, etc.)	loosening of soldered connections, CRT breakage, damage to printed circuits, glass sheeting, etc.; dirt and dust in general	buffers to absorb the energy, prevention of critical frequencies of the goods, protection from sharp objects	vulnerable components and housing, usually taken away from the point of sale; vibrations can be more hazardous than shocks
domestic and office furniture	exterior damage, breakage, dirt and dust in general	buffers to absorb the energy and to offer protection from sharp objects	these are generally sizeable and difficult to handle, as a whole they are vulnerable; usually delivered at place of use; sometimes in parts as knock down systems

Table 4.4 Indication of vulnerabilities of durables

Common Remarks

The amount of material required can be calculated on the basis of formulas, material data, and by using tables. Models must be made in order to make the proper calculations for springy and elastic constructions.

Specially equipped laboratories are frequently used for carrying out tests to establish the different loads at various locations on the packaging. The first publications on the engineering of packaging were issued many years ago, the publications mentioned in Chapter 1 (Hanes, 1990, Hanlon, 1992 for instance). Tests can be carried out in the Netherlands by several laboratories (TNO in Delft, Topa in Voorhout).

4.4.5 Industrial packaging, bulk goods

Many products, mainly raw materials, are packaged in bulk. Often-used types of packaging for this sector are barrels, kegs, Intermediate Bulk Containers (IBC), big-bags, Octabins, Squarebins, a variety of stackable containers, sacks, etc.

The raw materials range from extremely sensitive products of a biological origin to virtually invulnerable products. Generally speaking, all these products can be packed in bulk packaging. If a high-quality barrier is called for, then this can be added separately; this is usually referred to as a liner. For instance, paper bags are often fitted with a plastic inner bag to form a barrier against moisture. Metal open-headed drums are in some cases also fitted with liners because this facilitates reuse. These need not then be cleaned after emptying.

Liners are also used in pallet boxes, octabins, squarebins, etc. The connection between the liner and the packaging closure, the adequacy of sealing, and still making it possible to open the package, are problems which are usually difficult to solve for such applications.

Emptying industrial packagings is often done with specific equipment which can set requirements to the packaging. Filling industrial packagings is in many cases done by hand. Equipment and machinery can have the same vulnerabilities as the durables mentioned.

An overview of the vulnerabilities of industrial and bulk goods is presented in table 4.5.

Industrial and bulk goods			
Sort of vulnerability	Hazardous component + examples	Essential to maintain quality	Remarks
amorphous or separately poured products: a group of widely varying products	dependent upon the product, are generally unpacked or emptied by machine	any of the aspects mentioned in table 4.1, 4.2, 4.3 and 4.4	can generally be solved by using liners or making special constructions; often emptied by specific equipment
equipment and machinery (see also durables)	bumping, shocks, vibration, sharp objects	buffers to absorb the energy, to prevent critical frequencies and to offer protection from sharp objects	generally sizeable and difficult to handle, as a whole vulnerable; often packed by hand

Table 4.5 An indication of vulnerabilities of industrial and bulk goods

4.5 Packaging materials

Numerous interactions occur between product, package and the surroundings, many of which are at molecular level. For example, permeability and migration are processes which cannot be seen without special aids. These, however, are far beyond the goal of this study and there are many sources in literature which deal with materials, like IdeMaT, (Remmerswaal, 1999; a database of materials including environmental data), publications from UNCTAD about packaging, Robertson (1998) about food packaging, etc. A lot of facts about packaging materials can be found in publications from institutes like Packforsk (Kista-Stockholm, Sweden; www.packforsk.se) or PIRA (Surrey, Great Britain; www.pira.co.uk).

In literature the packaging materials are often divided into categories based on the nature of the molecules and the molecular structure. A division often used is: wood, paper and paperboard, metals, glass, plastics, laminates (sometimes belonging to plastics) and others such as biodegradable and natural materials.

Table 4.6 presents an estimate of the division of the turnover of the packaging materials over the world.

Material	Turnover (in G€)	Percentage
Paper, cardboard, corrugated	144	34%
Metal	108	25%
Plastic	126	29%
Glass	27	6%
Others	23	5%
Total	428	100%

Table 4.6 Turnover of packaging materials over the world in billion euro (source: World Packaging Organisation, 1996)

4.5.1 Choice of material

In figure 4.2 a possible way for chosing an adequate packaging material is presented.

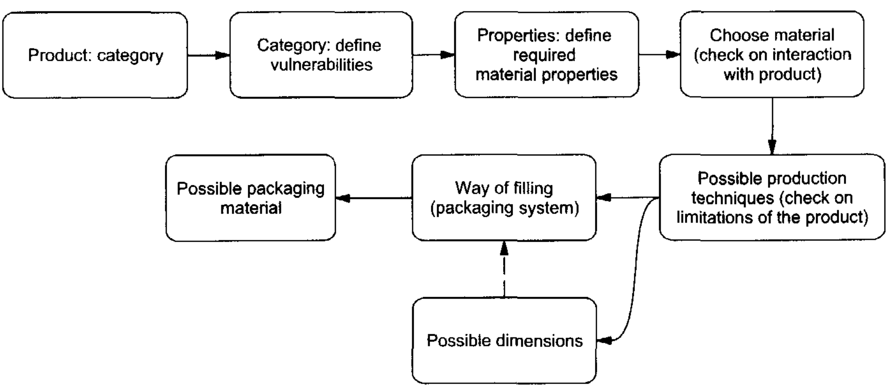

Figure 4.2 A schedule on how to choose a packaging material

In section 4.4 indications of the vulnerabilities were presented. With this in mind requirements can be formulated and a material can be chosen. Materials go together with possible production techniques, possible dimensions and a way of filling (closing, preserving, etc.).

This leads to an overview of material properties as presented in table 4.7 (see next two pages), and which can be used for first choices of adequate packaging material.

Material	Characteristics	Possible functions	Weaknesses	Design	Application	Remarks
Wood	anisotropic, (properties are influenced by structural orientation), fibres and annual rings	structural material for keeping together and giving support; gives off flavour; preserving; UV barrier; to optimize internal climate	moderate gas barrier, moisture absorption, fungal growth, discoloration by UV-light	from unmachined and not dried to high-quality machined, glued, constructed, etc., chipwood, plywood, medium densified fibrewood	pallets, boxes, crates for transport, small boxes, kegs for storage, barrels, die-casting applications	macro-biologically not clean, recyclable for applications in chip board, etc., relatively low energy contents
Paper and paperboard, cardboard, corrugated	small cellulose fibre with a variety of substances including chemicals, possibly direction-dependent	keeping together, shaping, making stackable, high quality presentation by printing, optimization of use, UV barrier	poor gas barrier, moisture absorption irreversibly changes the properties	paper, folding cardboard, solid cardboard, corrugated cardboard, numerous structures possible	labels, instructions for use, small folding boxes, boxes, trays, bags, sacks, etc., drums, rigid cilindrical packagings	recyclable, but not infinitely; numerous variations with wide tolerances in material specifications, moderate energy contents
Metals	accumulation of atoms, very compact, elec tricity conductor, shiny, shaping while maintaining strength	barrier against gasses, moisture and UV, electricity conductor, strong and unbreakable, lightweight (aluminium), heat reflecting	oxidation, rusting of steel, oxide emissions from aluminium, dissolves in an acidic environment	rolling, folding, welding, etc., majority on the basis of a cylindrical shape, shaped cans and honeycomb, aluminium foils as UV-light and gas barrier, deadfold properties, alum inium evaporation on a base (usually plastic)	steel cans, barrels, kegs, aluminium cans, aluminium lids, numerous sorts and types of closures, small boxes, aerosols, aluminium foil	easy to recycle and sterilize, can be constructed to withstand high pressure
Glass	amorphous mass, super-cooled liquid, transparent, colour determined by the sort of metal oxides	barrier against gasses, UV-light barrier depending on the colour of the glass and spectrum, virtually inert, transparent	breakable, relatively heavy	mainly blown, hollow packaging, tubular extrusion and final processing	bottles, jars, ampoules	easy to recycle, colour is a limiting factor, relatively low energy content

Material	Characteristics	Possible functions	Weaknesses	Design	Application	Remarks
Plastics	macro-molecules, from flexible to rigid, amorphous and crystalline, transparent and opaque, permeable for gasses, moisture, aromas, etc.	a barrier against unwelcome influences, UV- barrier by additives or colouring, gas barriers dependent on choice of material and can be used to optimize interior composition of gasses, sealing medium, combines well for flexible applications	variants, permeability to gasses, moisture, flavours and fragrances, relatively low resistance to high temperature, recycling thanks to the many variants, can dissolve involatile substances	can be processed by using a multitude of techniques; as a base for evaporated aluminium	films, foils, semi-rigid packages such as bottles, flacons, tubs, etc., and rigid applications such as crates, trays and pallets; complex shapes for caps, closures, small pumps, etc.	very innovative material group, as a mono-material easy to recycle for high-grade applications, relatively high energy contents
Laminates and composites	a combination of properties of different materials	combinations of functions such as rigidity, sealing, barriers against gasses, moisture and UV-light, protection of aluminium	no mono-material, difficult to recycle or to find markets for the recycled material	laminates: flexible materials which in many cases can be folded into packages on packing machines; composites: random or regularly ordered mixtures of different materials	flexible materials with specific properties	laminates counterbalance in many cases mono-materials with the same functionalities in terms of environmental impact and cost
Bioplastics	degradable under normal or specific conditions	for (potential) disposable use	in many cases not resistant to moisture, moderate barriers against moisture and gasses	films, foils, thermo-casting applications and injection-moulded products, foaming	beakers, films, foils, cups, trays, foam parts	this is a material field in development, position is as yet unclear

Table 4.7 An indication of material properties and some related aspects for packaging designer

Plastics form a category of materials with many differences in quality, appearance, possibilities to process and convert the material, price, etc. Producers of plastics can provide datasheets with most of the wanted information. Many literature sources deal with plastics and information about prices of the raw materials too can be found on the internet. Differences in permeability of different plastics can be more than a factor 1000. This means that the amount of gasses, moisture, flavours or fragrances that diffundate through a film can be a thousand times smaller or greater in another material. Because of such differences special attention should be paid to the choice of plastic or combination of plastics. Plastics are often combined in laminates with other plastics, with paper or with aluminium foil to create a material with optimal properties. Coatings are also used to optimize the properties.

Another usually relevant aspect is the choice of printing technique. Not all wanted print qualities can be realised on every packaging material or packaging dimension. In figure 4.3 a possible schedule on how to choose a printing technique is presented.

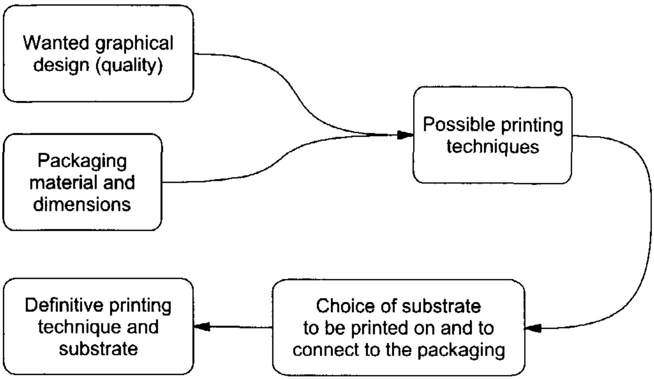

Figure 4.3 A way to choose a printing technique

If in a design project the quality of the printed information is important, attention must be paid to this in an early stage.

Attaching labels, glueing and sealing are processes which are complex because of the number of variables involved. Special attention must be paid to this before the choice of materials is made. The speed of filling can be a limitation, because this also limits the time for adhesion or cohesion of the materials.

4.6 Packaging dimensions

Below a schedule is presented on how to choose the dimensions and the load of the transport packaging and, consequentially, the dimensions of the primary packaging.

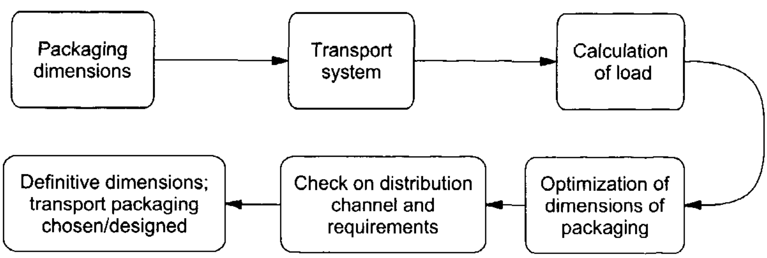

Figure 4.4 A possible way to choose the transport packaging and dimensions of primary and secundary (and tertiary) packaging

The dimensions of packaging, in terms of absolute quantity of packaged product, the packaging shape and the relative proportions, can have substantial influence on the shelf life of the product inside and on the amount of material used.

Absolute packed quantity

In general, the more goods packed, the less material required per unit of product. Increasing the quantity results in a raise in content by the third power, the surface raises roughly by the second power (squared). This is highly significant for a product's shelf life regarding packaging materials through which gasses can diffuse. This must be taken into account when optimizing the amount of packaging material used per unit of product. Plato product consultants and Pré showed that many packages could theoretically be re-engineered with less material (Plato product consultants, 1994) by using this approach.

This rule, however, only applies in general. For a flat package, a fillet of salmon for instance, the shelf life will not be improved if the package remains equally as flat but is made larger. The contact surface per unit of product will then remain virtually the same.

When calculating the amount of packaging material per unit of product, any essential structural solution incorporated in the package, such as sealing edges, closure rims, closure flanges, ribs, etc., must be taken into account. These structural parts tend to be essential for the actual functioning of the packaging, and cannot be omitted. For smaller packages these parts have an even greater effect on the amount of material per unit of product than larger packages, the width of the seal, for instance, depends on the required quality of the closure and on practical grounds such as the presence of certain seal cutters.

To find the optimum amount of food for packing, it is important to be aware of the demographic composition of the population, plus the eating habits of that population (Kooijman, 1995). In order to limit the amount of waste produced at the end of the chain, the amount of packaged product must be in line with the amount consumed per unit of time. In practice this means that for many products different sized packages in terms of content must be marketed, in order to achieve the optimum situation in terms of the environment and efficiency of use.

The shape

Based on the aim to achieve the least possible material per unit of packed product, a sphere offers the most advantageous ratios in terms of surface to content. For block-shaped packages this is a cube and a long, thin, flat package is not beneficial in this respect. Conversely, spherical or round packages mean wastage of space during storage and transport. An intermediate solution, for instance, is to use the so-called Cirkant shape, some intermediate between circular and rectangular form of section, that was developed for yoghurt packages by Veglaplast and TNO Product Centre.

Relationship between the different dimensions
If the shape of a package is more or less determined, it is possible to establish the optimal dimensions. The structural components of the package are rather important in this respect. For instance, for coffee a cube shape would seem in the first instance more favourable than the current oblong shape. However, this only applies if the seals are not taken into consideration. The current construction is based on seals on the side, the top and the bottom of the packaging. The machines have been adjusted or engineered to make this construction. To optimize the amount of material, a working drawing must first be made of the construction required. This drawing can then be divided into the dimensions that determine the volume (the parts that determine the width, depth and height) and the seals. The optimum can be found by making a systematic calculation, working on the basis of the volume required. For the coffee pack, the vacuum-shaped block (the currently used oblong shape) in the dimensions used, is the optimum solution in terms of the amount of material. The same applies, for instance, for the 'tetrabrick', hence the reason why this pack does not fit in with the packaging module system. It is also a matter of which carries the most weight: the cost of the filler or the cost of the distribution chain; in some cases the cost incurred by using more material can be higher than the amount saved by a larger loading area. It should be mentioned that the facing surface on the shelve improves merchandising. Working in this way makes it possible to determine the best possible dimensions for any shape by making a working drawing of different shapes. Computer software is available to this end. In combination with pallet loading programs, chain optimization can also be determined.

4.7 Legislation

Legislation governing packaging is incorporated in several different laws. There is no specific law that contains all packaging requirements. Below is a short overview of various facets and laws in force around 2000 on, or may apply to, packaging. This differs from country to country. Legislation is being worked on in Europe which will be identical for all Member States of the EU in the future.

There are different reasons for this legislation; these are set out first of all. Functional applications, such as transport and pressurized packages are then dealt with.

- Public health
  - Toxic substances or substances that are hazardous to health:
    Packaging materials may contain only a very small amount of certain heavy metals. Foods are not allowed to come into contact with any of a very large number of materials because of the possibility that hazardous particles or elements might migrate to the food inside. Lists of materials that may be used are available. The trend is towards more functional regulations; i.e. that the producer himself must determine how hazardous the materials he has chosen are, but that – should any problems arise – he still carries the liability.
  - The human aspect:

Heavy loads and conditions under which people are required to work. This is an important factor regarding the transfer of packages. A package may not exceed a certain weight depending on the lifting frequency and the physical movement and forces involved.

- Safety and hygiene
  - Products may not cause damage to users or others:
    Migration has already been mentioned, other aspects concerning safety, such as injuries that can occur if a package does not meet the regulations. For instance, the wall thickness of aerosol cans is governed by law, as also are the tests that must be carried out.
  - Extensive regulations are in place for medicinal drugs as to what information must be furnished along with the product, how documents must be dealt with when packaging and labelling the product, the mandatory instructions for use, data that must be included, how the product must be delivered.
  - Child-safe closures are obligatory for products that may cause a threat to the health of minors such as hazardous substances, various cleansing agents and medicinal drugs.
- Information
  - Guidance to provide information in a right way:
    A package must include certain information such as amount or quantity, the name of the product (see below), the use-by-date if applicable, an address that users can contact, information as to whether the package is or is not suitable for food depending on the sort of product.
  - If information is given about nutritional value, legislation is in force that aims to standardize the information methods used. A specific format is advised.
- Fair trading
  - The obligation to provide information:
    The package must clearly state its contents. Generic names are mandatory. If the generic names are not known then the contents must be described. The description may on no account cause confusion.
  - How information must be presented:
    Certain information must be provided in a certain legible way. Depending on the product's shelf life, the user must (or may) be informed of the use-by-date in a certain way. For short periods the day, month and year must be specified; longer periods can suffice with only the month and year; and even longer periods need only make reference to the year (use before end of [year]).
- The environment
  - Packaging waste:
    Packaging waste is covered by extensive European legislation; this is dealt with separately in section 4.7.2.
  - Packaging design:
    Qualitative guidelines are set out regarding packaging design in various laws in the field of packaging and packaging waste.
  - Pollution prevention:
    European legislation decrees that preventive procedures must be followed, that

the efforts made in this respect must be demonstrated, and the results must also lead to a decrease of the total packaging waste.
- Identification and the use of marks:
  If the packaging includes a reference to the sort of packaging material, then it must be in accordance with certain standards; the same applies with regard to recycling symbols.
- The Dutch Covenant:
  This will be dealt with separately in sections 4.6.1 and 4.6.3.

• Drugs
  - Legislation in the field of medicinal drugs is much stricter than for foods and is usually contained in separate laws or directives. The industry in this sector produces for different countries and therefore will work according to the most strict rules mainly (in practice Germany or Switzerland).

• Transport
  - Dangerous goods:
    Codes must be printed on the packaging to indicate the presence of hazardous substances; the nature of the hazard (combustible, toxic, corrosive, etc.).
  - Directives apply for the transport of hazardous substances over land, sea and by air.
  - There are certain provisions relating to the trans-national transport of perishable goods in connection with conditioned transport.

• Pressurized packaging
  - Aerosols:
    Aerosol cans must comply with mandatory specifications.
    There is also an aerosol decree to prevent that the safety of those persons handling such packaging is at risk. The reduction of chlorofluorocarbons (CFCs) is regulated in the Decree on Chlorofluorocarbons in the Treaty of Montreal (1987).
  - Pressurized packaging:
    Specific regulations apply to pressurized packaging.

• Pesticides
  - Pesticides may only be sold in packages.
  - Information that the product has been authorized for use must be printed on the package in conformity with the relevant regulations.
  - Instructions are also in force regarding how and what information must be furnished.

• Other environmentally hazardous substances
  - There are several provisions relating to the packaging of environmentally hazardous substances and the presence of hazardous substances in packaging materials.
  - Decrees regarding packaging methods and how the user is informed as to the environmentally hazardous contents.
  - Cadmium decree: cadmium is used in pigments as a stabilizer in surface layers and may only be used if absolutely essential. Crates for beer and soft drinks are excepted (these were already marketed or were to be brought onto the mar-

ket within the foreseeable future), because these are covered by the so-called Cadmium Covenant (in the Netherlands).

- Protection of Models (Benelux Designs and Models Law)
  A design shape can be protected, or, if of aesthetic value, is protected automatically.
- Registered trademark
  The brand name of a product and the packaging can be protected.
- Product liability
  A producer is liable for all damages that occur as a result of imputable faults. All claims lodged with the producer are assignable to the suppliers. The vendor can also be held liable but he is able to transfer the claim.

4.7.1 The Dutch covenant

Since the early nineteen nineties legislation has imposed many restrictions on the use of packaging materials, yet regulations imposed by the branch itself were responsible for even more. In the Netherlands about 200 companies, represented by *Stichting Verpakking en Milieu* [Foundation Packaging and Environment], signed a covenant in 1991 which set out qualitative and quantitative goals.

The covenant is simply an agreement and thus the penalties involved were not specified. Consequently, most firms left their packaging unchanged because of the covenant. Partly because a new situation arose after 1994 (this is explained in section 4.7.3), only a few of the points covered in the covenant will be dealt with within the framework of this study.

1. A limitation is set of the amount of packaging that can be brought onto the market in relation to the base year, 1986.
2. Requirements were made regarding the division of the total amount of packaging over the different end-destinations: reuse, incineration or dumping.
3. The obligation to carry out extensive life cycle analyses on different kinds of packaging for the same product was included. If an analysis shows that a returnable packaging is better for the environment than a non-returnable alternative, then trade and industry are under the obligation to include the returnable packaging in the packaging assortment. Milk was one of the products that was subjected to a life cycle analysis. A comparison was made between milk packed in non-returnable folding cartons, in returnable glass bottles and in returnable plastic bottles. The consequence was that all dairy producers now include returnable plastic bottles – which obtained a more favourable score – in their assortment. The distribution channel is not very happy with reusable packaging since it calls for extra space, areas in which to sort and clean the packaging, extra transportation and storage capacity, and substantial work (costs) and logistics are needed. Nevertheless, as was agreed in the covenant, the distribution channel was forced to cooperate in making this change.

As mentioned in Chapter 1, *Stichting Verpakking en Milieu* anually publishes a booklet that contains examples of successful changes made by the association members. It is apparent from many examples that simple solutions were chosen, such as a change in packaging dimensions focusing on the product itself (it would seem from the examples that these were already planned), eliminating superfluous films, and other obvious solutions.

This covenant was overruled by European legislation on packaging and packaging waste in 1994. The Packaging Covenant was subsequently named *Covenant I*, indicating that the Dutch Government had chosen to incorporate the new legislation in a covenant which, logically, was named *Covenant II*.

4.7.2 European legislation on packaging and packaging waste

In 1994 the European Union obliged the Member States to develop national measures concerning the management of packaging and packaging waste, in order to harmonize the existing legislation/regulations. On the one hand the purpose of this was to prevent or reduce any impact thereof on the environment, and thus achieve a high level of environmental protection and, on the other hand, to ensure the functioning of the internal market and to avoid obstacles in the way of trade and the distortion and restriction of competition within the Community (EC Directive 94/62/EC of the European Parliament and the Council on Packaging and Packaging Waste).

The directive covers all packaging brought onto the market in the Community and all packaging waste, whether used or released at industrial, commercial, office, shop, service, household or any other level, and regardless of the material used. For the definition of packaging of the EC, see Chapter 1.

Prevention, re-use, recovering and recycling are the most important and far-reaching subjects on which measures have to be taken by the Member States. Other measures concern:

- marking and identification of materials; concerning the package;
- standardization of criteria; to be promoted by the Council;
- prevention reduction of heavy metals present in packaging;
- information systems; concerning packaging and packaging waste;
- information for users of packaging; in relation to the measures;
- specific measures on management plans, economic instruments, notification, etc."

The first requirement in the directive is the most important one for designers:

"Packaging shall be so manufactured that the packaging volume and weight be limited to the minimum adequate amount to maintain the necessary level of safety, hygiene and acceptance for the packed product and for the consumer."

Each Member State must observe the Packaging Waste Directive. If a Member State had already set up a system to reduce the environmental load down to a minimum, it is given the opportunity to incorporate the rules of the Directive into its existing system. Thus each Member State integrates the rules in its own way. The Netherlands

Packaging Centre (NVC, 1997b) of Gouda published an overview of all the legislation in force in the Member States in June 1997 and updates this list frequently.

There is an obligation to ensure that the amount of heavy metals does not surpass a specified standard. In the so called essential requirements obligation are formulated which count for every individual packaging which is brought into the market.These are:

1. the obligation to work on reducing the amount of packaging material,
2. if reusable packaging is chosen, then certain rules must be followed,
3. a choice must also be made from:
   4. material reuse,
   5. energy recovery,
   6. biologically degradable material.
7. the presence of heavy metals

If a packer decides to indicate the sort of material on the packaging itself, then this must be done in an established fashion.

The EC has laid down regulations for the governments of the Member States as to the amount of packaging material that must be recovered and the amount that must be able to be recycled.The percentages fixed for the government do not therefore apply to individual companies.

4.7.3 The Dutch Directive on Packaging and Packaging Waste

Because the Member States must ensure that laws, regulations and administrative provisions comply with the Directive, the Dutch Government developed the "Dutch Directive Packaging and Packaging Waste' (NVC, 1997a; VROM, 1996).

The Council's targets have been changed slightly and no ranges are specified:

- recovery: 65% of the total weight;
- recycling: 45% of the total weight;
- a minimum of 15% recycling for each material.

Three options were proposed for the execution of the EC Directive in 1996:

- By way of a covenant (Covenant II)
  Collective actions to meet the obligations – individual obligations are revoked but this does not count for the essential requirements; all parties in the chain, including the suppliers of raw material, packers, re-users, local councils, etc., may be involved. The Dutch Ministry of Environmental Affairs insists on the forming of so-called clusters of companies which means that the Ministry can communicate with about 200 parties of 'allied firms' instead of with more than 325,000 companies individually. When a company joins a cluster, its individual obligations are no longer valid but this does not count for the essential requirements.
- By way of individual obligations.
  In this case, each company is obliged to reach the targets individually.

- By way of collective manufacturer and importer announcements.
  Allied manufacturers and/or importers can join forces to reach the set targets.

The Dutch Government has thus translated the EC legislation into Dutch legislation in such a way that the majority of companies participates in a covenant.

The targets set by the Dutch Government are higher than those specified by the EC. In fact, for some of the package materials these targets had already been reached before the publication of this directive, thanks to collection systems that work quite well. Although the quality of the materials to be recycled is not always as high as wanted.

Because the Covenant of 1991 resulted in an increase in virgin materials used in packaging, the Ministry of Environmental Affairs proposed higher targets. A target percentage has been set for all packaging materials.

The Dutch Government had the opinion to continue the existing situation (Covenant I) regarding waste management to ensure a smooth introduction of the directive (Covenant II). The councils that already played a role in the collection of paper in many cases, have been made responsible for the collection of paper and glass according to Covenant II. Incinerators have the duty to gather the metals from the waste and companies have to gather plastics and wood.

This means that a large part of the collection system would remain as it was. The consumer will hardly notice the difference and the recycling percentage will stay high.

The target percentages of Covenant II and the already reached percentages of recycling are given in table 4.8.

Materials	Recycling percentage in 1996	Target percentage for 2001	Percentage as realised in 1999
Glass	72	90	91
Paper and cardboard	50	85	70
Plastics	10	35 (27)*	17
Metals	52	80	77
Wood	—	15	24

The total target for plastics is 35, including 8% coming from households.

Table 4.8 Recycling goals as set in Covenant II and situation in 1999

The Packaging Committee evaluates the Covenant II yearly and publishes a report about it (SVM-Pact, 2000). In the 2000 report the Committee expresses its confidence that the activities and measures as proposed will stimulate the participants and other relevant parties in the packaging chain to more prevention and recycling of packagings and the Committee believes that the objectives are within reach (p15).

The Minister of Environmental Affairs has doubts about covenants (in 2000) as was stated in his National Environmental Program (NMP 4). Covenants tend to be without sufficient engagement, it said. For instance the problem of the so called 'free-riders', i.e. companies who sign up the agreement but don't undertake any action and the problem of remaining litter all over the country.

4.7.4 The German *Verpackungsverordnung*

Germany also has an interesting history in terms of how the nation deals with its packaging waste; reason to take a brief look at the situation there, particularly given Germany's industrial strength in Europe.

In Germany, the *Verpackungsverordnung* placed the responsibility for the total package with the packer in 1992. The packer, the company that packs the product, is deemed to be the party that introduces the product to the market. A packer is responsible for taking care of the package after it has fulfilled its functions, and he is obliged to ensure the reuse of the packaging or packaging material. The packer is not obliged to see to this himself but may contract a third party: *Duales System Deutschland* (DSD). This is an organization which started at the same time with the goal of collecting packaging materials and delivering them to recycling companies. Agreements had to be made with DSD and the recycling companies. A company that enters into an agreement with DSD is allowed to use the specially designed green dot ('Grüne Punkt') on its packaging and thus inform the user that the packaging must be kept apart from the normal waste collection system (i.e. A dual system).

Depending on the packaging material concerned, DSD charges a fee for making the collections and deliveries. A fixed price is charged according to weight, volume or quantity for all the different materials. The prices are determined on the basis of the material's recyclability. This means that the fee charged does not reflect the real amount the packaging material is worth in terms of its functionality and contribution to the environmental problems. Recycled plastics are restricted to be used for the primary packaging of food, and this system will therefore never ensure a closed material cycle. Also, the waste generated by faulty packaging or from insufficient or incomplete products is not taken into account. Some materials are more difficult to recycle than others because of the number of varieties in which they are used. Paper can always be brought back to the starting point: cellulose fibre. This is impossible with regard to plastics. In many cases plastics cannot be replaced by other materials without using more material and energy, and causing more environmental harm. Therefore the DSD system is not based on the environmental harm that is caused, but only on reducing the amount of waste.

Most other European countries also have legislation in force that governs packaging waste. Some of those countries have a system which more or less resembles the German one, using the green dot, others have a system which more or less resembles the Dutch one (like Norway). Such systems have generally been adapted to meet the existing local situation.

In conclusion, legislation in the EC in the field of packaging and packaging waste has been drawn up for the purpose of harmonizing the various national regulations. Considering the differences in approach and rules in the different nations, and also considering the fact that in the one country payment is due on packaging material brought onto the market and not in another, the aim of harmonization has not completely been achieved. What *has* been achieved is that packaging and packaging waste have been placed on the agenda in each country and that, as a result, efforts are being made to reduce the amount of packaging material.

Chapter 1 showed the relation between the product and its packaging. If, for instance, a television set is more vulnerable because less material is used, then more packaging material is required. This can imply that a lower amount of a more environmentally hazardous material is 'exchanged' for a less environmentally hazardous material. Although such an approach would be better, it would make legislation on packaging dependent on the product group. For instance, attention could be focused in the case of televisions on packaging that falls within the scope of the 'return packaging' ruling.

This shows that the current packaging legislation in the field of the environment – which focuses mainly on weight – is incompatible with the approach taken by packaging experts (to bring the product and the packaging into line) and does not always benefit the environment.

The general vulnerabilities of products have now been discussed, an overview was attempted of packaging materials with an indication of their properties, the importance of packaging dimensions has been explained and the general outline of current legislation has been presented. The overviews thus made can support packaging designers in the design process. It is obvious that product and package are strongly related to each other and design of packaging requires much and divers knowledge. Therefore research question A has been answered only partly, because the way the tools can be used in the design process has not been presented yet. The next chapter will deal with the process in which this knowledge can be used: the packaging design process.

5 A method of approach to show how packaging designers work

Summary

According to some psychologists an analyst is only able to follow the thinking process of a problem solver if the analyst himself has already solved the problem. Using this as the basis, a method of approach will be developed which is able to show how packaging designers set to work in practice. The method should yield a great deal of information in a short time, to answer research question A.2: What method or methods are currently used in (three-dimensional) packaging design and what can be learned from this? A design method was developed on the basis of the analysis given in Chapter 2, of the description of functions in Chapter 3 and of the possible tools as presented in Chapter 4. Descriptions of two other design methods were also used to set up an appropriate method between rational problem solving and reflective practice.

5.1 Introduction

This chapter looks for a method of approach which can show how packaging designers work in practice and whether they implicity use a design method as suggested in research question A.2.

There are several practical objections to following people with practical skills in packaging when carrying out or being involved in design projects. There are also certain fundamental objections that can be made to fathom out the way designers think. Brugman and Dudink (1976) state that it is virtually impossible to analyse how a person has solved an existing gap between a 'fact' and a 'desired step'. They explain this by saying that it is impossible to say precisely how the problem has been solved: exactly which data has been used, and to what purpose. In the case of closed problems, the process is reasonably easy to follow, but the actual designing of a package is an open problem, and this makes it more difficult to follow the thought process. An additional aspect is that a designer tends to think, as Bartlett (1964) puts it in an adventurous way. Brugman and Dudink (1976) claim that it is impossible for a mental psychologist to set out how a person solves an open problem without using any tools. A mental psychologist who has mastered (knows the way) the task (of solving) has, according to these two authors, a tool with which to judge others. They claim that if the problem is first mapped out by the mental psychologist himself, then he is better able to analyse the procedures followed by the subject. The tool is therefore the procedure monitored by the mental psychologist.

By analyzing thinking-aloud-protocols, the authors conclude that it is characteristic of the human thought process that not all options are taken into consideration (Brugman and Dudink, 1976). Humans work on the basis of heuristics; these are plans that restrict the search process. This, they claim, makes analyzing thought processes on the basis of a protocol analysis very difficult. The search is in fact for the heuristics used by packaging designers in practice. This assumes that, when solving an open problem, a designer follows a plan that restricts the search process. If packaging designers use a method, it will therefore be a reasonably well defined one.

The thinking aloud method, the protocol analysis, is an analysis method for the design process which has proved its merits in researching the nature of the activities of designers in the design process (Cross et al., 1996). Protocol analysis may yield proper data, despite the objections put forward by Brugman and Dudink. The advantage of this method is that it makes quantitative calculations possible and also facilitates examination in a reasonably objective manner. There are, however, four reasons for deciding not to carry out a protocol analysis. The first one is that experts frequently skip over steps in the thought process, because of their – what they feel is only obvious – routine character. The second is that a protocol analysis is able to demonstrate the nature of an activity, but it is far more difficult to demonstrate the functional background of a certain step or choice in the design process and thus of the sequence in which the actual decisions are made. This insight is made more complicated by the many iterations a designer tends to make in the design process. The interest is particularly in the functional background because it lays bare the actual method. The third reason is that only a limited number of projects can be carried out with a protocol analysis over a certain space of time and thus the amount of information obtained is also limited. The fourth reason is that a subject in a protocol analysis is not able to judge the way he/she works and in fact to evaluate one's own vision (reflection). Because the field of packaging is broad, and it is hard to recruit a group of subjects involved in packaging problems, another approach of data collection was advisable for our study.

At the beginning of the 20^{th} Century, Selz claimed that the 'schematic anticipation', as a line of action, precedes the solution. Newell and Simon (in Brugman and Dudink, 1976) claim that the person solving the problem constructs 'the information processing system' by making use of several sources of information. An interesting comment they put forwards is that during the problem-solving process, new ways of solving and different sequences can be constructed. A simple exercise, suggested by Brugman and Dudink for students to find the coherence of a piece of text, is to cut the text into separate parts and then assigning the students to place the parts in the correct order. When solving the problem the system of solving becomes clear, and the coherence of the text follows naturally.

On the basis of the foregoing the choice is made for a framework by which a thought process is literally mapped out. First of all, similar to Brugman and Dudink's mental psychologist, the thought process is mapped out by developing a feasible design method for packaging. This method is then written down on a set of cards, each of which indicates a step, being a decision or action, in the sequence of designing. Then these cards can be presented to a packaging designer, as a subject of an experiment. Each subject will then be asked to lay the cards out in the same order as they would follow in the design process. The assumption behind this method is that, as claimed by Newell and Simon, the sequence of these cards, as laid down by the subjects, reflects the processes followed for solving this problem. This method is used frequently, especially in educational studies such as De Jong and Ferguson-Hessler (1986) who used the method to map out and to make it clear to the participants how they themselves solve technical engineering problems. This method of individual sequencing of steps of a design process is a preferable alternative to observation and introspection of designers in practice, as objective interpretations of actions, little awareness of subjective criteria and decisions, the incomparability of individual wording, etc. hamper valid and reliable assesment.

Another reason for using these cards is that a great deal of information is obtained in a relatively short time.

The method of approach that is chosen, that of using a set of cards, makes statistical analysis possible and therefore increases the level of objectivity. The wording on the cards forces the participants to make choices regarding the priority of the decisions they are about to take. Subjects, however, should be allowed to reject steps (cards) or individually add new ones and to freely comment about the method in general and on the own methods followed.

In other words, a design method must first be developed for packaging which can be converted into separate steps on the basis of which people with skills in packaging will be able to indicate their own method and preferences. As became apparent from the analysis in Chapter 2, a design method for packaging must incorporate the following items:

- work must be carried out in accordance with a well-thought-out systematic way, preferably in accordance with a set of methods and techniques that constitute a method;
- the basic design cycle must be a recurrent theme;
- tools must be available, especially concerning knowledge in the field of packaging and the role of material properties;
- a system approach must be possible, and preferably used;
- it must be possible to draw up a hierarchical structure of the functions;
- it should allow the steering of design proposals on previously made choices; inclusive iterations;
- it must be possible to design the product and packaging in combination;
- the method should be a combination of rational problem solving and reflective practice.

Several tools were developed in Chapter 4. In order to work out a design method, a structure of the packaging functions must first be drawn up. This explains what the package will need to do; the enumeration of functions given in Chapter 3 can be used to do this. Subsequently, a systematic method can be set up for the purpose of detailing the design process in steps, in which the choices already made will steer the solution, probably a necessity to design within restrictions. Inclusion of the possibility to design the product and its packaging as a combination can thus be incorporated in the method.

To be able to detail the design process step by step, and to incorporate the option of designing the product and the packaging together, a search will need to be carried out in the literature of designing and design methods for simular methods of approach. These methods can then be used to describe a design method for packaging. Once this has been done, the design method can then be set out on cards. Besides literature, insights based on the examination of the MSc-reports of the DUT-IDE and based on own experience will be used too.

Section 5.2 sets out the structure of packaging functions. Section 5.3 presents a potential method for packaging design on the basis of two design methods. The specific activities that can apply to each stage of the design process are also pointed out. Finally, in section 5.4, a look is taken at the nature of the products to be packaged according to the categories given in Chapter 4. Section 5.4 also names those aspects of the design method which are very likely to be stressed.

5.2 Hierarchical representation of packaging functions

As stated in Chapter 1, a structure of interdependent packaging functions can provide a greater insight into functions and thus allow the design process to progress more efficiently and effectively. Pahl and Beitz (1988, p.33) say the following in this respect: *"The solution of a problem can be brought nearer by structure analysis, that is, the search for hierarchical structures of logical connections. In general, this type of analysis can be said to aim at the demonstration of similarities or repetitive features in different systems."*

A hierarchical representation of packaging functions is drawn up on the basis of the functionalities and functions set out in Chapter 3. The starting point in this respect is the three use functionalities of preserving, distributing and informing. The use functionalities are divided into main functions, sub-functions, functional aspects and packaging requirements.

Evidently, the basic elements taken from the definition of packaging, to keep together, to envelop, to contain and to protect, must be included in this representation. Where these basic elements should be positioned is debatable. In fact the basic elements should be dealt with first, and then the ensuing three use functionalities.

The basic elements are close to the use functionality of protecting/preserving. After the basic elements this is the first function that comes to mind for any packaging. And as was demonstrated in section 4.3.1, the aspect of protection is mentioned frequently in overviews as one of the main functions of packaging. The basic elements are often not even mentioned. It is apparently assumed implicity that they will be incorporated in the design. The use functionalities are elaborated upon by using the above framework as the starting point. Figure 5.1 shows the basic elements.

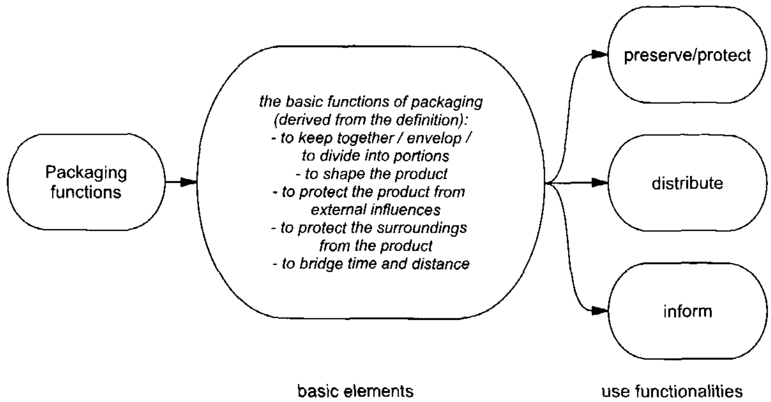

Figure 5.1 Basic structure of the functions of packaging

Basic elements

- There can only be talk of packaging if something is added to the product, if it bundles the product, envelops it, gives it shape, keeps out external influences that would be detrimental to the product or vice versa.

Use functionality of preserving/protecting

- User adjustment: the users must be able to use the product.
- Bridging (a certain) time.
  Offering protection against the effects of the following processes evolving in time: biological, biochemical, chemical, physical.
- Bridging distance.
  Offering protection against the effects of mechanical processes of and during transport etc.
- Possibly taking calamities into account. Events which are hard or impossible to forecast or which occur stochastically but when cannot be foreseen. A packer can make a choice on the basis of the risks involved, the potential damage that can arise, in the event of calamity and the extra costs involved: risk management. Extreme climatological circumstances can also be influential, infrequent bouts of extreme hot weather, frost or heavy rainfall, for instance, failure to protect against the immediate surroundings, such as the break down of equipment for refrigera-

tion or heating, humidity levels, measuring and recording equipment, plus aspects such as collision, rodents, insects and theft, etc.

As shown in Figure 5.2, the basic elements are included in the schematic representation of preserving. This was because of the large amount of overlap in functions arising from the basic elements and those arising from the use functionality of preserving.

The use functionality of distribution

- Making it possible to ensure that the product arrives at the required destination, preferably at a pre-determined time or within a certain period of time.
- The adjustment to the various users; especially the handling of products plays a role in distribution, the weight per item and per packaging, removing the product from the secondary packaging and placing it at the point of sale, etc.
- Distribution is subdivided according to the functions that arise from the logistics concept chosen: basic structure, control system, information system, organization. Particularly the basic structure determines the packaging's outward appearance. The control system has little influence on the outward appearance of the packaging. The information system determines the sort of information that must be included on the packaging. Organization, just like the control system, has little influence on the packaging's outward appearance.

Aspects of relevance when choosing the basic structure are: the distribution system and the means of distribution. These determine the dimensions and the weight for specific units such as container and pallet, i.e. the tertiary packaging. They are the determinants for the potential dimensions of packaging, secondary packaging and, ultimately, for the primary packaging. The point of sale, including the actual shelf inside the store, can also be a determinative factor for packaging dimensions. Size and form of durable goods determine to a large extent the packaging dimensions, but it is the distribution system that has a strong influence on the packaging dimensions for food, as is the case in the packaging module system.

Durable goods, such as large machines, of which the dimensions can give rise to problems during distribution, are frequently packaged in separate parts and the dimensions of the machine as a whole are geared to the specific route that has to be taken, such as MRI scanning equipment used in hospitals and industrial machinery.

The information system determines the sort of information that must be included on the packaging; the packaging is thus adapted to the system used to distribute the packaged product.

The main product distribution aspects, those aspects that lead to requirements, are given in Figure 5.3.

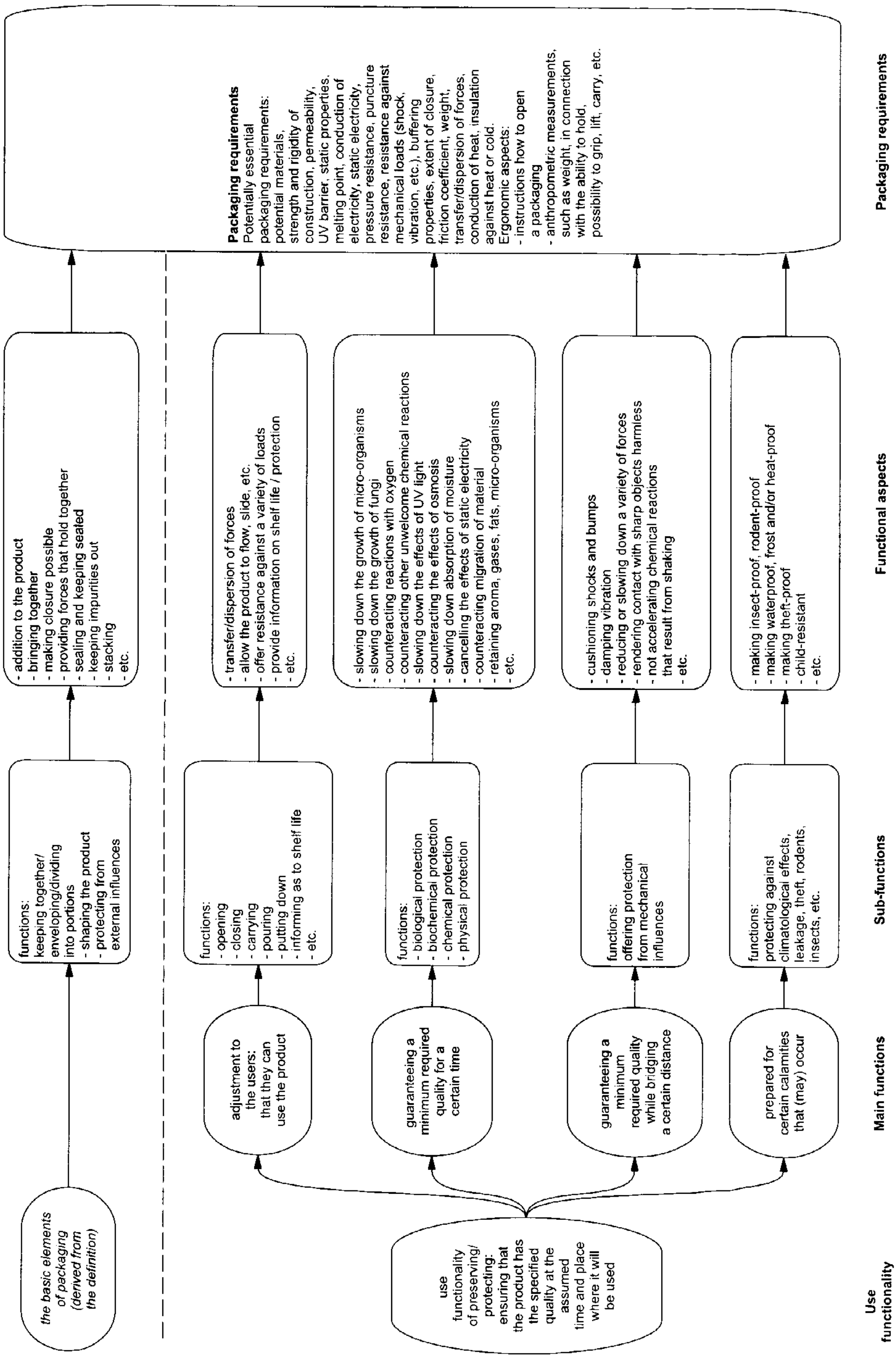

Figure 5.2 Use functionality of preserving/protecting

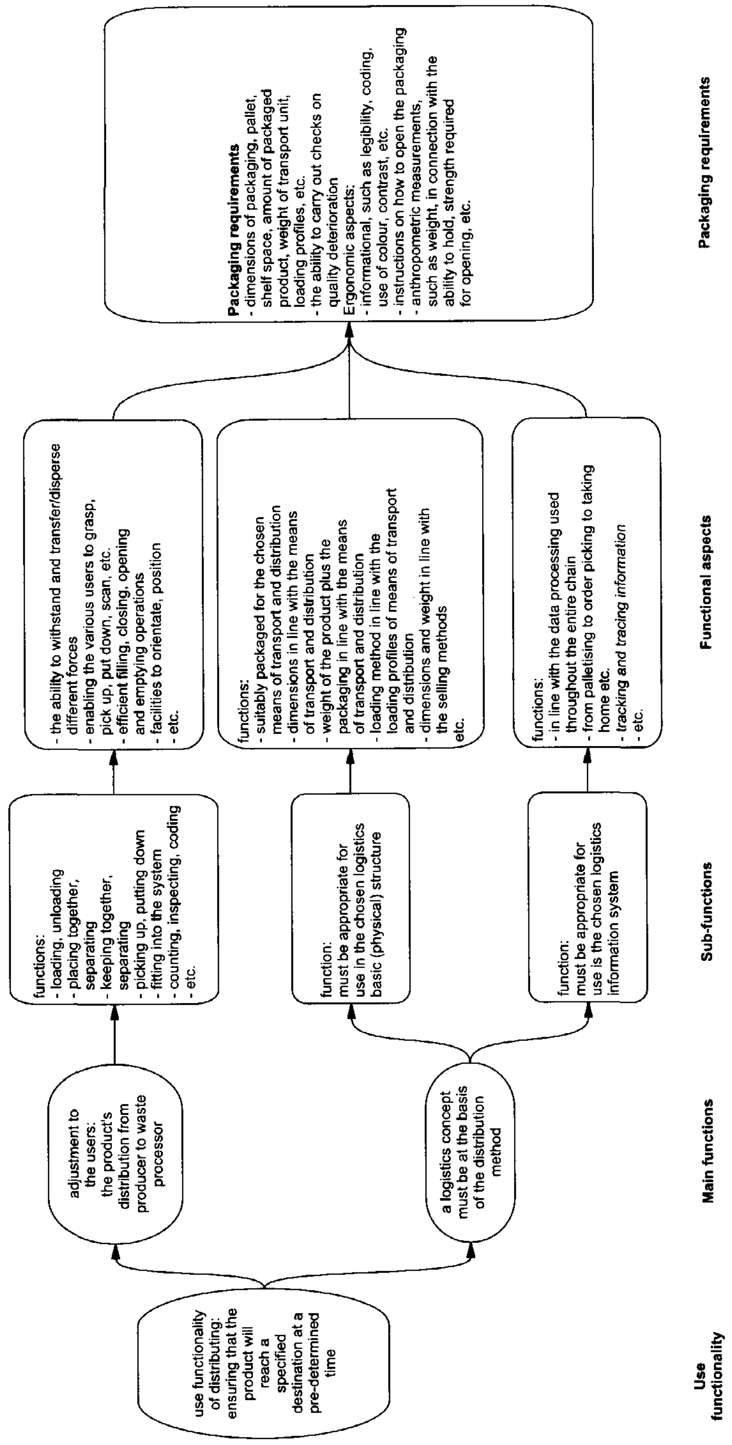

Figure 5.3 The use functionality of distribution

The use functionality of informing

- Communicating the information to and with the user should enable him to use the product:
  - the nature of the contents/product;
  - the quantity;
  - information explaining how to handle the package, i.e. holding, opening, closing, storing, putting down, emptying;
  - additional options for use, limitations and dangers, etc.
- Information that must be included by law, such as information relating to:
  - content;
  - sort of product;
  - quantity;
  - composition, structure and possibly ingredients;
  - how to use / not use the product;
  - the manufacturer's address;
  - the environmental aspects of the packaging such as material, etc.
- Information needed for or in aid of production, or for the further processing of the packaging material or the packaging itself:
  - control codes, sensor surfaces, barcodes, transponders, chips;
  - for the purpose of quality control, such as register marks printed on the packaging to check correct alignment of the separate plates for colour printing;
  - information on tools (moulds);
  - marks for filling purposes.
- Information for filling:
  - filling quantity;
  - filling level;
  - data processing.
- Information needed for distribution:
  - quantity, dimensions, weight;
  - codes for storage and choice;
  - tracking and tracing data;
  - transport method;
  - hazard classification;
  - origin;
  - how to stack on shelves;
  - how to handle the secondary or transport packaging.
- Information for purchasing, consisting mainly of information to promote sales such as:

- the brand; also as identification to improve handling and tracing, protection of unique characteristics, to stress the level of quality, to facilitate retrieval, to make price differentiation possible;
- advertising aspects or special offers;
- information concerning additional uses;
- enumeration of service options;
- telephone numbers etc. that can be used for information;
- colour coding;

  - use of the shape of the packaging for purposes of identification.
- Information on use:
  - how to take home;
  - where to store and/or storage temperature;
  - how to open;
  - how to close;
  - how to use;
  - to use for what;
  - how to obtain information;
  - how not to use;
  - data concerning quality and shelf life.
- Disposal information:
  - how to throw away or hand in;
  - where to take it, into which circuit;
  - legal aspects;
  - information concerning material used.

The main aspects concerning information that can lead to requirements are set out in Figure 5.4.

This concludes the enumeration of use functionalities. When designing a packaging this list can be used in combination with the potential product functionalities, to set out the functionalities of the packaging to be designed. This can then be used to draw up a list of the sub-functions, the functional aspects and the requirements. This enumeration can therefore be regarded as a tool in the design process which is probably used, at least subconsciously, by packaging designers.

5.3 Two design methods: Fundamental Design Method and Systems Design

Literature on design methods (see Chapter 2) was searched for those aspects that probably and urgently deserve to be made more explicit and systematic: step-by-step designing on the basis of previously made choices, and the synchronous designing of both product and packaging. Two methods were found in literature which describe the wanted aspects.

A brief description of these two methods is given below, after which attention will be given to the specific features. The first method, Matchett's Fundamental Design Method (Matchett E. And A.H. Briggs in The design method, edited by S. Gregory, 1966) describes the design process as a step-by-step process, in which the choices are preceded by previous choices, based on functions. Functions are the start of every design project (Roozenburg and Eekels, 1995), but a way to describe or analyse functions is not presented by them. For this reason Matchett's Fundamental Design Method is chosen. The second method, Systems Design (many sources, see section 5.3.3) describes the design process of separate components which, together, form the solution. In fact, every design project can be described by a systems design method.

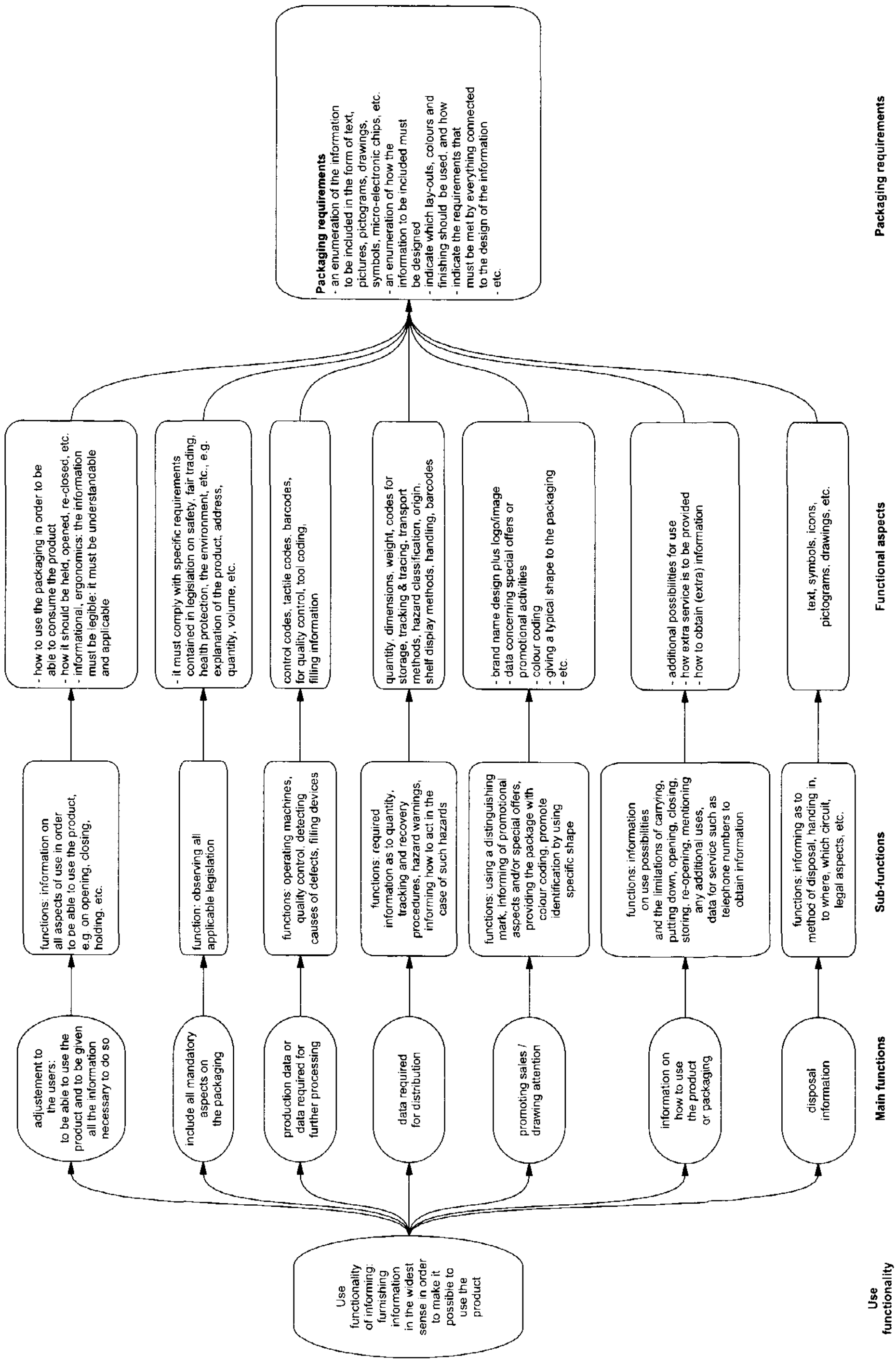

Figure 5.4 The use functionality of informing

The difference in the design of packaging is that a packaging can hardly ever be designed isolated from the product to be packed, while many products can be designed isolated from the surroundings in which they have to function. For this reason systems design is chosen.

5.3.1 Analysis of the Fundamental Design Method

Figure 5.5 shows a schematic representation of Matchett's Fundamental Design Method. Malotaux (1982) added a phase and therefore this source is used. Matchett starts by gathering the needs and limitations, a sort of problem analysis: what is the exact need, what is the problem, and to what must, or must not, a solution comply (restrictions). The goal is to reach a selection of primary, functional needs: if these needs are not fulfilled, then the solution is of no value.

These functional needs can in fact be compared with the use functionalities set out by Dirken (1999) discussed in Chapter 2. If the solution fails to meet the primary expectation of the user(s), then the solution is not practicable.

It is notable that Matchett eventually arrives at functional needs, which he then takes to the next step. The role played by the requirements is not dealt with any further, yet it would seem that they are specifically intended to mark out the solutions. This differs substantially from the methods of approach as described by Roozenburg and Eekels (1991), in which the emphasis is on collecting the requirements and on the completeness of the set of requirements, although it is known that in practice many approaches are being used. The way Matchett defines the design process can be seen as a combination of rational problem solving and reflective practice.

In the second step, Matchett categorizes all functions according to the fulfiller of the function. To do this, he uses a description of the life cycle in ten steps which was supplemented with an additional step by Malotaux (1982). This is comparable with the process trees used by Nijhuis (1980) as discussed in Chapter 2. The result is a list of functional needs and, in essence, this step can be compared with Dirken's product functionalities as discussed in Chapter 4.

In the subsequent step, Matchett analyses the functions in great depth to arrive at a changed hierarchy. Iterative steps can be carried out. It is not exactly clear where the analysis of the problem stops, but it is quite plausible to assume that the analysis ends and the synthesis starts at the point when the hierarchy is changed. This is probably why the next step is referred to as the fundamental design cycle.

His fundamental design cycle comprises seven stages. Typical of this procedure is that one's own solutions are looked at extremely critically, and that repeated checks are made as to whether the primary functional needs are indeed met, in other words reflection on whether the most important qualities – which the product to be designed must have if it is to be a viable product – are met.

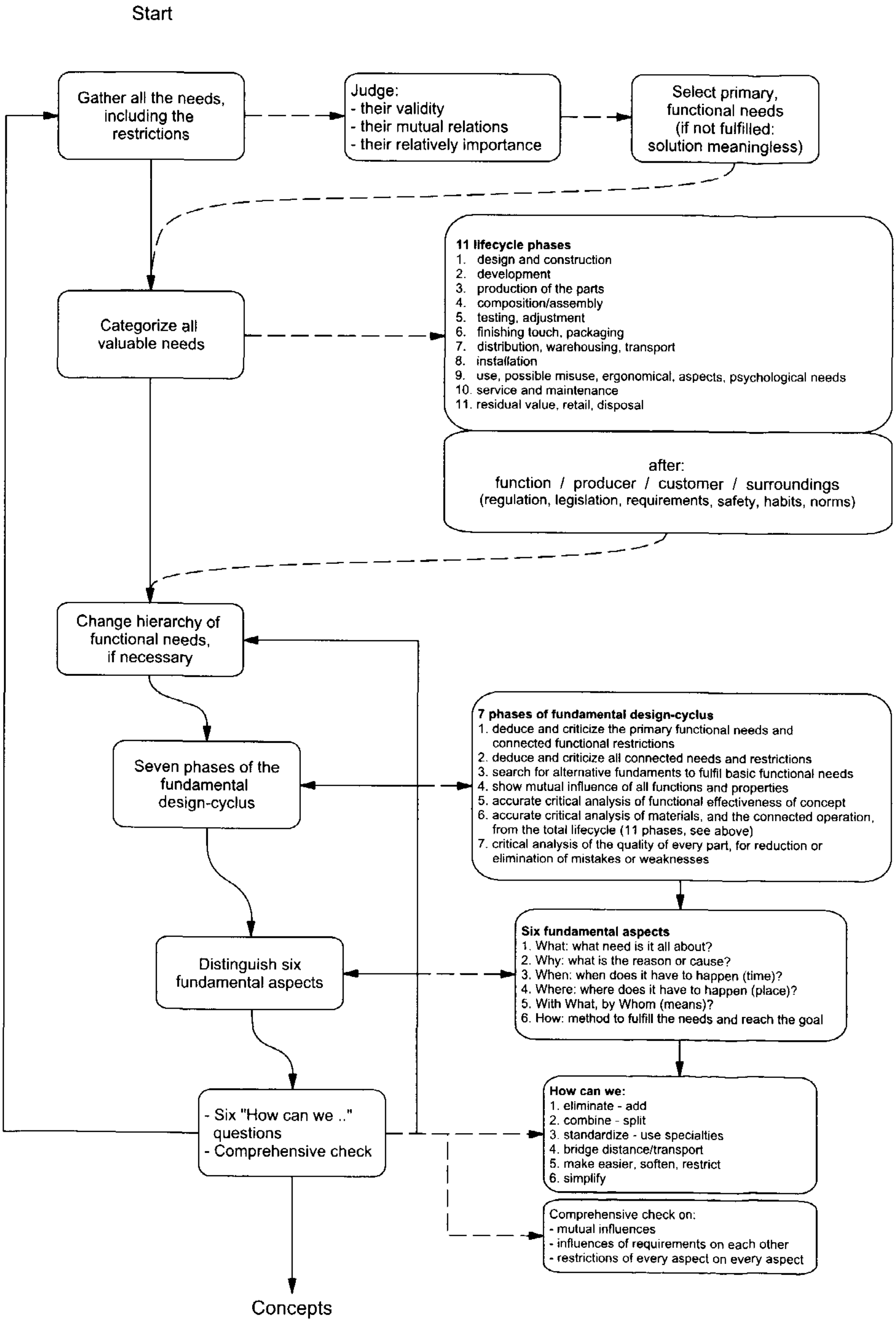

Figure 5.5. Schematic representation of Matchett's design methodology (the eleventh lifecycle phase added by Malotaux)

If possible, the design must be looked at on the basis of six fundamental aspects. Six questions are then asked, all of which look at whether the design can be changed, i.e. optimized. When doing this one should not hesitate to take a critical look at the primary functional needs and to ask questions concerning the needs and the underlying reasons for, if necessary, changing the required primary functional needs. This might change the starting point of the actual assignment. The assignment to design a car can, for instance, be understood as: design something that will take one from A to B safely, quickly and comfortably.

At the end, a systematic check is carried out on the mutual influences, on the requirements and aspects, and on the restrictions the individual aspects impose on one another.

Matchett's Fundamental Design Cycle is apparently more or less similar to a quality function deployment (QFD): attributing product features to the customer's wishes (see for instance Cross, 1994, Roozenburg and Eekels, 1991), whereby in this particular case solutions are sought for the most important product feature which is then tested again, after which the next product characteristic is integrated into the design, tested again, etc. On the basis of this approach a parallel can be drawn with the way in which people attach meaning to a concept as set out in Chapter 1 (Fodor, 1998, Marconi, 1997). According to this mode of thought, the concept of 'packaging' could be defined on the basis of typical examples, from which, depending on the examples, certain functions can be deduced. Compared to Matchett's method of approach, the thought process involved in defining a specific concept is in actual fact the reverse of designing a package. The analysis is set out schematically in Figure 5.6.

To conclude, it can be stated that one of the most essential aspects of Matchett's method of approach is the working with functions and the (intermediate) testing of solutions to the functions and not to the requirements. This is a combination of rational problem solving and reflective practice, based on a functional hierarchy. Matchett inevitably returns to the goal of the development. During and/or on the basis of analyzing and designing, Matchett determines the most fundamental functions and moulds them into a hierarchy. Working with functions provides insight and defines and criticizes the concept. The view that a design must be built up on the basis of functions that determine the right of a product to exist, and in which the starting point can change, is applicable for the wanted methodology.

Brugman and Dudink (1976) stress that Matchett's Fundamental Design Method is a method that endeavours to track down the regulating mechanisms in the way people think, and is not intended as a standard procedure for solving problems. In other words, Matchett is attempting to bring about a favourable change in the total way of how people think: that it becomes more penetrating, more flexible, more profound and more liberated from patterns that have become second nature due to conditioning processes.

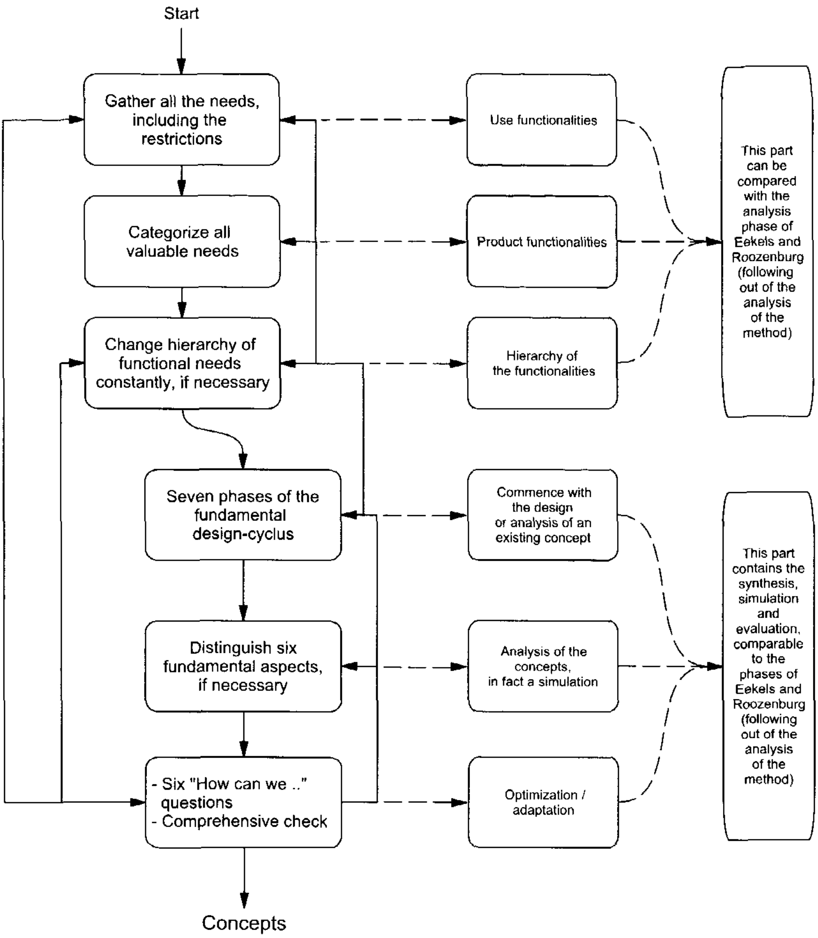

Figure 5.6 Schematic analysis of Matchett's methodology

5.3.2 An analysis of Systems Design

Publications on Systems Design go back as far as the nineteen fifties (see that part of Gosling in Jones, 1962, p. 23), in which reference is made to Goode and Machol, 1957. System Engineering is also referred to as systems engineering, system design or systems design. In this study the term 'systems design' as defined by Gosling, will be used. Systems design is concerned with the design of complex systems in which separate subsystems, which are assembled to form a whole, can be distinguished. Complex systems are apparatus and machines such as refrigerators, washing machines, cars, packing machines, etc. Many subsystems in these products, like pumps, drums, driving gear, etc., can be designed separately from the use functionalities. Pahl and Beitz (1988) speak of a system approach. "*The system approach reflects the general appreciation that complex problems are best tackled in fixed steps, each involving analysis and synthesis*" (pp. 15-16).

The goals are set after the problem has been analysed: System Studies. This results in criteria which the solution must fulfil: Goal Programme. Feasible solutions are devised in the stage referred to as System Synthesis. The properties and behaviour of variants must be determined: System Analysis. They are subsequently examined against the goals set, after which a solution can be chosen. This method of approach is shown in Figure 5.7.

Attention must be given to the consequences of a possible solution for the solutions for other areas. Restrictions play a particularly significant role in this respect.

The most essential element of the Systems Design approach is that the separate areas are indeed regarded as separate design projects, with analysis and synthesis. The solution for a specific function (e.g. the supply and distribution of electricity) is coupled to solutions for other specific functions (circulating water, spinning a drum, etc.), after which the 'whole' can be assembled. No mention is made of priorities in the sequence of solution.

Pahl and Beitz (1988) state that function-oriented synthesis is an important field of application for the system approach. A function model, based on known solutions, or considered concepts, plus the mutual links, the inputs and the outputs, can be worked out into an optimum solution with the aid of mathematical variation.

This last part, the mathematical variation, resembles the wish of Alexander (as discussed in De Wilde, 1997) to solve design problems totally rationally and it also shows similarities with the VDI models mentioned in Chapter 2.

Pahl and Beitz's model does, however, remain applicable, especially its tackling the problem in fixed steps, each involving analysis and synthesis.

Matchett's method takes functions as the starting point and involves looking for a hierarchy during the design process. The design is built up function by function. Systems design, as can be found in many different sources, tackles complex problems by solving them in fixed steps. These two methods are combined in the next section for the development of a method for packaging design.

5.4 A method for packaging design

Almost every design project starts out with an assignment. This assignment formulates the goals of the development to be undertaken, and these can vary extremely, such as to lower packaging expenses, higher profits from the packaging lines, a lower environmental impact by the packaging, a packaging conform changed statutory requirements, or that is easier to use, or has a shape which is more appealing to the consumer, etc.

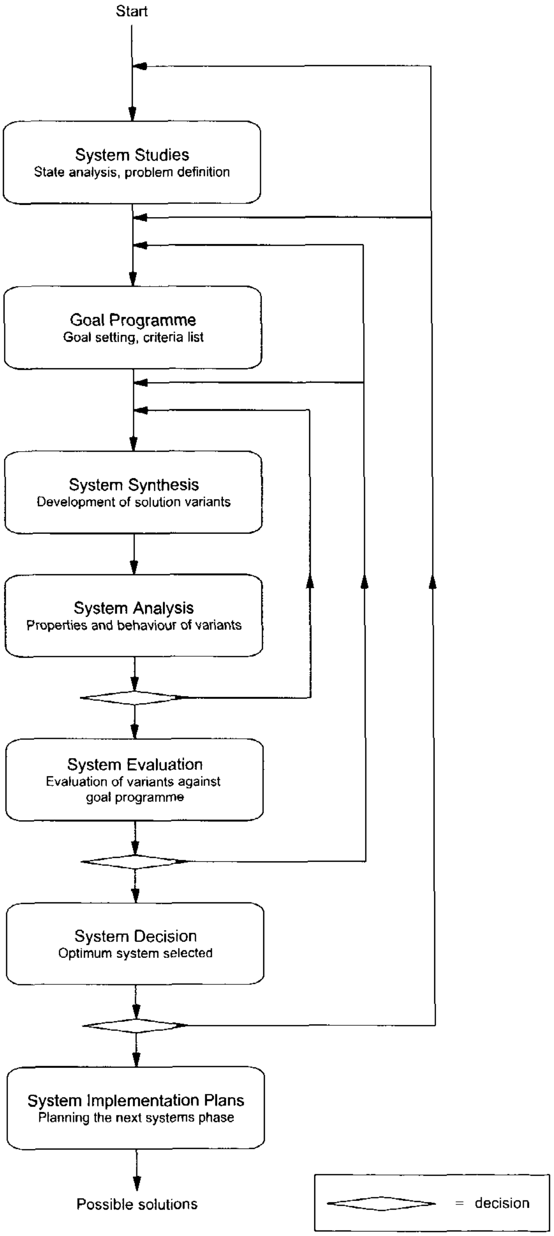

Figure 5.7 Schematic representation of systems design according to Pahl and Beitz (1988)

In the majority of design projects the starting point for such a development is the packaging and not the contents packed. As pointed out earlier, functions can sometimes be shifted from the product to the packaging and *vice versa* in order to achieve the goal. The methodology must give consideration to this aspect, and that is why the packaged product is taken as the starting point.

At first, the process resembles every other design process, such as the methodology reflected in the basic cycle for design set out by Roozenburg and Eekels (1991): analyse the problem and search for potential solutions, i.e. Analyse and synthesize.

However, a tool for the analysis has already been described: the use functions of the packaging, the goal of the design process, and the product functions that indicate other influences that are also, or may be, important, as set out in Chapter 4. The use functions can be used more quickly to devise preconditions, functions, requirements and wishes.

At a very early stage in the process it is essential to be aware of any aspects that can be very persistent, in the sense that they must absolutely be complied with, in fact limit the project, such as legislation prescribing specific packaging procedures (pressurized packaging, the packaging of hazardous substances). It is therefore also important to be mindful of any requirements that can emerge therefrom at an early stage of the project.

There are many techniques that can be used to find solutions in the synthesis stage as mentioned in Chapter 2. It is not advisable to impose any restrictions on the degree of divergence that is generally inherent in any design project, especially during this stage. The wider the variety of the solutions brought forward, the higher the chance of a usable solution or solution component. This stage of the project is the most suitable stage in which to draw up an image or view of the product and packaging combination, a sort of preliminary 'sketch' of preferable outcome. Suppose, for instance, that a packaging is required for a product that has to emanate the freshness of the sea. The designer, or the team, can put forward suggestions with a shell shape, how it must be used, how it should stand, the requirements that must be met by an outer packaging, etc. If the team and/or the customer decides that the sketch will be able to meet the required goal, then it will become one of the starting points, or the only one, for further development. A starting point is regarded as a fixed piece of information to work on or to use for further development. This, however, need not mean that it may not be brought up for discussion at a later date.

As stated in Chapter 2, this method of approach was chosen in one of the DUT-IDE MSc theses. It concerned the positioning and design of a packaging for a flower variety, a totally new concept. The decision was made to first generate an image of the required solution. One of the cases presented in Chapter 2 showed that this way of working is also used in practice.

Devised solutions can then be examined against the project goals and the ultimate goal of the packaging: that of being able to use the product. This examination should be seen as a selection of the ideas, in which those suggestions that will probably *not* meet the required goals, must be abandoned. If this cannot be decided with any certainty, then the suggestions should be further looked at. This examination cannot take details into account, since the essential details have not yet been worked out. Nevertheless, a professional packaging designer can, by using simple tools, come up with several results that will reduce the level of uncertainty. For instance, it is quite possible to estimate the amount of material required on the basis of the estimated dimensions and the volume to be packed. In turn, the amount of material can then be used to estimate the costs of the packaging by using standard rules. Many manufacturing firms and traders of product and packaging make use of these standards. For example, subject to large orders, the cost of glass packaging (bottles, jars) is about € 320 per tonne of manufactured packaging for green glass and approximately € 360 per tonne for brown glass. A standard figure used for corrugated board, which is easy to deduce from the turnover of a corrugated board factory and the production in square metres, is that 1 square metre of average produced quality costs approximately € 0.45 (figures from 1999). The cost of specific barrier foils is about € 4.0 per kilo, etc.

An estimate of the amount of energy that goes into packaging can be made on the basis of the energy content of the materials, expressed for instance in MJ per kg (see f.i. Remmerswaal, 1999), or by using the various computer programs (for an enumeration see Brezet, Van Hemel, 1997) for calculating standard figures on the basis of material quantities.

It should be pointed out that suggestions made during the synthesis stage can vary enormously in terms of presentation method and degree of detail. It may concern descriptions, with or without explanatory drawings and sketches, potential models (or limitations), standardized components (closures, screw chaser, etc.), descriptions of moulds, technical principles or techniques used, etc. Obviously, combinations of the presentation methods or details are also possible.

Figure 5.8 shows the first part of the design process, the starting point being the functions that must be fulfilled.

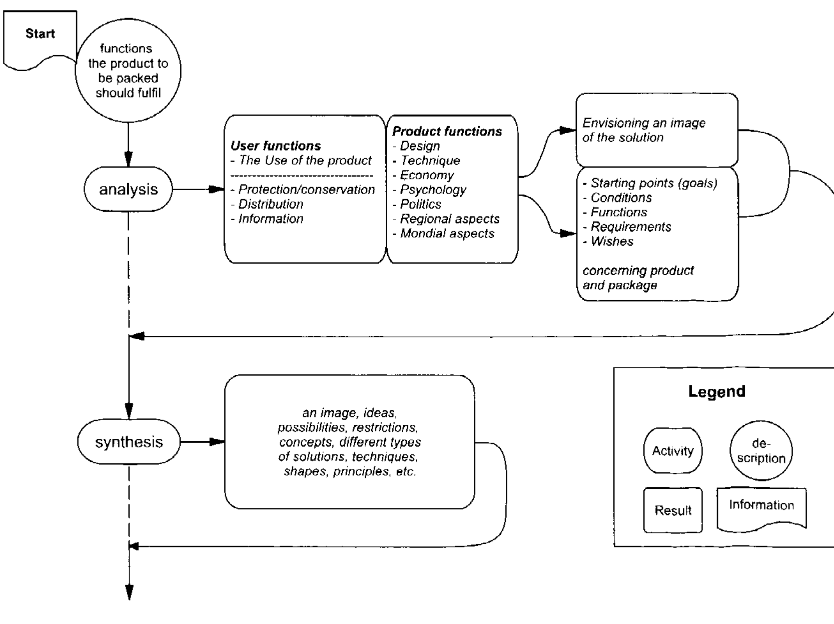

Figure 5.8 Representation of the first part of the design process (iterations are not presented)

This brings the design process to a point where Matchett's methodology can be applied in combination with System Design.

Matchett states that a solution must first be sought for the most essential functions of the product, in our case this means the combination of product and packaging. Three use functions were set out in section 5.2, all of which have always been given attention over the years when producing packaging. These functions have been divided hierarchically into main functions, sub-functions and functional aspects. A mutual hierarchy of these three use functionalities that must, or may, be used in the design process has still not been discussed. An example of the glue packaging was discussed in section 2.8.3. This involved in the first instance a search for a material with the least possible environmental impact on the basis of qualitative assumptions. It was then discovered that the glue itself would be left unprotected and all options so far had to be abandoned. By now it will be clear what the aim is: the most important c.q. primary function when designing a product and packaging combination, is the use functionality, i.e. preservation/protection of the product. One or more solutions must first be found for this functionality. The resulting solutions are subsequently elaborated upon, adjusted and possibly expanded in the next step of the design process, in which the use functionality of distributing has the central place. This is repeated for the use functionality of informing, with the possibility of adjusting the functionality solutions reached earlier by repeating the process.

The reasons for placing preserving/protecting above distributing, and both these two above informing, are as follows. A packaged product that is easy to distribute but which is not adequately protected by its packaging, will ultimately fail to satisfy the goal: that of being able to use the product. The primary goal of the packaged product is its use, and the packaging is principally instrumental in achieving that goal. A product that is well protected by its packaging, but which is difficult to distribute, will ultimately still be able to satisfy the goal: that of using the product. At most, the costs of distribution will be higher, or more effort will be needed to ensure that the product reaches its destination. As long as the product is of use to the user, this need not be a problem. It strongly depends upon the turnover per transported volume.

If the previous two functionalities of use have been specified, then in principle the decision has also been made what materials are to be used for the packaging, and what the dimensions and weight of the packed product will be. It can then be determined which and how extensive the information must be, and how, and with what means that information is to be presented. The priority in searching for solutions is roughly the same as the attention given to the packaging functions during the actual lifespan of the packaging, as was set out in Chapter 3 and as presented in the schedules in section 4.5 about materials.

The design process that takes place after the synthesis is divided into separate design cycles in the first part, each with its own synthesis and analysis in accordance with the description of System Design. The methodology as has been explained up to now is illustrated in Figure 5.9.

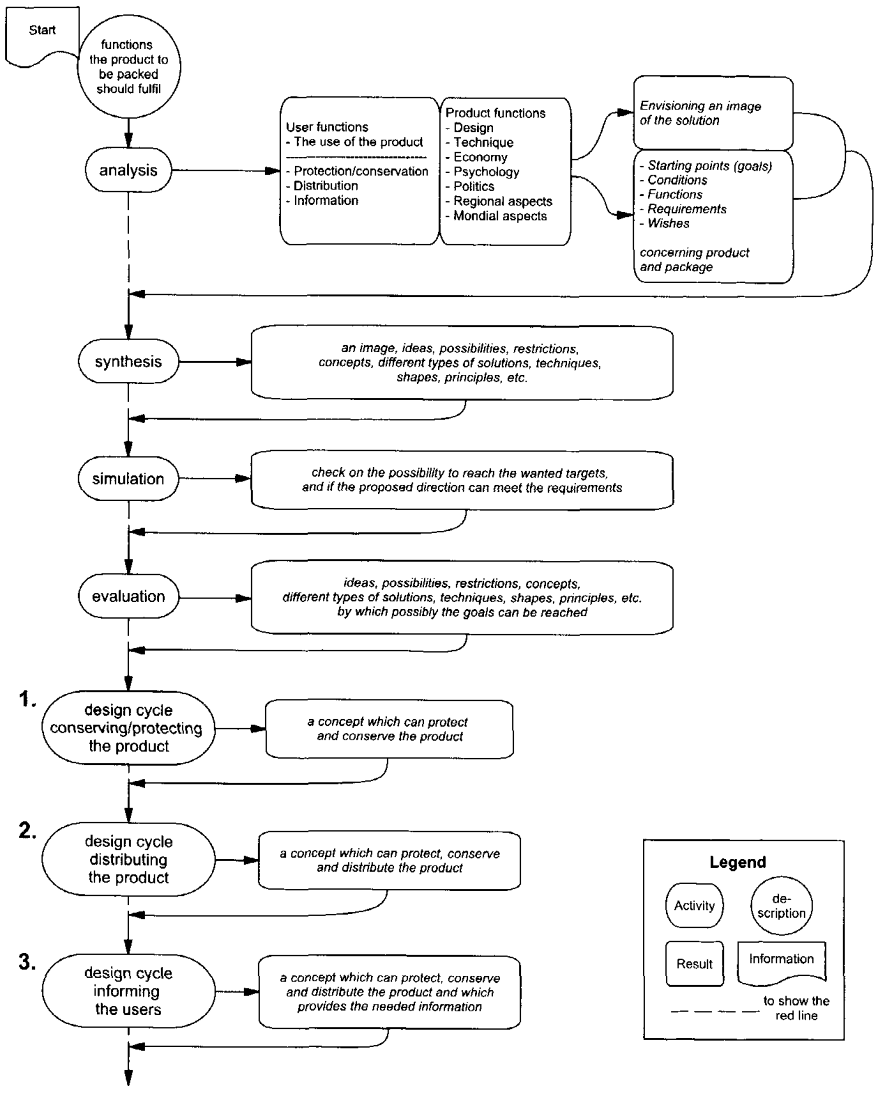

Figure 5.9 Representation of the first part of the method (iterations are not presented)

The difference between the design process of System Design and the methodology outlined here is, that the solution is not used as such (as in the case of a pump, drum, driving gear, etc.), but is used for the purpose of expanding or adjusting other functions that emerge from the next use functionality. In these design cycles, methodologies such as those outlined by Matchett can be used. Thereby the best possible solution within the design process is searched for systematically, and then subsequent examination focuses more on the goals to be ultimately achieved and not on all subfunctions. Within such a design cycle attention must obviously be given to the product functionalities, since they form part of the packaging goal. Realising the use functionality must, however, come first and foremost. How the three use functionalities are used, is illustrated in Figure 5.10.

After each individual design cycle, the concept can be examined against the goals specified, in which the element of 'being able to use the product' is crucial.

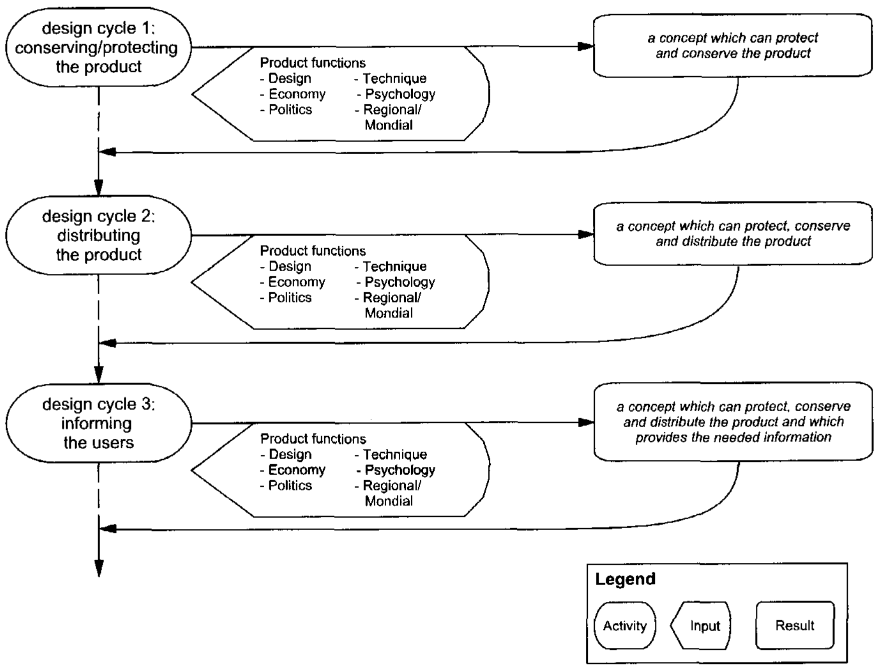

Figure 5.10 The three use functionalities applied (iterations are not presented)

Worked out one step further, the schematic representation is shown in Figure 5.11. The concepts that emerged as the outcome from the design process of the first use functionality can be combined with the outcomes of the design process of the second use functionality. It is in fact a multiplication, yet in practice it is quite possible that not every combination can be realized. This is not taken up in figure 5.11.

Matchett points out that functions must be examined critically and that the solutions must be examined against these functions. He also states that, if necessary, the primary functional needs must be changed for the result to be a better all-round solution for the required goal. It should be pointed out yet again that the primary functional needs must be the functions expected of the product and that the packaging is instrumental. Esse (in Harckham, 1989), referred to in Chapter 1, also indicated that he would not hesitate to adapt the product so that it could be packed better.

Figure 5.12 illustrates how the product can be adapted to achieve an optimum solution for the combination of product and packaging.

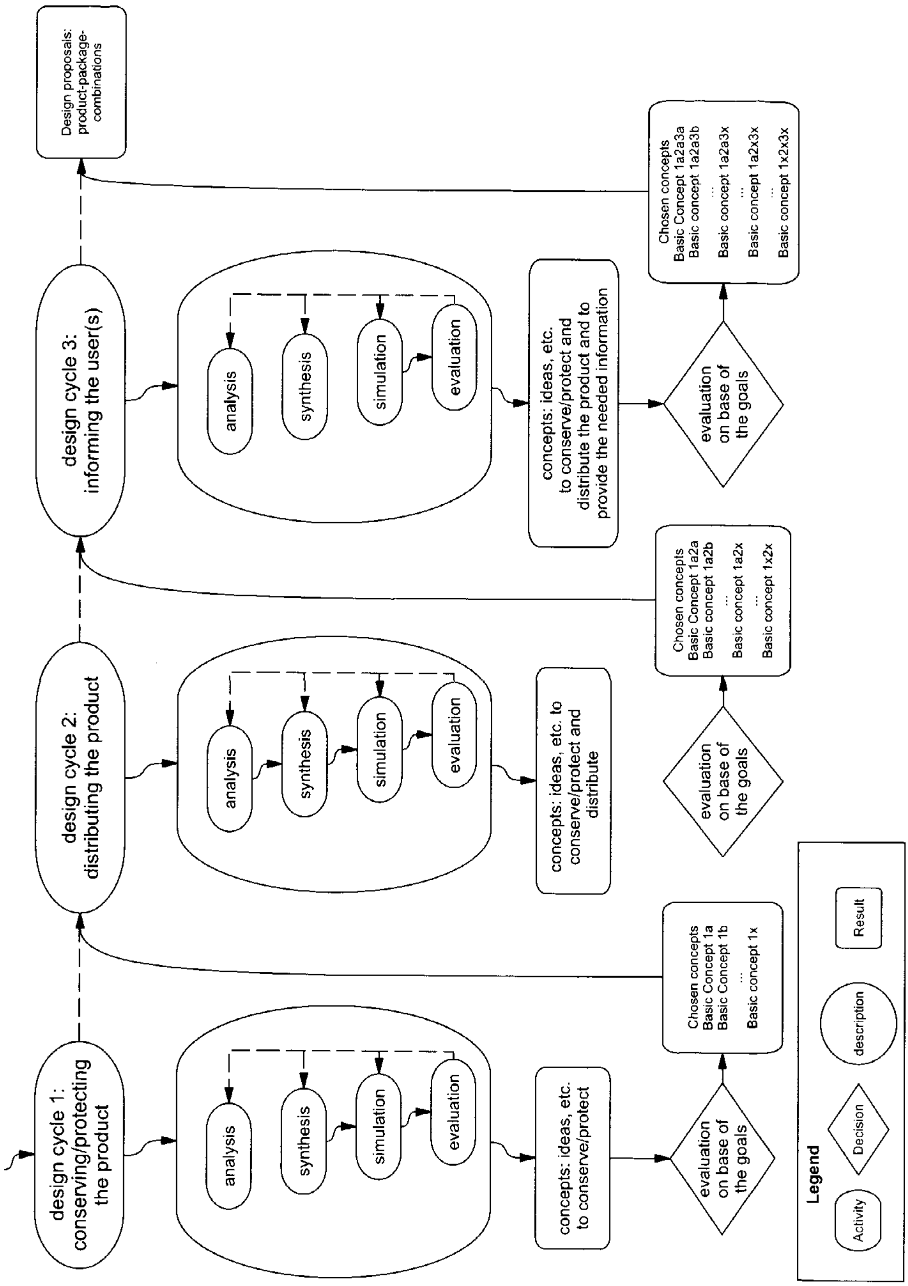

Figure 5.11 The three separate design stages (iterations are not presented)

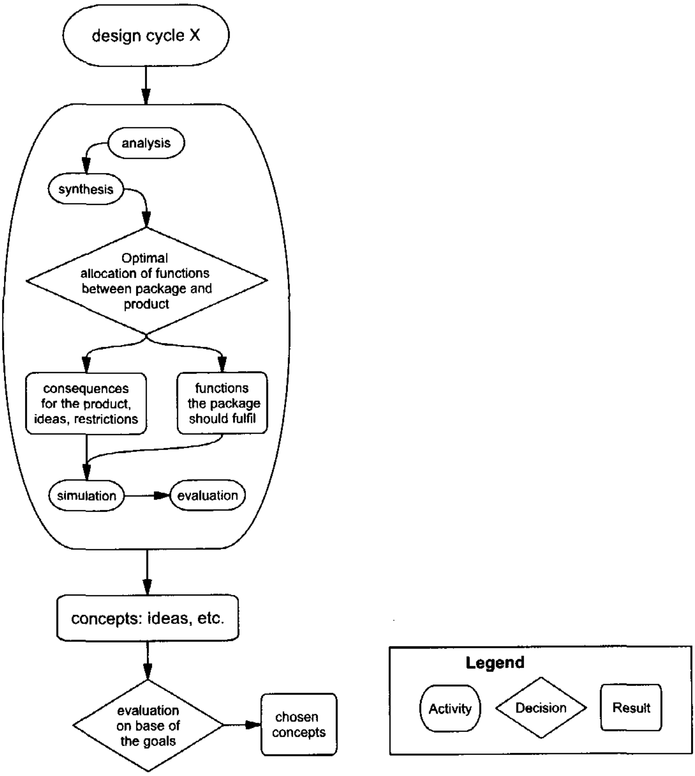

Figure 5.12 It must be possible to adapt the product in the design cycle to achieve a better combination of product and packaging (iterations are not presented)

The headlines of the method for packaging design are set up now. Three design cycles are distinguished, based on the hierarchy of functions. Matchett's method and Systems Design are integrated into a method for packaging design. It is possible to describe the design activities within every design cycle. The main functions, conserving/protecting, distributing, informing, of the three design cycles are leading in this. In the next section this will be elaborated on.

5.4.1 Design activities in the design cycle of preserving/protecting the product

The biological, physical and chemical vulnerabilities of a product determine which properties a packaging must have to preserve/protect the product. Chapter 4 provides the reader with an overview of the vulnerabilities of a variety of product groups. This overview can be used to check the completeness of and to gain insight into the product's vulnerability if it is not yet known or if it is not included in the assignment. It can also be used to examine the vulnerabilities of the packaging itself. Chapter 4 also provides an overview of the functions that packaging materials can fulfil. The potential materials for the required function can be found set out in a schedule on how to choose a packaging material (see figure 4.2 in section 4.5). The choice of material plays a considerable role in the first design cycle. Other choices are also linked to the choice of material, such as production and/or processing techniques. In turn, these determine the actual shape of the packaging. All of these insights are in line with the views held by Briston and Neill (1972) who claim that the first design activity consists of conducting a study into the appropriate material, as was quoted in Chapter 1. The next step, according to Briston and Neill, is that the choice of material steers three activities which are carried out in parallel: cost study, storage tests and pack design. As said earlier, an estimation of the costs can be made in the early stages by using standard rules. Tests can also be carried out, but to do this the packaging must have already been designed, at least the technical and material details must have been designed (hypothetically) in order to simulate the real situation as well as possible. Tests can be carried out on materials to reduce uncertainties regarding certain properties and principles. Naturally, a great deal of other design work is also involved in this stage.

Legislation can play an important role in this stage, because the use of materials, especially when packaging food and medicinal drugs, must comply with certain regulations as set out in Chapter 4.

In machines that shape, fill and seal, the packaging is generally made during the filling process. Although many machines can handle a variety of different materials, the choice will generally be limited. If this is the case, the choice of material is usually made together with the choice of machine type. This means that the greater part of the packaging concept has by then been established. The processing properties of the material are extremely important, to ultimately realize the packaging and, to a large extent, to determine the costs.

Other aspects that play a role in this stage of the design process relate to the actual amount of product that must be packaged and the dimensions of the packaging. In most design projects it is known beforehand how much of or how many product(s) are to be included in the package, yet it is quite possible that the packaging design or the choice of material will also play a decisive role in this respect.

Dimensions and construction determine the amount of packaging material needed; this was dealt with in Chapter 4. The degree of environmental impact of both the product and the packaging will more or less have been established at this point of the design process.

While dimensions can impose restrictions on the production techniques used, they can also present other options. Machines can be adjusted, or even new machines might have to be built.

At this stage, it must be given serious thought to whether the designed concept, or the concept that was chosen as the starting point, can indeed be realized with the potential materials and the associated production techniques. As put forward by

Matchett in his methodology, each step can always be repeated. The ultimate goal in this design cycle is to realize an image that is able to meet the specified goals, that a material has been selected, an appropriate production technique has been established which is able to ensure that the product is maximally protected or preserved, that all relevant legislation has been observed and that everything is in line with the required product functionalities and meets all the other criteria, such as costs and environmental requirements. As said earlier, it must still be possible to adapt the product, if this would result in a better concept of the combination of product and packaging.

Design is a discipline that does not go from activity to activity in a rational manner only. A designer usually has a reasonable overview of the requirements and constantly takes a subjective step forward before examining them rationally (Dorst, 1997). It is therefore neither possible nor relevant to set out the most appropriate sequence of activities *within* a design cycle.

The assignment or starting points can, for instance, guide the activities in a certain direction. The manufacturer of a certain type of material can order the design of a packaging for a specific product category on the basis of his material. His objective will obviously be to boost sales of his material and he will hope to accomplish this by penetrating new markets. In such a case, the activities in the first design cycle could be carried out in a different order. For instance, a machine manufacturer can also follow the same procedure. Many packaging designs rely heavily on graphic design, as put forward by Hine (see Chapter 1). In such cases, the material will generally already have been selected and the packaging design will be restricted to the graphical elements of the packaging, for instance a different design for a label, an alternative design for a pack of coffee, a box for macaroni, etc.

Because the product requires a certain amount of protection and a specific material will be chosen with this in mind, it is easy to see that a different method of approach than described above can be very difficult. Finding a suitable product on the basis of the packaging material, in order to pack that product and thus bridge the elements of time and distance, and still retain the required quality, is therefore no easy task.

5.4.2 Activities in the design cycle aimed at distributing the product

Both the product route, in logistics referred to as the 'basic structure of logistics' - and the chosen information system are important. The basic structure describes the exact route that the product will take, including all the supplementary layers (primary, secondary and tertiary packaging), thus establishing the exact way in which the product will be transported. One of the simplest basic structures known is the method used for distributing drinking water in a country, a system of pipes running from the producer to all the users. A more complex basic structure, whether or not for fluids or discrete units, consists of a great deal of storage and transfers in which the amount of product(s) can change. In connection with the effective and efficient bridging of distance the aim is to achieve the fewest possible transport movements and transfer activities. For discrete products, containers and pallets are good tools in this respect. Primary packaging in this stage is, if necessary, provided with a secondary packaging. Preserving/protecting the product obviously may not suffer. This aspect should be given adequate, systematic attention. As well as the product itself, the primary packaging too can be vulnerable, for instance glassware (breakage), metal packaging (denting), folding boxes (denting, tearing), etc. The secondary packaging must offer a solution here and will generally involve the use of a corrugated board box or tray and/or tight shrink foil or a plastic crate or tray. In figure 4.4 in section 4.5 a possible way to choose dimensions was set out.

The means of transport, whether vehicles, moving bands or otherwise, determine the maximum dimensions (loading floor and height) and weight (axle load and floor load) of packed products. In many cases use can also be made of standardized dimensions allowing transport through the chain to proceed as smoothly as possible (see also the extensive description of the functionality of distribution in section 3.3.2). In practice, this means complex calculations have to be made to reach the best possible situation.

Possibilities that should be looked into in this stage of the design process are the so-called hybrid packages: by strengthening the primary packaging, the secondary packaging can be designed using less material or *vice versa*. This therefore also implies that the primary and secondary packaging must be designed synchronously and interactively, just like the packaging and the packaged product.

Legislation governing the transportation of certain products or packages can also impose demands on the packaging construction; this deserves proper attention (see also section 4.4).

Information that must be included on the packaging for the purpose of distribution, such as code numbers, barcode, contents, origin, hazardous substances, etc., is also regulated.

At the end of this stage, the concept of how to combine product and packaging must be examined against the specific requirements from the point of view of distribution. The objective is, of course, that in a future stage the product must reach the user. It might also be necessary to adapt the product if it is apparent that this will result in a better concept. If the concept meets the requirements of this design cycle, it can be examined against the goals of the project as a whole, i.e. proposed costs, environmental impact and, obviously, the possibility of using the product and packaging combination in terms of the primary functionalities. The estimated amount of material can be used again to gain an insight into the costs and the environmental impact.

Evidently, iterations can also be made here. These steps must be taken time and again in order to find a suitable solution. The steps defined by Matchett can be used to optimize the design.

5.4.3 Activities in the design cycle of user information

How to pass on information to the user must be designed too. A medium must be designed for the graphic part of the information. This will in many cases be the packaging itself, and a printing technique must be selected on the basis of aspects, such as the packaging material, batch size, required print quality, and obviously, the cost. A possible way to choose a printing technique was already set out in figure 4.3 in section 4.5.

A tag or label often has to be attached to the packaging; this requires specific attention, as described in Chapter 4.

Product functionalities and the goals of the design project can steer the design activities even further. For instance, attention can be given to the information, added for the purpose of increasing sales, such as providing non-obligatory information on possibilities of use, telephone numbers and WWW addresses for information, etc. Graphic elements, such as dots and lines, can be added to comply with the wishes of those user groups that use such elements, or for the purpose of hardening or softening the visual appearance. Attention must be given to the colour of the packaging, obviously in combination with the colour of the graphic elements, or to the option of making the product visible by including transparent sections. Psychological effects are, evidently, important when choosing colour. Certain details in shape can be added to make the package appealing to certain target groups or to optimize the shape in view of the goals.

At the end of this stage, the concept must first be examined against the goal of this design cycle: to provide information. If necessary, the decision must be taken at this stage to adapt the product, if this will result in a better concept of a product-packaging combination. If the concept meets the requirements of this design cycle, then it can be examined against the goals of the design project itself, such as the proposed costs, environmental impact and use. If the concept meets these goals too, then it can be presented as a feasible concept for the market, an adequate product-packaging combination.

The design process will now start to resemble the schematic representation illustrated in Figure 5.13.

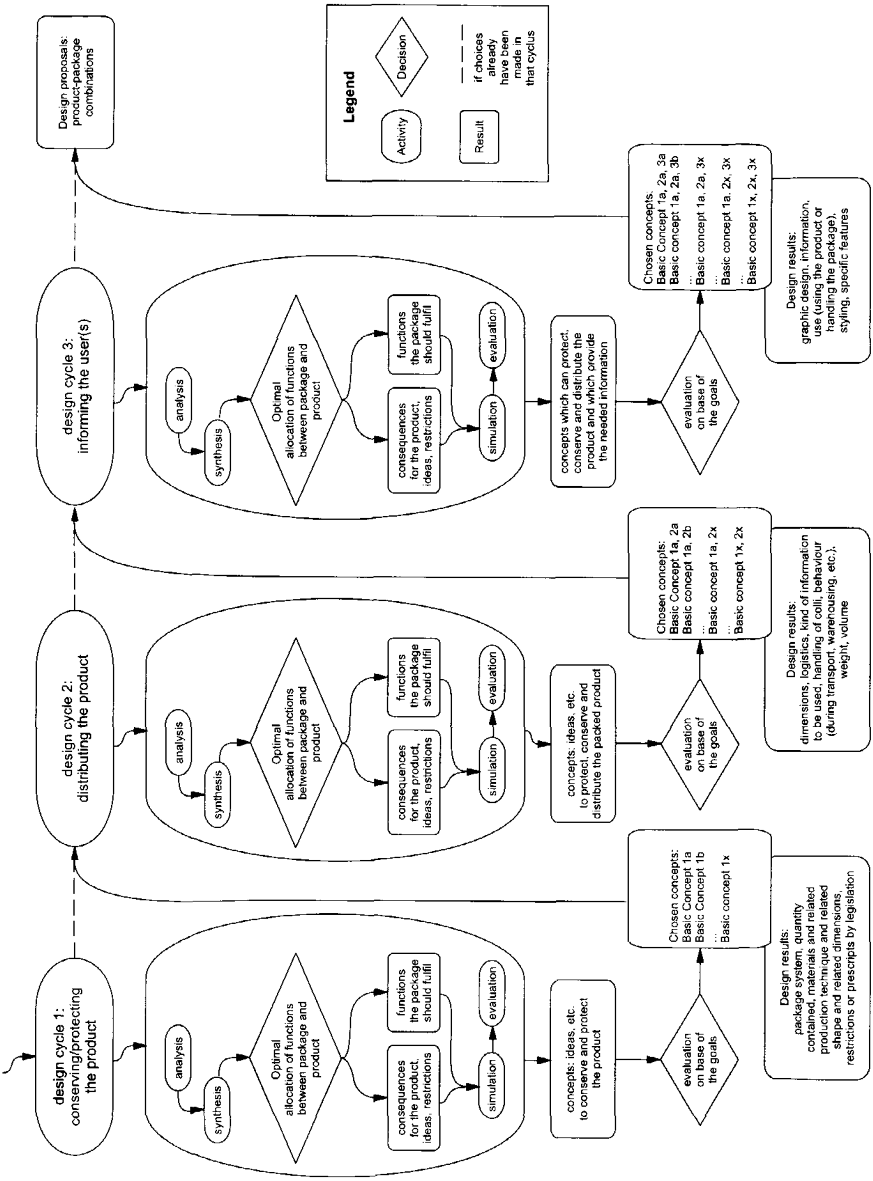

Figure 5.13 The design cycles again, this time with the design results underneath each cycle (iterations are not presented)

For the sake of completeness, Figure 5.14, shown on the next page, illustrates the total methodology developed. The project starts by defining the project goals, creating an image of the solution, searching for ideas, evaluating the options found, after which the three design cycles explained above can be undertaken.

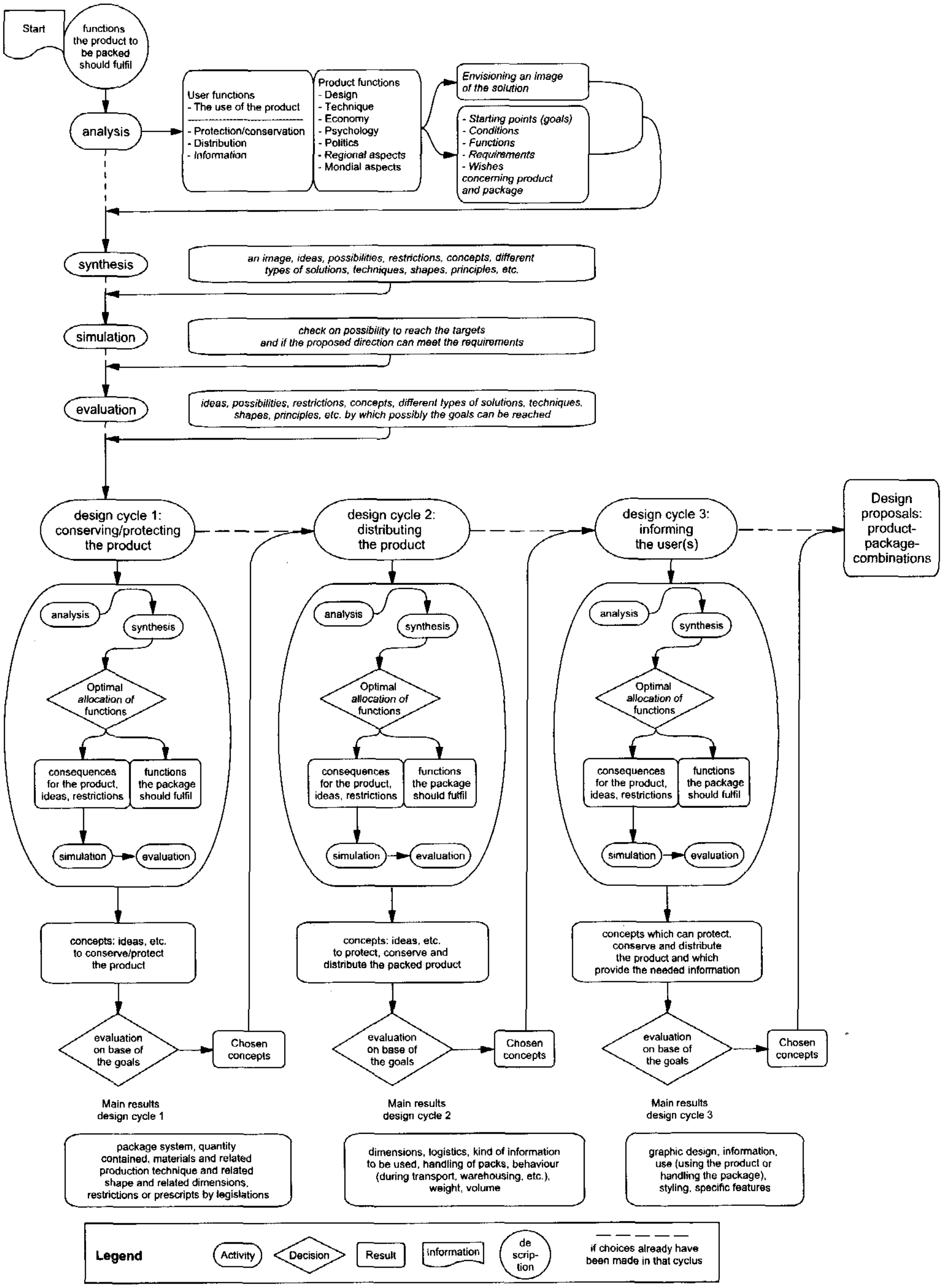

Figure 5.14 Schema of the entire method (iterations are not presented)

This concludes the description of a method for packaging design. Before moving on to discuss how the developed method must be checked and validated empirically, it will be explained, depending on the sort of packaging to be designed, how the method can be used. This explanation should clarify the different ways in which it can be followed.

5.5 The nature of the product or the nature of the packaging

Whether all three design cycles are equally important, depends on the product that has to be packaged and/or the nature of the packaging. The following explains in brief the distinctions that can be made, and also the extent to which a design cycle plays a role in the design of a packaging for certain products or in the design of certain sorts of packaging. The categories and the importance of the design cycles may be seen as a guide and an example. The designer himself must decide on the importance of the aspects taken from the method for each product to be packaged or for each type of packaging. Table 5.1 presents an overview.

	1st design cycle preserving/protecting	**2nd design cycle distributing**	**3rd design cycle informing**
Food	perishable goods and consequently very important	of high importance because the costs of distribution	are relatively high very important because of legislation and sales promotion
Medicinal	drugs perishable and potentially dangerous and thus very important	relatively of less importance (as yet) in terms of speed, but of importance that the product reaches the right consumer	of major importance in connection with safe use (less in con nection with sales)
Non-food / non-durables	apart from volatile substances or oxidation-sensitive products, etc., usually of lesser importance	relatively little importance	important, especially for use and application
Durables	buffers, mainly to protect against mechanical shock and vibration, electric charge	important in connection with the amount of space taken up	not very important, the packaging plays a minor role regarding sales
Industrial packaging and bulk goods	problems are generally easy to solve (larger units, i.e. less complex)	packaging is in many cases primarily optimized for transport	of little importance, information is essential for distribution only, occasionally logos for the quality image

Table 5.1 An assesment of the importance of function for specific product groups

5.6 Conclusions

A structure of the packaging functions has been drawn up, and on the basis of that structure a method has been devised for the design of packaging. Use was made of the analysis of DUT-IDE students' MSc projects, literature searches for the functions of packaging, and our own experience in packaging design. Examples taken from a variety of sources were quoted and methods of the product design process were taken into consideration. The developed method can be seen as a combination of rational problem solving and reflective practice.

The first step has therefore been taken towards a specific, systematic and applicable method for packaging design. The next step is to analyse how packaging designers bring this process into practice. Thus far a part of research question A.2 is answered: *What method or methods are currently used in (three-dimensional) packaging design and what can be learned from this?* In the empiric phase of the study, by using the set of cards, our approach will be tested. How this was done, and how it was used to answer research question A more fully, will be explained in the following chapter.

6 Structure of the empirical study

Summary

This chapter explains how the developed approach, which aims to show how packaging designers tend to work, will be carried out. This should provide the answer on research question A.2: What method or methods are currently used in (three-dimensional) packaging design and what can be learned from this?

Our study can be characterized as the development of a method and also as an orientational study, more to generate than to test hypotheses. Nevertheless, it was decided to test the developed method, as much af feasible, through a set of explicit hypotheses.

Two activities were carried out to test the method which will be described in this chapter:
- *conducting a pilot test for the experiment with cards, representing consecutive steps in the design process;*
- *carrying out the experiment with packaging designers and/or participants in packaging design projects, to asses their visual method of designing.*

6.1 Introduction

We have now developed a method for the design of packaging and its combination with the packaged product. This development was based on:
- a search of the literature on packaging and design methods;
- an analysis of the reports of ca. 100 MSc projects at DUT-IDE;
- own experience in analyzing and designing packaging.

The developed method raises scientific questions concerning validity, reliability and operationality, of which especially the following aspects:
- the correctness of the method in practice;
- completeness (superfluousness or inadequacy);
- applicability;
- acceptability.

Empirical new data are called for to answer these questions. Two studies were carried out to this end. This chapter sets out in brief how empirical data collected and analyzed to answer these questions and, by this, finally to answer research question A.2.

6.2 Empirical research structure

6.2.1 Pilot test with a set of cards

The basic method consists of ordering cards to describe the sequence of steps in a design process. Each card contains a brief formulation of an activity that must or may be carried out in the design process in a certain stage and in a certain order. When laying the cards in one's preferred/chosen order, there is freedom to make additions, changes, etc., (an overview is given in section 6.3.3). An exercise involving cards, which was first tested in a pilot test as to its acceptability, clarity, opportunity to make comments, structure, the time required to complete it, etc., required the participants to lay the cards in an individually chosen order. A discussion was then held with the interviewee and an evaluation made.

6.2.2 Five experiments carried out by people with practical skills in packaging

A more or less random sample could be recruited of people involved in packaging design and/or development projects, people with practical skills in packaging, further on called participants. To these subjects the task was given to systematically work with and assess the developed method by doing five experiments.

The five experiments performed by the participants were as follows: It involved:

- Three experiments involving 23 cards (with the option to add or omit cards):

  Experiment 1
  The participants were asked to determine the individually preferred order of the 23 cards on the basis of a specific assignment. Cards could either be added or omitted.

  Experiment 2
  The participants were asked to determine the individually preferred order of the 23 cards for packaging in general.

  Experiment 3
  The participants were asked to reduce the number of cards down to the minimum required for designing a packaging.

- One experiment with five pre-defined propositions, each stating a methodical principle on packaging design.

  Experiment 4
  Five propositions, specific to the method, plus examples, were handed to the participants and they were asked to attempt to falsify each proposition.

- One experiment consisting of a discussion:

  Experiment 5
  A general assessment was done of the method by using sheets with specific information on the 'ideal' method, using the 23 steps and by discussions both before, during and after the presentation.

6.3 Empirical study

6.3.1 The cards experiment

Functions fulfilled by packaging are dynamic; they change over the years in the same way as a definition changes. This could imply that participants agree more on functions that have been fulfilled by a packaging for a long time than regarding functions that were added later. This can be checked by analyzing the orders in which the participants lay the cards in cases of older versus newer packaging solutions.

6.3.2 Reproducibility and rationale of the cards experiment

It is important that the test can be reproduced reliably. To enhance the correctness of results, the participants were first of all asked to arrange the cards on the basis of a general assignment that can be interpreted in several different ways, in which the product is not named. Thereafter they were asked how much the order would change if the packaging had to be designed for a specific product. This forced the participants to take a critical look at the order in which they had arranged the cards, thus increasing the certainty as to their correct order. Changes in the order for other products can also provide insight into the dependance of the design process on specific types of products/packagings.

Another option to check the aspect of reliability is to use split-half reliability when performing statistical analyses of the data. In that case, the data are randomly split into two halves and then compared to see whether, on average, the two groups of participants come up with the same results.

6.3.3 The pilot test with the cards experiment

A pilot test was conducted at Delft University of Technology's Faculty of Industrial Design Engineering to make the first assesment of the cards experiment concerning its acceptability, clarity, the opportunity to make comments, structure, the time required, the nature of the results, and any unexpected events. As subjects five persons could be found with at least some experience in packaging design and who had (almost) graduated as industrial design engineers. Three were already graduated

Industrial Design engineers and two were still students. In Appendix D a list is presented. Two of the three engineers had graduated in the subject of packaging; the third had coached a study on ecologically-sound packaging. The two students that participated in the pilot test had no previous experience in packaging design. They were, however, included to ensure breadth in the experiment.

Pilot description

After their arrival, the participants were all given a set of cards in a blank envelope. Each participant had a different order of cards. After being shuffled, six blank cards were added, on which a participant could write any activity, experienced as missing. As an indication of the end of a phase, four cards showed the text 'interim check'; two more than required by the method. The intention of this surplus was to give the participants more freedom. The last card was: 'test the end result'. The assignment was given verbally: to design an alternative packaging for French beans, which is easier to open than the present ones: the standard glass jar and tin. The participants were then asked to arrange their cards in the order of the activities undertaken, or should be undertaken in the design process.

Findings

Arranging the cards in the individually desired order proved to take almost an hour to complete. The participants pointed out that it was annoying that the cards contained the full description but no brief heading. This meant that each card had to be read over and over again, costing a great deal of time.

Some participants asked very specific questions about the product to be packaged. Most of the questions could be answered.

There was apparently some confusion about the stage of the design process in which the cards would be used. For instance, some of the participants said that if an assignment was to design a package with an innovative design, then the first step would be to design a shape concept. And, if the assignment was to make the packaging cheaper, some of them said that a cost analysis would have to be set up first.

It was apparently difficult to establish the order in which the cards should be arranged.

Despite their comments, the participants still said that they found the cards to be enlightening. "A level of understanding had been gained that would come in useful when designing later in practice."

Changes made

Since the pilot, all the cards have been given a heading which explains the contents in brief, e.g. 'determine dimensions' for the card with the activity 'determine the dimensions of the packaging'.

The specific assignment to design a packaging for French beans has been replaced with a description of some product to be packaged. The discription was formulated in such a way that many products could be seen as the product to be packed.

Because some of the participants had not understood that the main thing was to establish the order in which decisions are made, it was decided to present the first, general part of the design process in the form of a flow chart. From then on the participants were asked to arrange their cards in the order they think the decisions should be taken. To be able to quickly and easily record the arranged sequence of the cards, each card includes a letter code which consists of three letters derived from the first three letters of the heading; this gives no indication whatever of a certain order.

Below is a schematic representation of the ideal order of the cards, as based on our preceding study, and the text on the cards. The columns represent the three design cycles. Ideally, it should be read starting at the upper left, down the entire column, then the middle column from top to bottom and last of all the column on the right. A Dutch translation of the cards is presented in Appendix C.

1. Group of cards of the design cycle of protecting/preserving	2. Group of cards of the design cycle of distributing	3. Group of cards of the design cycle of informing
Legislation product/packaging The drawing up of requirements and the formulation of conseq-uences resulting from legislation concerning the product and/or the packaging	**Customer requirements** Establish the requirements specified by the customer and/ or sales channel in terms of dimensions and equipment	**Design** Design the package (shape, colour, texture, dimension ratios, ...)
Draw up protection requirements Determine the requirements the packaging must meet on the basis of an analysis of the vulnerable parts of the product to be packaged (mechanical, physical, chemical, biological)	**Distribution / transport requirements** Formulate requirements that arise from the designed / established distribution and transport system such as accepted dimensions, weights and volumes, plus the required information	**Optimize use** Optimization of applications from the point of view of ergonomics, such as holding, opening, closing, putting away, etc.
Choice of material Determine the materials to be used for the packaging	**Transport legislative requirements** Draw up requirements and formulate consequences that arise from legislation concerning the transport of the product and/or the packaging	**Adapt product for the market** Change the product in order to promote the sale of the product and packaging combination

1. Group of cards of the design cycle of protecting/preserving	2. Group of cards of the design cycle of distributing	3. Group of cards of the design cycle of informing
Construction Determine the optimum distribution of the material in terms of strength and rigidity	**Distribution / transport system** Design / determine the distribution and transport system	**Determine information** Determine what information must be included on the packaging (recipes, tel./fax numbers for info., composition, alternative methods of use, etc.)
Choice of production technique Establish / choose / work out / determine the production technique	**Establish dimensions** Ensure that the dimensions of the packaging / outer packaging are in line with the distribution system	**Apply the information** Determine / choose / design / establish the method(s) of applying the information (printing, labelling, stickers, etc.)
Adapt product Consider adapting the product so that it is possible to package the product better and thus obtain the most suitable product / packaging combination and therefore provide the product with optimum protection	**Product dimensions** Adjust the dimensions of the product in order to bring the product and packaging combination more into line with the distribution system	**Graphic design** Make a graphic design of the packaging, including all the data to be given on the packaging
Product quantity Determine the quantity of the product(s) to be packaged	**Handling transport packaging** Optimize the transport packaging (the packaging that bridges the distance between the producer and the user) in terms of handling (lifting, putting down, dimensions, weights, etc.)	**Specialties** Include any special add-ons (pre miums, names, stickers, etc.) in the design
Choose packaging system Design / determine the way of shaping, erecting, filling, closing, making non-perishable (food), transporting on the packaging line, etc., (as a whole usually referred to as the packaging system)		
Interim check Carry out an interim check on the results of the programme of requirements	**Interim check** Carry out an interim check on the results of the programme of requirements	**Test the final concept** Examine the final concept against the programme of requirements

Table 6.1 The text of the cards and ordered according to the ideal method, as developed in the preceding study.

6.3.4 The participants

The participants that took part in the five experiments were selected in association with the Netherlands Packaging Centre (N.P.C.). The N.P.C. made a random list of persons out of their database. Invitations were sent to 28 persons who were known to be working in the field of, or had some other involvement with packaging design projects. This figure was chosen out of practical reasons based on the availibility of the room needed. The aim was to get hold of persons with a knowledge of and experience with design methods, for instance, the Eekels and Roozenburg methodology or that of eco-design. Persons were invited that succesfully had followed the course of the N.P.C., or those with university training and being employed in the packaging world.

Of these 28 persons a total of 19 responded and 17 ultimately participated in the experience (see Appendix D for a list of the participants and their jobs). When selecting the participants, an attempt was made to reach a balance in the sample on the following aspects:

- employed as a packaging developer or packaging innovator, or involved in development projects in the field of packaging;
- a good subdivision over the packaging materials: metals, glass, plastics, wood, paper/cardboard, bio-materials;
- from an organization whose main function is in one of the links in the chain: packer, packaging producer, distributor, waste processer;
- employed in one of the following product groups: foods, drugs, non-foods and non-durables, durables and bulk goods and industrial packaging;
- employed in one of the following sorts of packaging: consumer packaging, distribution/transport packaging, bulk packaging;
- from industry or education.

Table 6.2 (see next page) shows how these aspects were divided among the participants. Virtually all the aspects mentioned, with the exception of waste processing, were represented. On the basis of the participants' jobs, and the organizations in which they are employed, the overview shows experience in all the above-mentioned aspects. However, only general knowledge and not specialist knowledge was present on some of the aspects, i.e. paper/cardboard, wood and biodegradable materials. No packer could be found in the category of non-foods non-durables. One of the participants is experienced in industrial design engineering and has extensive experience in eco-design, but only little experience in packaging design. The overview shows that the composition of the group was divided rather equally over the various aspects. In order to test the method it is, evidently essential that the group of participants is sufficiently representative for the field, and that there is variation within the group in field of activity, job, background, etc. This requirement seems to have been adequately met.

Given the time it takes to arrange the cards, it was decided that the five experiments could be carried out on a single afternoon. A 3.5-hour period was planned, including breaks between the experiments, plus an optional extension of thirty minutes.

Expert	Company Description	Industry					Packaging Materials					Packaging			Nature		Extra		Education/ Experience		
		Food	Drugs	Non-food non-durables	Durables	Bulk & industrial	Glass	Plastics	Metals	Paper & paper board	Laminates	Primary	Secundary	Tertiary	Development	Production	Environment	Education	Diploma NPC	University of Technology	>10 years of experience
1	Technical Service Office - Beer Producing Company	X							X	X		X	X		X					X	
2	Glass Manufacturer	X					X									X				X	X
3	Environmental Consultancy Office														X		X			X	
4	Electronic Parts Producer				X			X		X		X	X		X				X		X
5	Food (Wet and Dry) Producer	X					X	X	X	X		X	X	X	X	X			X		X
6	Transport Packaging Consultancy				X					X		X	X		X				X		X
7	Flexible Foils (Laminating and Printing)	X		X				X	X	X	X	X			X	X			X		X
8	Consultancy on Production of Plastic Crates			X		X		X					X		X	X				X	X
9	Electronic Products Producer				X			X		X		X	X		X				X		X
10	Research and Consultancy on Packaging	X	X	X	X	X						X	X	X	X					X	
11	University of Technology, Industrial Design Engineering			X	X	X									X			X		X	X
12	Producer of Packaging (Consumer and Industrial)					X		X	X			X	X		X		X			X	
13	Producer of Plastics	X	X	X	X	X		X				X	X	X	X					X	X
14	Producer of Food / Non-food; Independant Consultant	X		X			X	X	X	X	X	X	X	X	X					X	X
15	Producer of Computer Equipment				X			X		X		X	X		X	X			X		X
16	Producer of Bakery Products	X						X		X	X	X	X	X	X				X		X
17	Producer of Confectionery and Snacks	X						X		X	X	X	X	X	X				X		X

Table 6.2 Overview of characteristics of the 17 participants of the experiment with the cards

6.4 Hypotheses

Our study can be characterized as the development of a method and also as an orientational study, more to generate than to test hypotheses. Nevertheless, it was decided to test the developed method, as much af feasible, through a set of explicit hypotheses.

Six hypotheses have been formulated as given below. Each is succeeded by an explanation and a description of how it was tested. The experiment instructions are given in Appendix E.

H1 Operationality

Using the 23 cards allows the participants to set out their views on (packaging) design methods adequately, completely and in a structured fashion.

Explanation

The experimental cards excercise described in the foregoing is a method of analyzing and assessing the decision processes that usually take place in the practice of packaging. The experiment must offer the freedom to omit certain cards or to add extra cards.

Experiment 1 requires the participant to determine his own card sequence for a specific assignment. Experiment 2 requires him to determine his own sequence for packaging in general. For both experiments the participants must fully accept the method of working with the cards. If participants use most of the cards and add none or only a few of their own extra cards, it may be concluded that the cards experiment presents a reliable picture of their views on design method. In experiment 3 the participants are asked to remove cards until they are left with the absolute minimum number of cards needed. If no cards can be omitted, or if only very few cards are removed, this confirms the outcomes of experiments 1 and 2.

Testing H1

The outcomes of experiments 1 and 2 are used to test H1. The addition or omission of cards is seen as proof of incompleteness respectively superfluousness.

Proof of incompleteness

Reject hypothesis (or do not reject the null hypothesis) if one or more of the following three conditions are met:

- participants add extra cards: if half or more participants, i.e. 8 or more, each add one or more cards;
- if a total of 10% or more of the total number of cards are added (17x23 = 391, i.e. 39 cards);
- if more than 1/3 of 17 (i.e. 6 participants or more) add one or more cards of a similar sort in approximately the same place.

Proof of superfluousness

Reject the hypothesis if one or more of the following three conditions are met:

- participants omit cards: if half or more of the 17 participants, i.e. 8 or more, each omit one or more cards;
- if a total of 10% or more of the total number of cards are omitted (17x23 = 391, i.e. 39 cards);
- if more than 1/3 of 17 (i.e. 6 participants or more) omit one or more cards of a similar sort in approximately the same place.

Both of the above three conditions are plausible criteria, albeit not in accordance with a standard statistics model. The norm is lower if the card contents are compared, 6 instead of 8, because the same content signifies an extra indication and also acts as a warning.

If experiment 3 shows that the number of cards can be reduced considerably, then it may be concluded that the cards experiment is not a suitable method for analyzing and assessing the thinking process of packaging designers. A question of superfluousness, as tested in experiments 1 and 2, will in this case be demonstrated. Should it appear that the number of cards cannot be reduced, it may be concluded that, depending also on the outcome of the test of incompleteness in experiments 1 and 2, the cards experiment is a suitable testing method.

H2 Uniformity
There exists a professional, more or less uniform design method for packaging.

Explanation
This means that there is a convincing level of congruence seen among the 17 participants in how they use the 23 cards and the order in which they arrange them. A certain amount of tolerance must be accepted for diversity among the subjects given the different reasoning that arises due to the different backgrounds and fields of activity.

Testing H2
H2 is tested on the basis of the outcome of experiment 1. To assess the results, any extra cards that have been added are first eliminated. If cards have been omitted, the average theoretical card number is filled in (11.5). Any ties (shared numbers) are included in the calculation in accordance with the appropriate statistical method.

For the acceptance of H2, the following requirements are made on the concordance coefficient Kendall's W:

- significant $\leq$ 1% one-sided,
- >40% of variance (i.e. $W \geq 0.64$) explained through congruence.

H3 Confirmation
The more or less uniform design method (order) of the 17 participants corresponds with the design method developed in this study.

Explanation
Phasing and prioritization was included in our method. The prioritization corresponds with the 23 cards numbered 1-2-3-...-23. Phasing corresponds with the numbering of the cards in accordance with the following stages:

- stage 1: cards 1 - 8
- stage 2: cards 9 - 15
- stage 3: cards 16 - 22
- card 23.

Testing H3
H3 is tested on the basis of the outcome of experiment 1. A distinction is made in accordance with the prioritization and phasing.
The following requirements must be met for the acceptance of H3:
For prioritization: Spearman's Rho:

- significant $\leq$ 1% one-sided,
- >40% of variance (thus $\rho \geq 0.64$) explained.

For the phasing & prioritization (quantitative) Spearman's Rho:
- significant ≤1% one-sided;
- qualitative: determine the phasing according to the participants. In other words: it is quite possible to gain insight into the phasing given by the participants, from the overall picture. It can also be seen how far the participants deviate from our theoretically ideal phasing, and which of the cards are involved.
- It must be noticed that the mean way of laying the cards will only then be compared with the developed method, if the concordance as mentioned at hypothese 2 is sufficient.

H4 Generalizability

The design method followed by a participant can be applied convincingly to a variety of packaging categories (including the vulnerability of the packaged product).

Explanation

In experiment 2 each participant was presented with a list of different products and packages and asked to rearrange the cards to suit the different products and packages. They were specifically asked to state the reason for the difference, and whether it probably applied with regard to a whole group of products or packages. The answers to these questions indicate the generalizability of the method arranged by the participants in experiment 1.

An example is given in experiment 4 on the basis of a specific proposition derived from the method. The participants were then asked to disprove the proposition by putting forward arguments or by giving examples of packaging that disprove the proposition.

Testing H4

H4 is tested on the basis of experiments 2 and 4.

H4 is rejected if, on the basis of experiment 2, more than 1/3 of 17 (≥6 participants) find it not generalizable.

H4 is also rejected if, on the basis of experiment 4, more than 6 participants have put forward examples that disprove the proposition, or if 2 participants each come up with the same example for which the method does not apply.

The variants of the method indicated, as specified by different types of product-packaging combinations, can then be taken into consideration.

H5 Synchronicity

Effectiveness and efficiency benefit if both the packaging and the packaged product are designed more or less synchronously and interactively.

Explanation

Three cards are included in experiment 1 that describe an activity concerning a change made to the packaging contents. A similar card is included in each design stage relating to changes made to the product, in order to reach a better product-packaging combination in terms of protecting, distributing and informing. If these cards are not used, it is an indication that the participants do not explicitly feel that the package and the product should be designed more or less synchronously. If these cards are used, the position they give it, can be considered.

In experiment 4, proposition no. 2 deals specifically with the synchronous designing of product and packaging; the opinions of the participants are specifically requested. The views of the participants on this subject will also be asked in experiment 5: the discussion.

Testing

The hypothesis is rejected if 1/3 or more of the participants (≥6) fail to use one or more of the three 'change product' cards in experiment 1. This test is in fact a specific widening of the test in experiment 1.

The hypothesis is also rejected if 1/3 or more of the participants (≥6) disagree with this proposition in the two different cases that are given as examples.

The hypothesis is also rejected if it appears from experiment 5 that this activity is not placed at all.

H6 Acceptability

A qualitative analysis of the results of the previous experiment may weaken or strengthen again the acceptability of the developed method, in terms of operationality, uniformity, confirmation, generalizability and synchronicity.

Explanation

In experiment 3 the participants are asked to eliminate cards to bring the number of cards down to the number essential for the method. If this cannot be done, then it may be concluded that the 23 cards, numbered from 1 to 23 and, phased as set out in the foregoing, soundly reflect the thinking process of participants and the process steps they follow when designing packaging.

If the participants disagree, or do not agree entirely with the propositions presented in experiment 4 (falsification), then it may be concluded that the main lines of the method, as set out in the propositions, do not hold true.

Should it appear from the discussion, experiment 5, that the participants hold totally different views, then it must be concluded that the 23 cards are not representative of a generally valid thinking method.

Testing

Experiment 3, reducing the number of cards: the hypothesis is rejected if at least 1/3 of the participants omit 3 or more cards.

Experiment 4, falsification: the proposition which forms part of the method is rejected, and therefore also the corresponding part of the hypothesis, if at least 1/3 of the participants say not to agree with the proposition.

Experiment 5, discussion: the hypothesis is rejected if during the discussion it appears that several remarks are made showing that a different method or sequence of activities can also be used.

Mutual dependency of the hypotheses

Table 6.3 shows the mutual dependence of the hypotheses. The first column (on the left) presents the supposition that the hypotheses are rejected. Then a look will be taken at the consequences for the subsequent hypotheses. The supposition is presented in bold print.

	H1 Operationality	H2 Uniformity	H3 Confirmation	H4 Generalizability	H5 Synchronicity	H6 Acceptability
tested empirically by:	experiment 1 experiment 3	experiment 1	experiment 1	experiment 2 experiment 4	experiment 1 experiment 4 experiment 5	experiment 4 experiment 4 experiment 5
If H1 rejected	Rejected	then H2 is not demonstrable	then H3 is not demonstrable	hen H4 is not tdemonstrable	then H5 is not demonstrable	then is H6 not demonstrable
If H2 rejected	Accepted	Rejected	then H3 is rejected	then H4 is rejected	then H5 is not demonstrable	then H6 is rejected
If H3 rejected	Accepted	Accepted	Rejected	then H4 is not demonstrable with certainty	then H5 is not demonstrable with certainty	then H6 is rejected
If H4 rejected	Accepted	Accepted	Accepted	Rejected	then H5 is demonstrable	then H6 is rejected
If H5 rejected	Accepted	Accepted	Accepted	Accepted	Rejected	then H6 is rejected

Table 6.3 Mutual dependence of the hypotheses

The table illustrates that having to reject certain hypotheses has consequences for the demonstrability of subsequent hypotheses, either they must be rejected with certainty, or demonstrability will be less convincing. This must be taken into account when assessing the outcome. The approach of analysis and conclusions on the basis of testing a number, in our case six, hypotheses, evolves into a network of data in relationships and conditions. This may prove to be empirically vulnerable, but the qualitative sources of the method developed justify the hope on, if not complete, sufficient confirmation for the method, as worthy of further development, specification and testing. As mentioned before, hypothese 3, confirmation, will only than be tested if the concordance of hypothese 2, uniformity, is sufficient.

This concludes the section on how the test will be conducted. The next chapter sets out the empirical results. Research question A.2 can then be answered on the basis of those results.

7 Results of the empirical study

Summary

This chapter sets out the results of the five experiments conducted with the 17 participants with packaging skills. The outcomes are used for testing the six hypotheses drawn up in Chapter 6. A description follows as to how, later, other packaging professionals, namely seminar participants, also worked with the card experiments. This latter result also contributed to the assessment of the acceptability of the developed method.

7.1 Results of the experiments carried out by the participants

Attention is paid to the attitude and enthusiasm of the participants and to the outcomes of the experiments with the cards, arranging and placing them in an order for general and specific packaging and reduction of cards; the results of the falsification of propositons and of the open discussion.

7.1.1 The attitude and enthusiasm of the participants

First of all some general information can be given about the participants and the attitude they showed while carrying out the experiments. Enthusiasm to participate was high, the attitude was a critical one and work was carried out seriously. There was complete silence for almost one hour during the cards experiment while the participants were engaged in reading the assignment and then arranging the cards in the order they applied for the assignment.

In one of the experiments the participants were requested to respond to propositions. In this experiment, which was carried out during the second part of the afternoon, the later it became, the fewer the number of reactions. More response was given to the first proposition than to the subsequent propositions. The length of the responses also declined. We can conclude from this that attention started to wane during the afternoon. Caution will therefore be taken when dealing with the responses to the second part of the propositions.

One participant reported that the way, the test had been organized, created resistance to the method developed as presented in experiment 5. He said that this was because the participants were first asked to demonstrate how they themselves worked, and then a method was presented with an air of "now this is how it should be done properly". This resulted in a more critical attitude and arguments were sought to refute the method. This, according to this particular participant, was also the case regarding the propositions in experiment 4, in which substantial steps of the method were formulated.

This critical attitude, actually, was required and beneficial to disprove a hypothesis. The more reasons to disprove the method, i.e. to falsify, the clearer the final conclusions will probably be.

7.1.2 Experiment 1 - Arranging cards

The participants arranged the 23 cards on the basis of a specific assignment; cards were allowed to be omitted or added.

Added and omitted cards

Table 7.1 shows how many participants omitted or added cards, and how many.

Number of extra cards added by participants	Number of participants who added the number of cards	Total number of extra cards added by participants
2	2	4
3	1	3
4	3	12
5	1	5
Total	7	24
Of the whole set	7 of the 17	24 of 391
Cards omitted	Number of times	Total omitted cards
2	2	4
Of the whole set	2 of the 17	4 of 391

Table 7.1 Added and omitted cards

The conclusion that can be drawn from this is that less than half of the participants add or omit less than 10% of the cards. Based on these quantitative data, Hypothesis 1 is not rejected.

Interpretation of the extra cards

The added cards are numbered according to the participant and the sequence according to the method set out by the participant. Whether the text on the card added is more or less the same as the text on a card added by another participant is indicated in italics so no attention has to be paid to the content of this card again.

2 cards added (by participant no. 4)

Participant no. 4 distinguished 4 stages. The following steps were added in the first stage:

4.1 commercial requirements: shape, quantity, weight, packaging, outer packaging, price, margin, appeal, etc.

4.2 production requirements: output, machineability, packaging speed, existing systems or new ones are allowed, etc.

2 cards added (by participant no. 7)

Participant no. 7 distinguished 4 stages. The following steps were added to stage 1:

7.1 environmental requirements

7.2 disposal choice/recycling, reuse, route

These two cards had not been mentioned earlier by other participants.

3 cards added (by participant no. 1)

Participant no. 1 distinguished 4 stages. The following cards were added to the end of stage 1:

1.1 choice between non-returnable – returnable.

This is the second time; the second card added by participant no. 7 (7.2)

1.2 take-back system (recycling).

This is the second time; the second card added by participant no. 7 (7.2)

1.3 product liability.

1.3 had not been mentioned before by another participant.

4 cards added (by participant no. 3)

Participant no. 3 distinguished 9 stages (testing the final concept was regarded as a separate stage, stage 0 is the first stage; this is counted as 9 stages in the analysis). Added by the participant as stage 0, called determine the investments, was:

3.1 determine the investments in: machinery, know-how, production areas, etc.

Added at the end of stage 1 (called formulate requirements) was:

3.2 requirements regarding the environment, possibly linked to the step 'take legislation on product and packaging into consideration'.

This was the third time that aspects relevant to the environment were mentioned as a requirement in the first stage.

Stage 4 is referred to as simulation and consists of the following two steps:

3.3 calculate the cost price

3.4 make simulations (calculations), Life Cycle Costing (LCC) / Life Cycle Analysis (LCA), strength, volume, weight, etc.

3.1, 3.3 and 3.4 had not been mentioned before by any other participant.

4 cards added (by participant no. 5)

Participant no. 5 distinguished 3 stages. The following step was added to stage 1:

5.1 research the competition, what is already available on the market

5.2 aspects of protection: how much freedom do you have / can the designed packaging be protected (patents research)

5.3 economic analysis: can the product bear the packaging costs

Added to the end of stage 1 was:
5.4 establish the provisional programme of requirements
Each of which had not been mentioned before by any other participant.

4 cards added (by participant no. 6)
Participant no. 6 distinguished 2 stages, based on the cards containing the text 'interim check'. The following steps were added to stage 1:
6.1 draw up a programme of requirements
6.2 test (not specified)
6.3 test (not specified)

Added to the end of stage 1 is:
6.4 programme of requirements definitive
Evidently, participant no. 6 had distinguished four stages, because he had added a card with the text 'test' twice.

While the aspect of drawing up requirements had been mentioned earlier on an added card, no comparisons can be made with other cards because they made reference to the sort of requirement that must be drawn up. In this particular case, which requirement had to be tested had not been specified, only that a general test had to be carried out.

5 cards added (by participant no.2)
Participant no. 2 distinguished 3 stages. The following steps were added to stage 1:
2.1 consumer perception
2.2 practical test (immediately prior to testing)
2.3 market testing of consumer perception (immediately prior to testing)

Added at the start of the stage, which runs parallel to stage 1, was:
2.4 consumer requirements

Added to the end of stage 2 was:
2.5 testing of (among other things) the programme of requirements by carrying out a practical test
The programme of requirements was mentioned here too; the emphasis here, however, was on testing the design as to how it is perceived by the consumer.

The additions are shown in Table 7.2

Partici-pant	Addition	In stage	Previously	Number of times	Subject interpretation
4.1	commercial requirements	1	no	1	requirements (1)
4.2	production requirements	1	no	1	requirements (2)
7.1	environmental requirements	1	no	1	requirements (3)
7.2	choice disposal / reuse	1	no	1	starting point (1)
1.1	choice non-returnable / returnable	1	yes	2	starting point or choice (2)
1.2	take-back system	1	no	1	starting point or choice (3)
1.3	product liability	4	no	1	analysis (1)
3.1	determine investments	0	no	1	starting point (4)
3.2	environmental requirements (associated legislation)	1	yes	3	requirements (4)
3.3	calculate cost price	4	no	1	test (1)
3.4	carry out simulations (strength, weight, LCC/LCA, ...)	4	no	1	test (2)
5.1	competition research	1	no	1	analysis (2)
5.2	protection aspects (patents research)	1	no	1	analysis (3)
5.3	economic analysis, relationship with product cost	1	no	1	analysis (4)
5.4	establish provisional programme of requirements	1	no	1	programme of requirements (1)
6.1	draw up programme of requirements	1	yes	2	programme of requirements (2)
6.2	test (not specified)	1	no	1	test (3)
6.3	test (not specified)	1	yes	2	test (4)
6.4	definitive programme of requirements	1	no	1	programme of requirements (3)
2.1	consumer perception	1	no	1	analysis (5)
2.2	testing in practice	1	no	1	test (5)
2.3	market test consumer perception	1	yes	2	test (6)
2.4	consumer requirements	1	no	1	requirements (5)
2.5	test programme of requirements by means of practical testing	2	yes	2	test (7)

Table 7.2 The cards that were added

The sum of this gives the following, Table 7.3, the types of elements added by seven of the participants.

Participant no. 5 gave attention to researching the competition, patents research and an economic analysis of the situation in order to obtain clarity regarding the costs involved. The formulation of the assignment assumed that the costs of the packaging were known, and that requirements had already been drawn up in this respect. The two other aspects were not mentioned in the assignment and could be used in two different places: in the analysis stage and when carrying out checks.

To include all the aspects when drawing up requirements, when formulating starting points, and when carrying out checks, use can be made of the check lists mentioned in Chapter 1. These lists could then include the aspects mentioned by the participants: product liability, patents research, budgets available for investments, market acceptance among consumers, competition research, cost price calculation, determination of environmental impact. Attention can also be given to activities that precede an assignment, especially the choice between returnable and non-returnable, which can be crucial for the starting points of a project. However, this choice is sometimes made while already working on the project, namely after the designs provide more clarity as to the consequences. Obviously, this also depends on the financing available for investments and the strategic decisions taken by the company.

Interpretation of the omitted cards

Two participants decided to eliminate two cards. One participant omitted one card. Omitted cards were:

- adapt the product to the packaging in order to improve protection;
- adapt the product in order to promote sales of the product-packaging combination (mentioned twice);
- create a graphic design;
- adapt the dimensions to suit the packaging.

It was strange to see that one of the participants omitted the card 'create a graphic design'. It is possible that the card had been mislaid or that the person in question had simply forgotten to include it in the schematic representation handed in. All the other cards relate to adapting the product to package it better; twice to promote sales, once to improve the protection aspect, and once to ensure that it fits in a dimension-based system. Some participants apparently have difficulty in adapting a product to suit the packaging.

Hypothesis 1 is not rejected on the basis of this result.

Nor is Hypothesis 5 rejected on the basis of these results. Adapting a product to make it suitable for the packaging, to achieve a better combined end result, is not unknown to the participants; this is illustrated by the fact that only 4 of the 51 cards related to product adaption in total were not used by a total of 3 participants.

The average card arrangements

There are several correlation measures for comparing the order of priority (this is what is established when the cards are arranged), the rank correlation coefficients.

Design activity	Total number
Analysis	5
Testing	7
Requirements	5
Programme of requirements	3
Establish the point(s) of departure	4

Table 7.3 Sum of the type of cards added by seven of the participants

The added cards generally detailed the activities that were already contained on existing cards or were starting points. One card, relating to testing, was added seven times. The aspects that had to be tested were all different. The cards specified 'interim check', and it was up to the participants to decide exactly which aspects had to be tested. The seven cards on testing set out the details of the various checks. The extra cards had been added in different stages. So, the condition for rejecting Hypothesis I was not met.

While they are of no significance for rejecting the hypothesis, certain remarks should be made concerning the other extra cards.

When giving the assignment, the starting points had not been specified in detail. It is therefore quite plausible that this could have been the reason for the addition of the extra cards.

Included in the assignment was the wording: "Several packaging requirements are formulated." This could have led to the deduction that the programme of requirements was not yet definitive, on the basis of which the participants could have concluded that additional requirements had to be formulated.

The enumeration of the requirements (given together with the assignment) did not include any environmental requirements. In the plan that was presented as the actual start of the card experiment, mention was made of requirements in the field of the environment, yet this can easily have escaped the attention of the participants. Probably with good reason, three participants consequently added environmental requirements to the programme of requirements.

One starting point preceding a design project can be the choice of a returnable or non-returnable packaging. Given that this has consequences in terms of potential investments, sustainability, extra functions, etc., it is important that this choice is made at an early stage. This is probably the reason why this option was added three times.

The cards arranged by participant no. 2 focused mainly on the acceptance of the design in the market. This relates to testing aspects and remarks on this subject have already been made.

Other statistical measures quantify the average mutual agreement among the rankings, of a group of 'judges'. For instance, the 'W', the value of Kendall's Coefficient of Concordance, can be determined (Rijken van Olst, 1969; Sprent, 1993). This can also be used to determine the average order in which the participants arrange the cards. A Kendall W > 0.7, is indicative of a strong unanimity, c.q. mutual agreement. In these calculations possible ties (cases of shared order of priority) can be included.

Cronbach's Alpha also indicates concordance by repeatedly leaving out the result of 1 participant and looking at the consequences for the total. This method can be used to obtain an indication of those participants that laid the cards different from the rest: atypically. An impression can be obtained of how many groups of participants arranged their cards in more or less the same order, by carrying out a cluster analysis. The Ward method was used in this respect.

By using Spearman's rank correlation coefficient, rho, the similarity can be calculated between the average order in which the cards were arranged by the participants and the order according to the theoretically ideal method. Spearman's rho can be used for the series of cards numbered from 1 to 23 and also for the individual stages, i.e. the 8 cards from stage 1: card numbers 1 to 8; the 7 cards from stage 2: card numbers 9 to 15; the 7 cards from stage 3: card numbers 16 to 22; and for all cards 1 to 22 arranged in accordance with the 3 stages, and the last card, number 23.

The usual criteria for Spearman's rho and Cronbach's Alpha are that a value of < 0.3 signifies weak correlation; a value between 0.3 and 0.7 signifies reasonable correlation, and a value > 0.7 signifies strong (above 50% of communality) correlation (the square of a correlation coefficient indicates the percentage of communality of two variables).

The question then arises: how should the cards be treated that were not used. There are several options here. Simply disregard them and not take them into account in the analysis. This would have a relatively great effect on the outcome, since a participant that omits one card ends up with the number 22 instead of 23. In that case it would be better as a second option to fill in for an omitted card the average value of ranks, i.e. 11.5. The third option is to attribute the missing card with the average value of the preceding and the next card. However, working in this third way implies working towards a desired end result. After all, the card is omitted, and thus according to the participant it has no place in the method, yet it is still given the average value of the card's position in the arrangements of the other participants.

The analysis shows that only four cards were left out. These four cards will actually not have such a great effect in a total of 391 numbers (17 times the value of 1 to 23). Hence it was decided, for the sake of curiosity, to fill in both the value of 11.5 as well as the average value of the other participants. This gave no difference in result.

The average order in which the participants arranged the cards		
1. customer requirements – sales channel, dimensions, distribution	2. Analysis + requirements relating to protection of the product	
3. requirements + consequences of legislation governing product and/or packaging		
4. determine amount of product		
5. legislation governing transport of product and/or packaging		
6. requirements of distribution + transport system, dimensions, weight, volume, information		
7. determine / design the distribution and transport system		
8. determine material for the packaging	9. packaging production technique	10. choice of packaging system
11. bring the dimensions into line with the distribution system	12. determine what information must be included on the packaging	
13. Adapt the product to the packaging in order to offer improved protection	14. Adapt the dimensions of the product to the distribution system	15. design the package
16. optimum distribution of material in terms of strength and rigidity	17. optimize applications	18. Adapt the product in order to boost sales of the product and packaging combination
19. Optimize the handling of transport packaging		
20. determine how information must be applied	21. make a graphic design	
22. include any special add-ons in the design		
23. examine the final concept		

Table 7.4 Average order in which the participants arranged the cards, based on the integer of the average value (read the rows from left to right, then the next row)

Concordance among the participants

Calculations show that Kendall's W is 0.68 and Cronbach's Alpha, 0.97. This implies concordance among the participants, but not a strong one, according to Kendall (in that case W has to be larger than 0.7), although a strong concordance according to Cronbach (if Alpha > 0,7). On the basis of these results Hypothesis 2 is accepted, or phrased more accurately: the corresponding null hypothesis is not rejected.

To what degree did participants follow the ideal method?
Spearman's rho between, on the one hand, the average ranking by the participants, and on the other hand the theoretically ideal ranking, for the cards numbered from 1 to 23, is 0.74, signifying strong similarity. This calculation could be made because the concordance was high enough.

- Spearman's rho for stage 1 is 0.52, showing reasonable accordance.
- Spearman's rho for stage 2 is 0.96; again showing a strong convergence. For stage 3 it is 0.75; a strong accordance again. For the total, based on phasing, we see a value of 0.74; this again signifies strong similarity.

There was less accordance about stage 1, the score is considerably lower. This was contrary to expectations. After all, it was assumed that the greatest amount of duplication would be found for those functions that have been fulfilled for the longest period of time. In stages 2 and 3 and for the total, both with and without phasing, concordance among the participants and similarity with the method developed was stronger.

It can be concluded from this that the 23 steps of our proposed design process strongly resemble those followed by the participants, implying that Hypothesis 3 can be accepted. With regard to the phasing, concordance was less convincing for stage 1 only. This leads us to conclude that Hypothesis 3 does not apply to the phasing, and that the reason for this is to be found in the design activities in stage 1.

Looking at the actual contents of the cards in the first stage two cards fall out of 'the picture'. These cards are *'determine the amount of product'* and *'packaging construction, determining optimum strength and rigidity'*. All 17 participants included the activity '*determine the amount of product*' in the first stage, thereby deviating from our method. *'Determining the optimum strength and rigidity'* was included in the second stage by 8 of the 17 participants, by 2 in the third stage and by 5 in a fourth stage. Many participants carry out this activity after the design has to a large extent been determined. The aspect of construction is apparently seen by these participants as 'optimizing' after the design has been determined within certain boundaries. Construction is in fact an activity that is carried out interactively with choosing the packaging system and the material, but the term 'optimization', used to define the word 'construction', may have given the participants other ideas. It is also quite possible that the participants optimize the design after the most important requirements have been defined.

In stage 2 it is particularly the activity 'optimize the handling of (transport) packaging' that deviates. This is also done in stage 3 by four participants and in stage 4 by five participants. Here too is it possible that the word 'optimization' might have played a role, or it might be assumed that participants incorporate an 'optimizing round' after completing the (transport) packaging design.

In stage 3, a major difference with our method is seen in the activity '*determine what information must be included on the packaging*'. This was placed in stage 1 by seven participants, by two participants in stage 2 and by six participants in stage 3. The remaining four participants placed this activity in a fourth or fifth stage. This activity can be seen as specifying a requirement in the sense of: all of this information must be included on the package. What must be included on the packaging is obviously known earlier. It is easy to imagine that participants will already have taken up this activity in an earlier stage, but all the detailed information a graphic designer must include, only becomes known after all the decisions regarding method of protection and distribution have been made. It is for this reason that these decisions were placed in a third stage in the developed method. For that matter, it is easy to imagine that this activity partly runs or could run parallel with other activities.

When determining Cronbach's Alpha it appeared that participant no. 7 held very different views from the rest of the participants, influencing the result noticeably. Without candidate no. 7, the value of Kendall's W increased from 0.68 to 0.72. This participant probably works in a totally different way. It is quite possible that the procedure he follows is equally as efficient and effective as the procedure set out in our theoretically ideal method. Hence, this participant was contacted later to find out why he works as he does. He explained then that he first looks at the requirements made by the customers, and that he thereafter attempts to meet those requirements in particular. His firm uses its own transport on its premises. Consequently, all requirements concerning distribution systems, transport requirements, etc., are only taken into consideration at a later stage. The Marketing department determines the products, the strategy (own brand or own label) and the packaging in consultation with the purchasing and production specialists. Only then are the consequences for transport taken into account. Here it is a strategic choice not to allow the product to be influenced by transport requirements. If it appears later on that the design is particularly disadvantageous in terms of transport, the design is rejected without further thought. Distribution aspects are dealt with in the testing stage, but they apparently play no role in the design process itself.

Remarkably, that the participant who confessed not to have many packaging skills did not appear to follow a different method, relevant when determining Cronbach's Alpha. Leaving out him or participant no. 7 was rejected, and, actually, would have had little or no effect on the testing of the hypotheses.

A cluster analysis, carried out according to the Ward method, shows that two groups of 8 verus 9 persons arranged the cards differently. This is an interesting element to investigate. The joint characteristics of the participants in the two groups might be able to explain this. So the list of the origins and field of activities of the participants was grouped and surveyed.

When comparing the two clusters, two aspects stood out:

- cluster 1 is mainly concerned with foods and has more working experience;
- cluster 2 has a broader background in terms of field of activities.

Then the average ranking of cards was determined for both clusters. It appeared that the card, containing the text '*determine what information must be included on the pack-*

aging', was placed in a position that differed on average by 11.5 steps. The 'judges' of cluster 1 included the card earlier than those of cluster 2 and proved to arrange cards less in line with the developed method. This could be explained by the importance that the food sector places on the graphic design aspect. There it is stressed that it is the packaging that has to sell the product. It also appeared that cluster 2 consists of participants who are mainly concerned with packaging concepts that can be produced from a wide variety of different materials, that they are generalists and probably have no need to go into great depths regarding the design process, mainly because graphic designers do the rest or simply because graphic design is of less importance.

Other cards that were placed on an average of 3 to 4 steps earlier by the persons of cluster 2 are:

- choice of production technique;
- adapt product to offer it better protection;
- construct the packaging on strength and rigidity;
- choice of material.

These four cards are very much interrelated. After all, the packaging production technique has strong links with the choice of material and both have strong links with the packaging construction. And in order to reach an optimum situation, the product must be taken into consideration.

The participants in cluster 2 placed the four cards referred to above earlier than persons in cluster 1 and more in line with the developed method. An explanation might be found in cluster 1, which placed the other cards earlier. The following cards are placed on average more than two steps later by the participants in cluster 2:

- distribution and transport requirements;
- requirements imposed by transport legislation;
- determine the distribution and transport system.

Because the participants in cluster 1 mainly work with foods, they probably have to take retailers into special consideration. Latter impose strict requirements on how the product is delivered. For instance, the fact that as many packages as possible must fit into the packaging dimension-based system. This is probably more important for cluster 1 than cluster 2, and thus the participants in cluster 1 are more likely to bring forward the associated activities or requirements.

The importance of the requirements imposed on the packaging seems to differ slightly among the various product groups. Consequently, the participants tend to bring some of the requirements more to the fore or they push them more to the back. Participants in the food sector are more likely to give consideration to the information that must be included on the packaging, and also relatively more consideration to the requirements relating to the distribution of the packaged products. Participants with less of an involvement in the food sector pay attention to distribution requirements and to graphic design at a later point in time, and tend to focus more on the choice of materials and in an earlier stage to the packaging construction.

The purpose of the cards experiment was not focused on finding out exactly when the specific requirements are drawn up, but rather on the actual decision-making regarding a certain requirement. After all, as was set out in the introduction of the assignment, the requirements had already been established. It is quite easy to imagine that the outcome of the cards would have been even more in line with the method if specific requirements had been formulated in the assignment briefing.

Split-half reliability

Because the group of participants was relatively small, and because repeating the experiment has its limitations, a split-half reliability test was carried out, in order to ascertain the consistency and reproducability of the data and the results found. Participants 1 to 9 were compared with participants 10 to 17. From the analysis we see no demonstrable difference between these two groups. The value of the Guttman Split-half is 0.96; the value from Spearman-Brown (both Equal Length and Unequal Length) is 0.97. Cronbach's Alpha was determined for both clusters to find out the difference in concordance among the persons in both clusters. The values found were 0.9473 and 0.9301 for both clusters, showing a high level of concordance. Because little difference had been found, no split-half reliability test needed to be conducted on all the potential combinations of two groups.

From the above it may be concluded that the experiment has produced a reliable and, probably reproducible, result, and that the outcomes may be interpreted as such and allow for some generalizations of the conclusions.

7.1.3 Experiment 2 - Sequence for general packaging

The participants decided on the sequence for general packaging.

Hypothesis 3 was not accepted for stage 1; it was however accepted regarding the order from 1 to 23. This means that Hypothesis 4 cannot be simply accepted if the outcome regarding the order from 1 to 23 is incorrect.

The participants stated the following on the effect of the nature of the product and/or the packaging. The terminology used here was taken from the comments of the participants:

Comments made by the participants	number
method remains the same	5
no substantial difference / basically the same	4
more or less the same / little difference / for the greater part the same	6
certain requirements have priority depending on the product	1
certain requirements become invalid depending on the product	1

Table 7.5 Comments on the general applicability of the design method

The following comments were made:

- minor differences can exist in the sequence, depending on the vulnerability of the product;
- the activity focused upon can depend on the nature of the product and/or the packaging;
- changes made to the product can in many cases only be minor ones;
- the following exceptions were mentioned:
  - display packaging (graphic design brought more to the fore);
  - returnable transport packaging for distribution pooling systems (aspects of relevance in this respect are: modular systems, automatic handling and cleaning, storage, etc.);
  - bulk packaging (less appeal value, and thus various steps can be omitted with);
  - medical applications, certain aspects can be mentioned; exactly which aspects were not specified;
- which activity can be omitted depends on the sort of assignment and the assignment background; this is because a choice has already been made for this activity.

Interpretation

None of the participants stated specifically that the essence of the method differs when a certain product and/or a certain packaging has to be designed. Nine of the 17 participants said that there were no substantial differences or no differences at all, and 15 said that there were no or no substantial differences and that their own method was basically the same, despite the product or sort of packaging. Most of the comments related to the possibility of skipping certain steps because they were less important or of no importance at all for the packaging in question. It is probably always possible to skip steps, especially for transport and bulk packaging, such as finding out what information must be included and making a graphic design. Obviously, as one of the participants rightly remarked, it can be a question of certain choices having been made already. These must therefore be included in the starting points for the project so that these choices are known and will not have to be made in the middle of the project.

Display packaging can in many cases be regarded as a cardboard addition to the shop shelf, an addition which attracts attention, even if only by breaking the monotony of the full shelf itself. The protective function of display packaging for the packaged product is in many cases very limited. The description of functions can be used in the project's analysis stage to see how far the steps mentioned are relevant to the display packaging, and in many cases it will probably appear that several steps can indeed be left out.

A different approach is to check the display packaging against the specific definition of the packaging. A display packaging will in many cases not be added to a product for the purpose of protecting and preserving, but mainly to promote sales. Most display packaging is not packaging at all, if we look at our definition of packaging, since it makes no functional contribution whatever towards protecting the product. In such a case it is more of a cardboard shelf. Display packaging such as display boxes, boxes that display the products inside when they are open, and from which the consumer may make his purchase, can usually be referred to as packaging.

It can be concluded from the results that Hypothesis 4 can be accepted. The way in which the participants arranged the cards, was seen as being generic for numerous products and packaging. Despite the fact that Hypothesis 3 is not fully accepted regarding phasing, the outcome is such that Hypothesis 4 can definitely be accepted. However, the definition of packaging must be treated with caution. Display packaging forms a category of packaging to which the method need not always apply.

7.1.4 Experiment 3 - Reduction of cards

The participants reduced the number of cards down to the minimum to design a packaging. The results show that there are large differences in the outcomes of this assignment. The number of cards varies from 2 to 23.

The participants used the following number of cards: [2], ([2]), [3], [5], 8, 10, 13, 14, (14), 15, 16, (16), 18, 18, 18, 19, 20, 21, 21, 23, 23.

If the number is placed between square brackets, the corresponding participants used their own formulations of activities, i.e. they did not use the 23 cards. If the number is placed between round brackets, the corresponding participant came up with more than one answer.

One participant formulated his own activities under one heading on his own cards and arrived at 5 activities. However, he also stated that there were no steps that could be left out, and thus 23 cards could be attributed to this participant (5 is placed between brackets, 23 is not).

Three other participants came up with two solutions. The participant that used 10 cards also made a second variant by using two cards that contained his own formulations (round and square brackets). One of the participants who had used 23 cards said that nine of the cards could be assumed as premises, and that it could therefore be done with 14. The participant that used 16 cards stated that there were another two activities that could be carried out later, and, consequently, 18 could be seen as the result for this participant.

Several participants stated that the cards could be used in combination, or that one card ensues directly from another and can therefore be brought under the same heading, sometimes under the heading of an existing card. For instance, it was stated that making a graphic design could include the activities *'determine what information must be included'* and *'determine how the information must be applied'*.

As said above, blank cards were used in three cases to formulate activities which in fact were combinations of activities. The most extreme were 'design a packaging' and 'test the end result'. Although the number of cards had been reduced, the abstract level taken into consideration, then the actual number of activities had not. This does not present us with an unambiguous picture of the most essential activities. The comment that all the steps were essential and that it was therefore impossible to reduce the number of steps, was made three times. At most, it might be that certain steps were known in advance, such as the choice of machine, material, method of distribution, etc. Six of the 17 participants ended up with a reduction of more than five activities. Nine participants came no further than a reduction of five cards, and two participants formulated a combination of activities, thus making a complete new set of cards.

It can be concluded that the 23 cards present a sufficiently detailed representation which is generally applicable. On this basis, Hypotheses 1 and 6 are not rejected.

7.1.5 Experiment 4 - Falsification of propositions

Five propositions, specific to the method, plus examples, were handed to the participants for falsification. See Appendix E for the complete descriptions. Hereafter the proposition is repeated and the reactions are enumerated.

Proposition 1
A packaging design process is more effective and efficient if undertaken in the shown order and each step is succeeded with a go-no-go decision:
- *design a packaging concept that, if wished, protects the product;*
- *work out the packaging concept such that the product can be distributed;*
- *work out the packaging concept so as to promote sales.*

Reactions to proposition 1 are presented in table 7.6.

dairy drink example	n participants	
agree	5	29%
do not agree	9	53%
agree in part	3	18%
don't know	0	0%
	17	100%
television example	**n participants**	
agree	9	53%
do not agree	7	41%
agree in part	1	6%
don't know	0	0%
	17	100%

Table 7.6.Reactions of participants to proposition 1

The participants made the following remarks:
- distribution is certainly just as determinative as the aspect of protection: if the customer does not want it, then it is equally as unsaleable as when there is inadequate product protection;
- does the most efficient and effective design process also result in the best packaging?

- sales promotion comes after protection and distribution;
- the box or packaging plays no role in the purchase of durable goods;
- the milk bag was mentioned twice as an example: high level of protection, good distribution but not attractive in the store (leakage) for the consumer (use);
- that use aspects should be taken into consideration earlier in the process, was mentioned once.

Interpretation

Considering the fact that nine persons disagreed with the proposition it must be concluded that the phasing used in our method gives rise to questions and doubts. Examples were put forward in which one of the stages was omitted entirely or followed inadequately, or need not be included at all. This in fact confirms our method of approach, in the sense that it confirms the order in which decisions are made. The aspect of phasing must be looked at in greater detail. Hypothesis 3: Confirmation, is only accepted in part. Nevertheless, no examples were mentioned to the disadvantage of Hypothesis 4: Generalizability.

Proposition 2

When designing a package the product must (also) be seen as a variable, otherwise it is impossible to achieve the best possible situation in terms of engineering, costs and the environment.

Reactions to proposition 2 are presented in the table 7.7.

monitor	n participants	
agree	14	82%
do not agree	1	6%
agree in part	2	12%
don't know	0	0%
	17	100%
carbonated drinks example	**n participants**	
agree	8	47%
do not agree	6	35%
agree in part	1	6%
don't know	2	12%
	17	100%

Table 7.7 Reactions of participants to proposition 2

The majority of the participants agrees with the proposition. Nevertheless, they added that it should be possible to adapt the product within certain limits (costs, the environment, logistics, design, function, etc.).

One comment that was made in connection with the carbonated drinks example was that food could not be adapted because of the effects on taste.

Interpretation
As set out in the method, adaptation of the product will in practice only be possible within certain limits. With regard to foods, the product will already have been adapted to the packaging, as pointed out above, and *vice versa*. Consequently, Hypotheses 4 and 5 need not be rejected.

Proposition 3
With regard to perishable products, the amount packaged determines the amount of environmental load to a large extent.

Reactions to proposition 3
Proposition 3 looks at the relationship between the amount of packaged product and the potential environmental impact, Hypothesis 1. Kooijman (1996) deals with this proposition in his book *Verpakken van voedingsmiddelen* [The Packaging of Foods]. This proposition was included to see how those participants from a background other than foods think in this respect.

Reactions are presented in table 7.8.

amount	n participants	
agree	15	88%
do not agree	0	0%
agree in part	0	0%
don't know	2	12%
	17	100%

Table 7.8 Reactions of participants to proposition 3

Two participants gave a 'don't know' response, the others agreed with the proposition. The comments made relate to:
- optimization of package size and contents;
- packaging that can be properly sealed;
- references to Kooijman's book;
- product residue left inside packaging;
- partitioning of the product packed into seperate parts fitting the average use;
- choice of material;
- the salesman's objective which, generally speaking, is to sell as many products as possible and is not to spare the environment.

Interpretation
It is obvious that the participants have an understanding of the role of packaging in relation to the amount of product; they are also evidently acquainted with the cases set out in Kooijman's book and with the current insights in the role of packaging in the total environmental load. No specific comments were made as to whether or not this proposition applies exclusively with regard to foods, or non-foods, durables, etc., Hypothesis 4 therefore need not be rejected.

Proposition 4

The choice of material, and everything associated with that choice (such as production technique, design options and options relating to dimensions, the packaging system, construction), determines whether an adequate guarantee can be given in terms of required product quality.

Reactions to proposition 4 are presented in table 7.9.

television	n participants	
agree	11	65%
do not agree	5	29%
agree in part	0	0%
don't know	1	6%
	17	100%
dairy drink	**n participants**	
agree	9	53%
do not agree	5	29%
agree in part	1	6%
don't know	2	12%
	17	100%

Table 7.9 Reaction of participants to proposition 4

The majority of the participants agreed with this proposition. It was pointed out that matters such as realization, design, material distribution, etc., are equally as important; otherwise the solution can be disappointing. It was also pointed out that it must be possible to find a suitable, existing material.

Other aspects that play a role are: temperature during distribution, aseptic techniques, sterilization techniques, packaging system, etc.

According to one comment: on the contrary, a creative designer should not accept this proposition, because the designer should search specifically for new materials for existing techniques, or for new techniques for existing materials.

Interpretation

As defined in our theoretically ideal method, the choice of material plays a central role in the first design cycle. It is evident that the distribution channel also plays a role when determining the potential materials. Requirements can be imposed regarding e.g. temperature, aseptic packaging, etc. Such circumstances impose requirements on the way in which, and the extent to which, the product must be protected.

A designer will always attempt to find materials and techniques within the conditions specified for the project, in order to comply with the specified requirements. In other words, materials will always play a dominant role in the first design cycle irrespective of whether it is an innovation or a redesign. The participants' reactions again confirm

Hypothesis 3. It may be concluded that the prioritization pointed out earlier in the experiment with the cards, still demands attention.

Proposition 5

If the potential methods of protecting the product are known, and the concepts have been adapted to feasible methods of distribution and points of sale, then the exterior dimensions (height, breadth, depth) will be known.

Reactions to proposition 5 are presented in table 7.10.

steps	n participants	
agree	10	59%
do not agree	4	24%
agree in part	1	6%
don't know	2	12%
	17	100%

Table 7.10 Reactions of participants to proposition 5

The participants' comments:

- the machines and the aspect of convenience also play a role; for example the new Albert Heijn fruit juice packaging (same distribution system, different dimensions);
- solutions can vary extensively and must all be presented;
- breadth and depth are determinative, the height is variable;
- standardization can carry more weight than sales promotion such as e.g. specially designed containers for spareparts for the car industry;
- consumer storage can be an important factor;
- variation in dimensions can be a distinctive element.

Interpretation

The comments made by the participants here mainly relate to the preconditions that ensue from the functionalities. As in the previous experiments, here too the participants have detailed the activities described in the method. The participants felt that the case descriptions were very brief and they had consequently elaborated upon the activities which they felt should not be forgotten but which had not been explained in detail.

This proposition also relates to the element of phasing. Although Hypothesis 3 cannot be accepted in full, it need not be rejected completely either.

If a closer look at the results is taken, it becomes evident that the level of attention, concentration and enthusiasm probably declined over the period of time it took to read through the propositions. The percentage of participants that agreed with the propositions was higher in the second half than in the first half (53% as opposed to 66%). The number of 'don't knows' increased from 2 in the first half to 7 in the second half (12% and 41% respectively). The number of comments also dropped considerably from an average of 12.8 respondents in the first half to an average of 7.4 in the second half (75% and 44% respectively). The length of the comments decreased radically towards the end of the experiment. If all reactions are added up, then 81% agrees with the propositions. Whereas this is more than 2/3 of the participants, there are no convincing conclusions that can be attached to this.

However, on the basis of these results Hypothesis 6 need not be rejected.

7.1.6 Experiment 5 – Presentation and open discussion

General evaluation of the method, on the basis of a presentation of the method using sheets and with a discussion both during and after the presentation.

At the end of the afternoon the method was presented on sheets depicting a step-by-step schematic representation of the structure of the method, plus the relevant explication. An open discussion was held both during and after the presentation.

One important element of this discussion was the difference in method of approach used for development and design. Several packaging participants said that they "*...develop packaging on the basis of proven techniques and apply solutions that are known to work well*". Innovations within the scope of the assignments they undertake in practice are not, or only to a small extent possible, because new solutions have not yet been proven. The risk of damage and product loss is deemed to be considerable. These participants consequently follow the three stages presented more or less in parallel. People with packagings skills know partial solutions to quickly produce a single concept for presentation. It is possible to asses the economic feasibility and risk of failure of this concept. Alternatives for uncertain aspects can usually be found. Certainty of success is apparently important.

Designers that search for innovative solutions work in a different manner. Assignments generally imply searching for (substantial) improvements on the existing solution(s). Because the requirements will be specified differently, it is important to have a good understanding of the requirements. In those cases where the developer is able to work on a limited programme of requirements, the designer wishing to innovate needs more functional insight.

The level of abstraction for finding new innovative solutions will be higher than in the case of development. It is therefore essential to have a good insight into the functionalities.

To obtain this insight, any designer wishing to innovate can follow the three design cycles. This will enable him to draw up requirements and formulate the essential functions. Subsequently, he can use the method as explained. In other words, the three design cycles are thus gone through twice. The first time, in the analysis stage of the design process in order to define requirements and functions; the second time to elaborate on the concepts that ensue from the synthesis stage in three subsequent design cycles.

This proposition sheds some interesting light on the testing of the phasing. It is quite possible that a substantial number of the participants arranged a large number of the cards earlier in the process, because they assumed these were related to requirements. Particularly, this was done by those persons working for the food sector as was illustrated in the cluster analysis. It was also encouraging to see that none of the participants came up with a different method of approach or method, and that the order of activities was thought to properly reflect the situation in practice. On the basis of these results, Hypothesis 6 needs not be rejected either. The difference between development and design, should, however, not be forgotten.

7.2 Introducing the packaging design method to participants of seminars

To increase the level of certainty regarding acceptance of the method, the experiment using the set of cards was repeated at seminars on the subject of Pollution Prevention and Innovation in packaging design. This meant that a larger number of people repeated the experiment, with the added advantage that it was now accompanied with an instruction manual. A total of four seminars, each focusing on a different perspective, were held in the autumn of 1997 and the spring of 1998. All were organized by the Netherlands Packaging Centre, Gouda.

The seminars in question dealt with the following subjects and were attended by people in the same target groups: European trade and distribution, Food, Retail (non-food) and Preventive & Innovative Packaging (general, in response to an information session on the Packaging Covenant II). The objective of these seminars was to give extensive information about the Packaging Covenant II and EU legislation governing packaging and packaging waste. Essential requirements contained in EU legislation were dealt with extensively. To offer the participants a tool for helping them to comply with this legislation, and for the redesign or adaptation of packaging, it was decided to present the developed method in brief. The participants were asked to split up in groups with a maximum of five persons. According to the list with functions of the participants and the companies where they are employed, they are responsible for packaging in some way like the purchasing of packaging, the responsibility for the implementation of EU legislation or packaging design. Persons who had already joined in the previous experiments, were asked not to join the groups.

To this end, the essential requirements were translated into specific activities that were included on the cards. These activities were :

- to choose the production technique that makes use of the least possible material;
- to adapt the packaging shape to suit the amount of material;
- to increase the amount of product to be packed;
- to use mono-material;

- to construct the packaging in such a way that the materials used can be separated for recycling;
- to use recycled material where possible;
- to choose packaging materials that have a low impact on the environment.

For the sake of preventing a rather long session of the exercises, the number of cards was reduced. This was done by eliminating cards or by combining the text on those cards containing activities we had reasons to assume to be irrelevant in the target group sector. For European Trade and Industry, for instance, we reduced those cards containing activities in the field of graphic design. All cards containg aspects concerning the graphic design were combined to one card with the text: take care of the graphic design. In this way the number of cards for the four seminars were reduced to 17 or 18.

The packaging participants still took approximately three quarters of an hour to arrange the cards.

The assignment given to the participants was to arrange the cards in the right order. After that, they had to insert the cards that ensued from the essential requirements. The normal cards were coloured white and the cards with the essential requirements were coloured red. The fact that all participants had been given a brief description of the method made the experiment easier to carry out and gained time. If the participants disagreed with the order of activities they had been presented with, then this would become apparent from the order in which they arranged the cards. The additional cards all belong in stage 1, linked to choice of material and choice of amount of product. Activities relating to choice of material are again seen in stage 2, partly in connection with the method of transport and customer requirements.

It was made clear that variations were welcome in this experiment too, and that cards could also be omitted or added. This approach made it possible to observe and measure reactions to the method of people involved in packaging.

The hypotheses to be rejected is derived from hypotheses no. 6:

The design method, with a reduced number of cards as adjusted to each target group, is operational and acceptable.

Test

The hypothesis will be accepted:

- if at least 90% of the groups, i.e. 22 of the 24 groups, arrange the cards in three separate stages;
- if 5% or less of the cards at most are omitted or added;
- if at least 95% of the added (red) cards are included in the first stage by 24 groups (i.e. 24 x 6 x 0,95 = 137 cards).

Result
All in all, 24 groups of, on the average, 5 participants, in total 120 persons, did this experiment. The cards were arranged in three stages by 22 groups, in two stages by one of the groups, and in four stages by one group. Of the total 192 (24 x 8) extra cards, three were not used by two groups in the first stage. So it can be concluded that 98% of the cards were used in the first stage. 22 of the 24 groups (91.6%) worked with the cards according to our developed method.

This means that there is a high level of acceptance of the method in the packaging world. The hypotheses is not rejectd and this again firmly confirms Hypothesis 6.

As last contribution to confirming the utility of the developed method, two examples can be given of new design projects in practice, be it within the frame of Masters studies, and whereby the method was followed and evaluated.

D. Wijnans used the method, still in a preliminary stage, for his MSc thesis in Industrial Design Engineering. This involved a project for the design of a packaging- and distribution concept for a company in Costa Rica (Wijnans, 1999). His conclusions were that the method "has been helpful in assessing the current packaging", gave "much insight in the packaging system", and was "useful in determining the demands and requirements of the new packaging system" (p9-78, p9-79). Because of the results of the analysis phase, the first and third design cycle were, however, not further applicable in the project.

Also M. Baas used the method for his MSc project at the same Subfaculty, also in Costa Rica (Baas, 1999). He concluded that "the approach is applied succesfully. Not as a standard design structure, but more as a checklist en background process", "the three design cycles (...) are applied three times in this project: in the generation of ideas, completing the concepts and finally in setting up a marketing approach" (p111).

7.3 Conclusions

Hypothesis 1 Operationality
Participants can use the 23 cards to express their views on their design method sufficiently, completely and structurally.

Hypothesis 2 Uniformity
There is a professional, more or less uniform design method for packaging.

Hypothesis 3 Confirmation
The more-or-less uniform design method (order) used by the 17 people with packaging skills is not entirely in line with the design method developed in this study.

The sequence of the various steps is right, but the phasing indicated is not always completely correct. The activities in the first stage still give rise to questions. This is probably because participants engaged in work in the foods sector give consideration to customer requirements and requirements from the distribution channel in an earlier stage than those who do not work in this sector. This imperfection is solved if the method is run through twice: the first time to select the requirements, the second time to make the decisions.

If a packaging has to be developed routinely, then the stages must be undertaken more in parallel than if a packaging is to be designed innovatively. In the case of development of re-design, participants work on the basis of existing solutions that are combined. In the case of innovative design, however, the requirements receive more specific attention. This also means that a solution is worked on at a higher level of abstraction.

Hypothesis 4 Generalizability
The design method is convincingly applicable in many categories of products and packaging.

One exception here is display packaging. This is because display packaging is in many cases just an extension of the shop shelf and, consequently, limited in functionality and in the phase of the packaging chain.

Hypothesis 5 Synchronicity
When both the packaging and the product are designed independently and synchronously, both effectiveness and efficiency of process and outcome benefit.

Hypothesis 6 Acceptability
Qualitative analysis of the results of the previous experiments again confirm the acceptability of the developed method in terms of operationality, uniformity, confirmation, generalizability and synchronicity.

Finally the objection could be made that using the developed method will cost more time than not using it. Considering that this method is a representation of the design process, as is more or less already being followed by packaging designers or people with packaging skills as proven in this chapter, this objection is probably incorrect. Systematically following a method, on the contrary, usually results in saving time. We can also claim that the developed method leads to higher quality solutions. As said before: enhanced efficiency and effectiveness.

This answers research question A.2. The developed method of approach by using the cards, augmented by several other experiments, came up with a picture of how packaging designers and participants set to work in practice.

On the basis of the results in this chapter, research question A: "What method can packaging designers use to design packaging effectively and efficiently, such that it incorporates all the essential functions, and as many of the desired functions as possible?", can be answered. This is done in the following chapter.

8 *A first version of a method for packaging design*

Summary

The principal question of this study will be answered in this chapter. The outcomes of the different research questions are combined and used as a basis on which to define a first version of a method for packaging design in which as many packaging functions as possible are combined.

8.1 Introduction

This chapter answers research question A: What method can packaging designers use to design packaging effectively and efficiently, such that it incorporates all the essential functions, and as many of the desired functions as possible? The conclusions as found in the foregoing chapters are combined in this chapter. When possible, the developed method will be presented by schedules and reference will be made to preceding chapters.

8.2 A method for packaging design

A design process works effectively and efficiently if the process is structured. Among others, Roozenburg and Eekels' basic design cycle (1995) is presented in Chapter 2, a method for structuring design processes which is commonly used at Delft University of Technology, Subfaculty of Industrial Design Engineering (DUT-IDE) and which has proven to be succesful. This basic design cycle, which consists of the activities: analysis, synthesis, simulation and evaluation, was taken as the starting point for the development of the method for packaging design.

The basic goal when developing packaging is that it will be added to a product in order to provide that product with economic benefits. The preferable method assumes that both the product and the packaging are developed synchronously and interactively, given that they are strongly connected, both physically and functionally. This presents innovative opportunities that can be beneficial in terms of both cost and environmental load. The packaging – which will usually contain the product, keep the product together, keep out any external influences and/or protect the environment outside the packaging from the product, - is therefore seen as a means to ensure that the product can ultimately be used in the way it is intended to be used and in the intended situation.

The first steps in the method for packaging design are the same as those in the basic cycle mentioned above. Reference is made to tools, some of which have been developed in this study and which are added to the existing methods. The first three steps of the basic design cycle are carried out. Subsequently, a detailing stage has been incorporated. The stages are discussed in the following.

8.2.1 The analysis stage

The goals of this first stage are understanding the problem and formulating the requirements, wishes, limitations and finally coming up with an acceptable problem definition.

Activities are:

- Examining the preliminary problem definition.
- Drawing or describing a sketch, possibly combined with visualisations of the solution, before moving on to draw up a programme of requirements as recommended by Dirken (1999) and practiced by some packaging designers.
- Setting the criteria that must be met by the solution to the problem; many methods are available to this end, such as process trees and check lists (see Chapter 2).
- Setting up a function description; Dirkens' model (1999) can be used to distinguish the use functionalities and the product functionalities (see figure 3.1 and Chapter 3). The use functionality is divided into three main functionalities: conserving/protecting, distributing and informing; these are then subdivided into sub-functions, functional aspects, and ultimately into potential requirements. The detailed lists of use functionalities were presented in Chapter 5. By using figures 5.1, 5.2, 5.3 and 5.4 functions and requirements can be formulated.
- Brezet (2000) works out the problem definition by first of all designing a business which is able to deliver the product required, and in doing so he also looks at whether the problem can (partially) be solved by a service instead.
- Examining the vulnerabilities of the product itself; hereto use can be made of the product vulnerability listings contained in section 4.4.
- Taken into account any legislation that may apply to the product to be packaged and the sort of packaging in good time. Use can be made of the list of the aims of legislation in the field of packaging, which includes many regulations applicable in the Netherlands. This is contained in section 4.7.

Using the actual goal of the design project, the product vulnerabilities and the legislation, an enumeration can finally be drawn up of the starting points, the functionalities, the main functions, sub-functions, functional aspects and requirements, and the wishes that must be satisfied by the solution.

The analysis stage of the packaging design project can then be set out as shown in Figure 8.1.

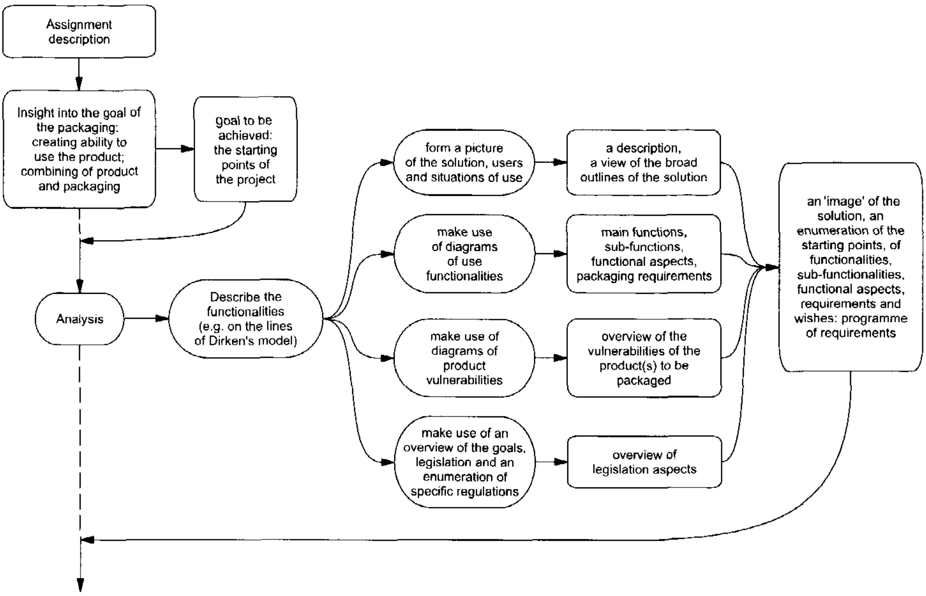

Figure 8.1 The method's analysis stage (iterations not represented)

8.2.2 The synthesis stage

The goal of this stage is to find solutions which can meet the requirements.

Activities are or can be:

- Using one or several creativity techniques available for this purpose (see the references Buijs, Walravens and Melis f.i.).
- Finding an appropriate material to offer optimum protection to the product inside the packaging. Hereto use can be made of the schedule and list of functions offered by materials contained in section 4.5.1. This is in fact the point at which coordination takes place between the product vulnerabilities and the possibilities offered by the packaging.
- Working out the picture or perception sketched in the analysis stage on the basis of the functionalities.
- Devising ideas, making sketches, elaborating on details, or choosing existing solutions if appropriate for some of the problems.
- Copying and applying existing norms or standards for parts of the problem if too little time or budget is available to develop new solutions or, for instance, because the numbers to be produced are too few and do not balance the costs involved. Examples in this respect are standardized closures such as crown caps, lids, screw

threads, etc., standard dimensions for cans, standard measurements for cardboard, beverage packaging, etc.
- Plans can then be drawn up which include all the steps required for filling the packages.

It is recommendable to concentrate not so much on the specified requirements, as on the functions that have to be fulfilled. This stage culminates in one or more concepts. Iterations can be made to define more or other requirements or to change the problem definitions.

The synthesis stage can be set out as shown in Figure 8.2.

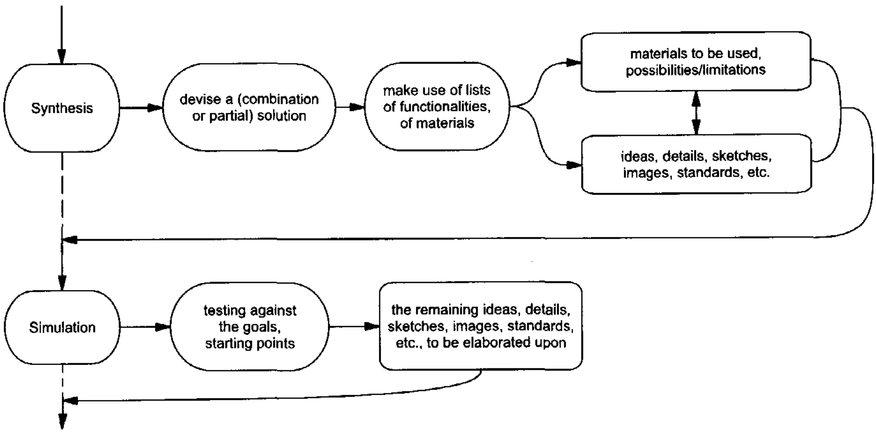

Figure 8.2 The method's synthesis and simulation stage (iterations not represented)

8.2.3 The simulation stage

Whether the proposed solution meets the specified requirements is checked in the simulation stage. The main thing here is to clearly set out the properties that may be expected of the design. This is difficult, mostly because of limitations in terms of time and costs.

Questions that probably have to be answered are: Can the product ultimately be used as intended? Does the concept offer the product sufficient protection? Can the product reach its destination effectively and efficiently? What information may and must the packaging present, and in what form and detail must that information be presented?

The solutions to these questions must fit in the specified framework of the product functionalities. To ensure that the design process itself progresses efficiently and effectively, the path set out below could be followed.

First and foremost an attempt must be made to estimate whether the concepts meet the specified criteria, particularly the starting point, and the ultimate use of the product. If it seems certain that a concept is unable to meet the criteria, then it should be eliminated. If there are doubts, and depending on the number of concepts, the decision can be taken to either still include it for the time being or to absolutely eliminate the concept. After all, it is theoretically impossible to find the 'best' solution ever.

Also a decision has to be made to procede or to go back and redefine the problem, requirements, etc.

8.2.4 The evaluation stage

Preliminary conclusions can be drawn about the feasibility of the concepts and about the possibility to reach the formulated goals. Conclusions are drawn in this stage about continuation of the project, and if so with which concepts, or about stopping the project or maybe even about redefining the goals.

8.2.5 The detailing stage

Conserving/protecting the product

The number and complexity of the functions the packaging has to fulfill can in many occasions limit the possible solutions. To efficiently and effectively find those solutions the rest of the design process is divided up into three sequential design processes in which the output of the first process serves as the input for the second, and the output of the second process as the input for the third process. If many solutions are found and the expectation is that these solutions will meet the requirements and the project goals can be reached, a choice can be made out of the proposed solutions. The schedules hereafter can than serve as a checklist. This was already represented schematically in Chapter 5. Figure 8.3 shows this part of the method.

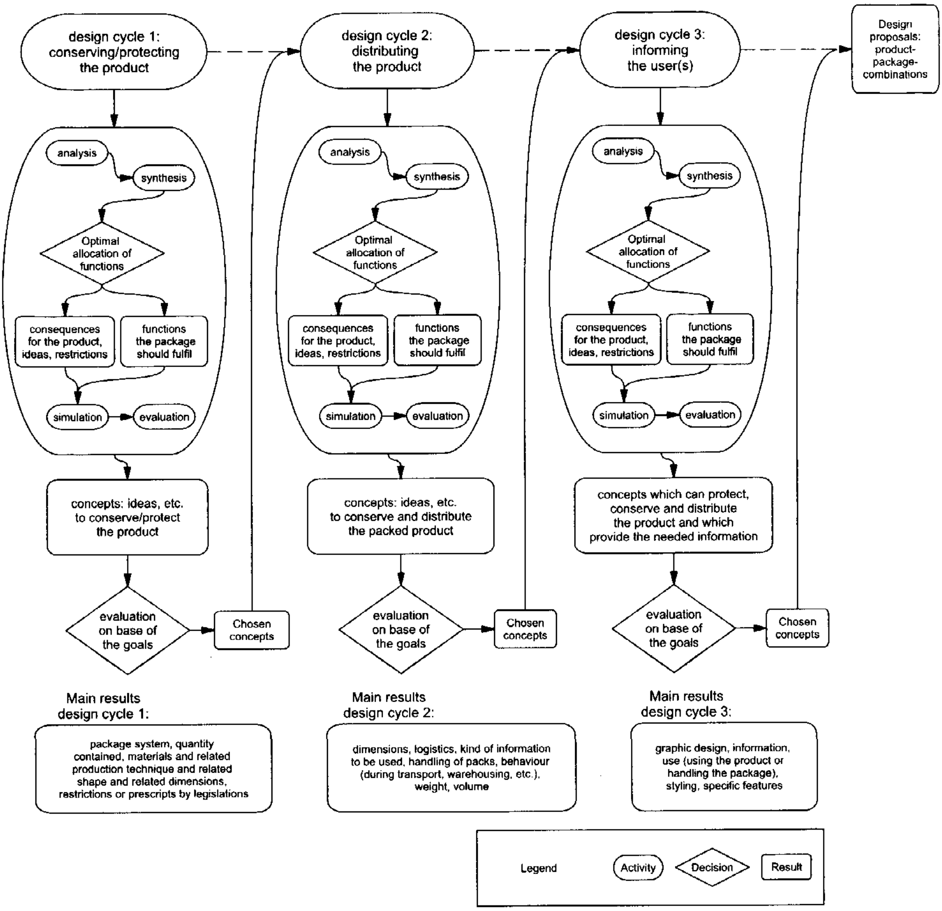

Figure 8.3 The method's detailing stage (iterations not represented)

The first design cycle focuses on the use functionality of conserving/protecting. Ideally, both product and packaging are designed synchronously and interactively. Initially, the existing concept is worked out at least to such an extent that a confident judgement can be made as to the use functionality of conserving/protecting.

Various simulation techniques can be used such as models for different goals like shape, usability, etc., making mock-ups, carrying out material tests, drawing up calculation models for processes like permeability, buffering characteristics, isolation of heat, etc.

Ultimately, in the simulation stage, a judgement is made as to the feasibility of the concept in terms of the use functionality of conserving/protecting. Evidently, the ability to produce the packaging, and the properties of the product prior to filling, will need to be given careful consideration here. The solution developed so far can be tested against the goals and starting points of the project, for instance: those relating to costs and environmental impact. If the concept cannot meet the goals or starting points, a decision has to be made about going back or stopping the project.

This concept consists of a description - usually with sketches, drawings, standards, etc., - of how the product will be protected. The ability to actually use the product in the different phases of the chain, which remains the ultimate goal of the packaging, must be tested exhaustively.

Aspects, which have been taken into consideration although still in concept, are materials, production techniques, feasible shapes and dimensions, the precise way to protect the product, the volume or amount of product if not already set by the requirements.

Distributing the product

The concepts are the starting point for the next design cycle in which the objective is that the product can reach the required destination at the required time and with a quality suitable for use.

Main factors are the means of transport (including storage and transshipment) and shelf space; the dimensions and weight of primary, secondary, etc. packaging, filled packages, pallets and means of transport, see figure 4.4. Certain sorts of information are compulsory and impose specific demands on the graphic design of the packaging.

The packaging concept, which was incompletely detailed in the conserving/protecting design cycle, is now further established in terms of dimensions and capacity. This can be detrimental to functions of protection. Iterations between the first and second design cycle are therefore always imaginable.

The concept must then be tested again against the requirements specified in this stage. It is now evident that the uncertainties concerning the distribution of the product have been eliminated. The concept can be tested against the project requirements. Thereafter a decision must be made about going on or stopping the project.

Informing the users

A similar exercise can be repeated for the use functionality: informing the different users. Once the materials are known and the dimensions established, it can be determined *how* the packaging must be provided with *what* information (see figure 4.3). The diagram contained in figure 5.4 can be useful in this respect. The sub-functions, functional aspects and requirements can be listed and specified.

In practice, graphic design agencies are frequently used for this design stage, especially if the packaging is consumer- or shop packaging.

The concept or concepts that emerge from this cycle must first of all meet the requirements drawn up for this stage. Subsequently, the remaining concepts can be tested against the requirements specified and a comparison can be made on the basis of the differences, such as financial and environmental consequences in the various stages of the distribution chain.

Because the main uncertainties have now been eliminated, the various concepts - if available - can be compared and one can be selected.

8.3 To innovate or to develop?

The sequence of these three design cycles can be different, depending on the starting points of the project. If practical solutions need to be found in a reasonably short time, mainly involving routine work, it is called re-design. If solutions are sought to achieve a certain degree of successful modernization, it is called innovation. A distinction is often made according to the nature of the modernization: in the product (and the packaging), in the market or in the technology (PMT) or a combination of two or all three.

If it is a question of re-design, then existing solutions, or partial solutions, are often used. In the case of innovation it is usually a matter of a radical change in one or more aspects of the product, market or technology.

The method developed can be applied in a variety of ways. In the case of development, the three design cycles can be carried out in parallel: concurrent engineering. Known solutions are combined and the designer more or less visualises the solution. Especially those designers with many years of experience and a great deal of know-how will probably do this in the majority of cases, even though these designers are perfectly equipped to make an innovative 'leap' as well. Innovation is usually restricted to one or a few functional aspects and these are then dealt with in more depth. This usually implies that the three cycles of the method will be undertaken more sequentially, although it is quite feasible for two of them to be carried out in parallel.

In practice it will usually be a question of many intermediate forms of innovation and development. Only certain parts of the product and packaging system can then be adapted. Nevertheless, the method and insight offered here still remains in force.

A graphical representation is given in Figure 8.4.

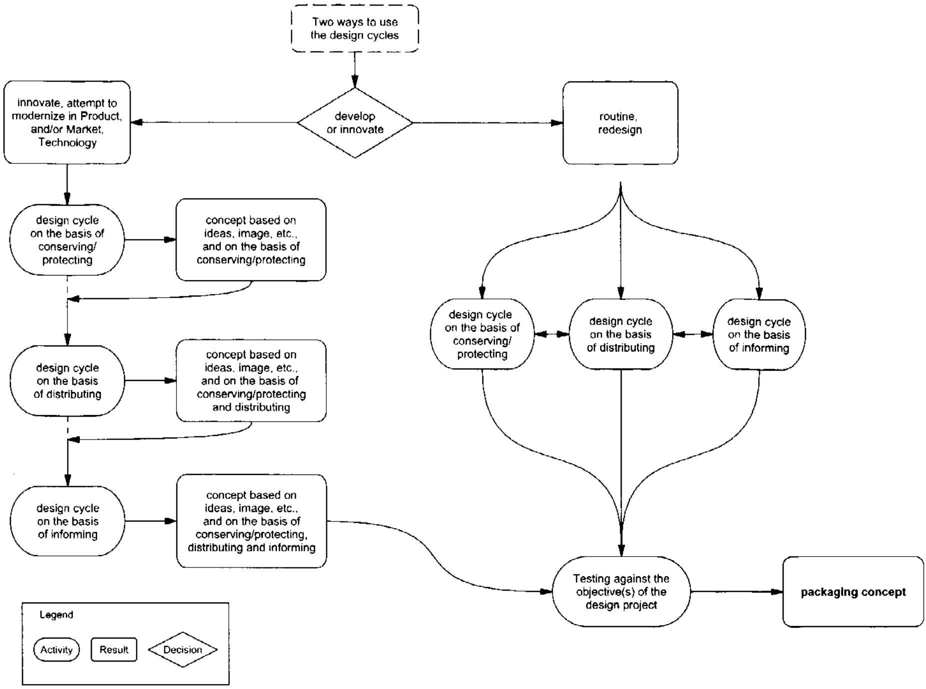

Figure 8.4 Re-design or innovation (iterations omitted in the presentation)

8.4 Options for using the method

EU legislation on packaging and packaging waste dictates that all businesses are actively involved in preventing pollution and can explicitly demonstrate the activities they undertake. Dirken's elaborated model (1999) offers opportunities for establishing the whys and wherefores of packaging. Not only relating to the use functionalities, but also to the framework within which the product is marketed. For instance, a business that packages perfume in glass needs to and can explain why a metal sleeve is placed around the glass and the product; the glass, and the metal sleeve are subsequently placed inside a can (Jean Paul Gaultier). If this perfume was packaged in a more simple fashion, then the consumer would be less willing to pay about 50 Euro for the product. In other words, the functionality of business economics would be at stake.

Another option the method offers for a new design project that still has to be planned, is to take the different steps into consideration and to run through all the tools for the purpose of establishing the starting points and project planning.

So, the method can serve to steer a project step by step. After determining the general objectives and some view of the solution, those persons engaged in the first design cycle in particular can attempt to realize that view. These will mainly be engineers involved in aspects of product protection. Logisticians can then enhance the concepts and, last of all, the graphic designers can put the finishing touch on the concepts. The entire team can then come together to assess the end result.

Another option is to use the method as a teaching aid and an educational route for designers and/or decision-makers working or preparing to work in the packaging world. The method can also lead to the standardization of procedures in a company, a chain or subbranche.

For the sake of completeness, Figure 8.5 presents a total overview, including all the steps advised in a packaging design process.

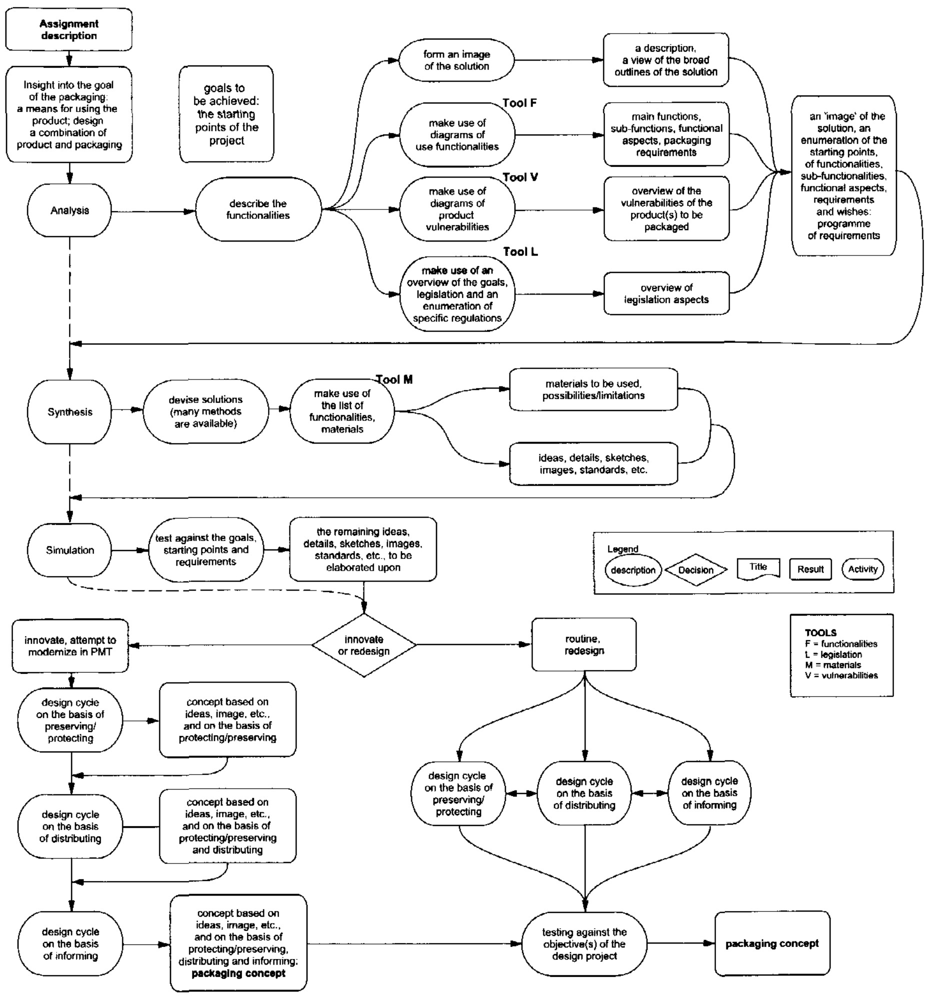

Figure 8.5 The method, including the tools (iterations omitted)

In figure 8.5 the mentioned schedules about functionalities, vulnerabilities, material properties and legislation are included as tools.

This description concludes our study into the development of a method for packaging design. Reason enough now to take a critical look at the study as a whole. This will be done in the next chapter.

9 *Conclusions and recommendations*

9.1 Conclusions

Packaging is not superfluous, but is very necessary to protect, transport and use most products to be sold. If products are packed using solutions which do not protect the product well enough, there will be a certain quantitative and/or qualitative loss of product. This can increase very strongly when products get damaged during transport on the pallet. Nevertheless, sometimes an excess of packaging can be found. In fact, there is an optimum amount of packaging material by which a product can be packed functionally. In many cases solutions are chosen with more packaging material, to be on the safe side or because of a lack of knowledge. This can be explained in part by the fact that the specialization of packaging design has not yet reached maturity, compared with its immense economic and cultural values. Hardly any scientific approach till now has been formulated to deal with the relevant problems. It can be a strategic choice of a company to use packaging material which is more damaging to the environment, with the only goal to gain more than with the optimally designed packaging. This means that environmental requirements can be in conflict with economic wishes. In packaging design a choice has to be made between as much packaging material as needed and the profits that can be reached by the design. This depends on the kind of packaging, primary, secondary or tertiary, the kind of products packed, the target market, and the social policy of the firm.

In the media packaging is more often than not seen as unrestrained luxury. This reflects the underestimation of the complexity of functions and also shows the lack on knowledge in this field. There is specific training, education and research on the subject of packaging, but it is not as large as would be expected in view of the magnitude of the market. Existing definitions of packaging mainly define only a part of the packaging chain or are restricted to a few of the many functions packaging can fulfill. We tried to define packaging with all or most of the possible functions in mind.

About seven percent (a dozen each year) of the students of the Delft University of Technology, Subfaculty Industrial Design Engineering, chose packaging design as a subject for their masters thesis (in the analysed period from 1973 till 1996). From these projects about one fifth has environmental improvements as an objective. Students use the methods which are mainly based on the methodology of Roozenburg and

Eekels (1995) and they tend to use tools as developed in the Eco-design programme (Brezet et al, 1994). Analysis of these projects shows that there is a lack of knowledge concerning so called packaging insights. The same conclusion can be drawn from analysis of design practice.

At the start of a design process, choices of a strategic and of a tactic level have to be made concerning the functionalities of a 'function fulfiller'. The model described by Dirken (1999) is used to distinguish and design these functionalities. A long list of functions a packaging can fulfill is presented in this study. This list can also be used as a checklist for packaging designers.

The value of the packaging material compared to the value of the products to be packed, is an important parameter in the way packaging is approached by companies. Even companies with relatively expensive products are not always very willing to spend much effort on packaging material, unless it is proven to be crucial. This can be the case with products produced and packed in large amounts, for which efficient and standardized transport is essential. In general the market of foods requires more attention given to packaging material and the packaging process than the market of non-foods. Because the risks of mistakes can be very high when packaging medicinal drugs, the attention given to the packaging material and the packaging process is very high in this sector.

Designers who develop or innovate food packaging stress that the requirements, set by the distribution channel and the information to be placed on the packaging, are of a higher importance than designers who design packaging for non-food products.

Because of the high level of efficiency to be reached in the retail chain, requirements related to sales are often seen as inevitable rules, which tend to receive even higher priority than requirements related to final use. This gives the retailers power over the producers and consumers.

Packaging designers implicitly use a method of thinking based on a hierarchy of functions. A package must protect/conserve in the first place, must fit in a certain channel of distribution in the second place and must, finally, provide the prescribed and wanted information. This way of designing is different from most other methods of product design. The difference mainly stems from the peculiarity of the packaging chain, in which several phases need to be distinguished. Each of these phases tends to fulfill a different set of functions, some of which can even be unique for one phase only. The design of a product-packaging combination, consequently, means the, successive or concurrent, designing of these functional sets, each phase having its own design processes of analysis, synthesis, simulation and evaluation. At the end of each phase, also called cylce, the results are evaluated against the goals of both the phase and the entire chain. In the ideal case product and package are designed at the same time and in strong interaction with each other. This way a higer level of innovation can be reached and solutions can be found which are less damaging to the environment than if the packaging is designed separately from the product, especially after the design of the product itself is already finished. At the start of the project it is recommendable to generate some general, qualitative view of the product-package combination and to take this solution as the ideal design to be reached (Dirken, 1999). It is also advisable to keep thinking about the solution the product-package combination will offer in a broader context and about the business which is best able to deliver the product required. It is also worth considering whether a service can replace or assist the product request (Brezet, 2001).

If the method is used to develop solutions in a relatively routine-like way as 're-design', without innovative aspects, the three design cycles can be carried out in parallel. If the method is used to reach a certain degree of modernization of the product, market or technology, worthy to be called innovation, the three design cycles should be processed more sequentially.

Insights into a large body of aspects and factors regarding packaging are, of course, necessary to be able to find solutions for a packaging design problem. The principal insights concern the vulnerabilities of products, the properties of packaging materials, the influence of the dimensions of a packaging on the amount of packaging material used and legislation. Overviews of vulnerabilities, properties of materials and legislation are presented in this study, to use as a start in design projects. These can be used as design tools too.

Some attention is paid to European legislation on packaging and packaging waste. The European Directive on this issue, restricts unlimited use of packaging material. In many countries costs have to be paid in line with the amount of packaging material placed on the market. For companies prevention in these respects is one of the topics for which efforts have to be made. This is one of the most difficult points in the directive, because environment and economy can be in conflict with each other. Government ought to recognize the indispensable functionalities of packaging and should stress the choice of material as a very important step in the design process. Innovations in material properties, especially concerning the vulnerabilities of the products and the improvements in recycling technology can be important to use less or different packaging material.

The professionalization of packaging is evolving and this study might be able to contribute to building up a more methodical, innovative and scientific background of this specialization, in order to cope with its economic and socio-cultural significance.

Although the study was of a descriptive nature for a substantial part, it also involved - as a core - an empirical part. The exercises using the cards, representing steps and decisions in the process of designing packaging, were very enlightening, in terms of the way packaging experts think. This procedure might perhaps also be suitable for other industrial design studies, and possibly even in other projects of product development in practice. As became evident, the precise formulation of the text on the cards is of immense importance, and this aspect must therefore be given a great deal of attention when using them in an exercise or in practice.

9.2 Recommendations for further studies and development

Application of the cards exercise

Research should be done on possibilities of a wider application of the experiments with cards, representing the steps in packaging design for several specific types of packaging design projects or for other studies in product development.

Manual for packaging designers and other product designers

On the basis of the developed method a manual can be made, that can be used by packaging designers and other designers to improve the efficiency and effectiveness of design projects. Different overviews as presented in this study can be worked out, so that they can be used by different decision makers in the area of packaging, especially with regard to strategies and innovations. This will help professionalization of this specialization.

ICT-manual

Research is recommendable into the opportunities of information- and communication technology to render the accessibility and background of the method as large as possible. This, especially, counts for the overviews and updating of data like legislation, characteristics of materials, vulnerabilities, etc.

There are several software means that support companies in finding packagings that meet the requirements set by the Dutch Covenant on Packaging. Unilever has developed a tool for internal use (Storm, 1998). Plato product consultants in Delft has developed a tool for small- and middle-sized companies (Houtzager, 1999). These tools focus on the weight of the packagings, and on the goals set by the European Commission. As cited in this study, product and package have to be developed together and the environmental load of the materials used cannot be judged on base of the weight only. More research can be done on the appropriateness of the developed method, to improve designing the combination of packaging and product concerning environment and, possibly, doing this without using life cycle analyses.

Standardization of the method

Standardization could be based on our method as developed. The exchange of knowledge will be improved by using standards. Research could be done on whether ISO 14000 is appropiate. This will enhance the acceptability for trade and industry.

Testing the method in the practice of packaging design

To obtain more insight into how processes of packaging design are carried out, it is recommended to examine systematically in practice the method developed in this study. To do this, for instance, exercises or assignments can be given to students following a variety of study programmes (such as in the Netherlands courses of the Netherlands Packaging Centre, Haagse Hogeschool IPO, Delft University of Technology-IDE, University of Agriculture Wageningen, but also in other countries this could be profitable). The successive stages/cycles can be examined further, as also the applicability of the method in various sectors of packaging. Setting up an expert system is the next step in this specialization. It may be instrumental in the actual (2001) plans in the Netherlands to establish a professional Bachelor's plus Master's curriculum for designers and managers in packaging.

Vulnerabilities of products

Sourced by the professional associations and trade organizations, the list of vulnerabilities of products to be packed, ought to be further enhanced and detailed.

Databank with properties of materials used for packing

Setting up a databank is recommended for lists of the properties of materials used for packaging. The most ideal body in the Netherlands would seem to be the Netherlands Packaging Centre (NVC) or Delft University of Technology-IDE, given that they are both independent bodies. Packaging aspects could be incorporated in the IDEMAT database (Remmerswaal, 1999) at Delft University of Technology-IDE. The producers of packaging materials and packaging could be involved in doing this. Using today's technology, everyone interested could then have access to a databank of this sort.

A database in the field of materials could also be used for assessing several crucial financial and economic aspects. Standard figures for many kinds of packaging are known by insiders. These calculations on the basis of standard figures could be linked to up-to-date raw material prices and data on the environmental load of different materials and processes. By means of such a data base fair estimates could be made of the cost price and environmental impact of a design.

Calculation models for shelf life, buffering, etc.

To make calculations for shelf life, product buffering, etc. use can be made of several mathematical models to help a designer in determining packaging dimensions. This can relate to thickness of foils, to the dimensions of buffering elements, and to ratios of depth, width and height of packaging. It should not be difficult to design these models in the form of software. This could also boost the competitiveness of trade and industry.

Key figures for costs and amount of material of packaging in relation to the product packed

Much research has been done with regard to the costs of packaging, but still not for all packaging materials and all product categories. The same accounts for the amount of packaging material in relation to the packed products. Rules of thumb about costs and amount of material can help setting priorities, in economical as well as in political aspects.

Conducting research into various optimization problems

A consequence of a rather low level of professionalization is, among others, that very little systematic research is freely accessible. So far, the research carried out generally also tends to be fragmental and detailed. The building up of systematic research into different areas of packaging can improve the way the packaging functions and can develop into a professional body of knowledge and methods, typical for a mature discipline.

Product characteristics and packaging lines

The planning to set up a packaging line is steered to a large extent by the technical feasibility and the costs. Product characteristics that determine how the product is processed play a determinative role in this respect. Insight into a decision structure for setting up a machine configuration can have high value for any packaging firm.

Legislation

With regard to legislation, it is recommendable to make lists of all relevant national and international (EU, USA and other important countries for export) laws and regulations and amend them on a regular basis. This is particularly important for exporting companies.

List of software programs

A list of software programs in the field of calculating optimal palletizing, plus optimization of the amount of material used for primary and secondary packaging, is also recommended.

Packaging and the Government

The Dutch and other European governments play a major role in the public opinion on packaging. A more differentiated judgement and communication about packaging would benefit the government, industry, trade and society. It could be argumented that it is even more important that governments catalyse the improvements of R&D in neglected areas, which are of substantial relevance for national policies, such as packaging and sustainable development. In this area the stimulation of more explicit strategies, combined with valid and operational design methodology, promises to be very rewarding. The method of packaging design, developed in this study as a first version, can be an interesting tool for (subsidised) projects of packaging innovation in industry.

Appendices

Appendix A - Rules of thumb for permeability calculations

Permeability is usually expressed in the amount of gas that can pass through one square metre of foil of a certain thickness over a certain amount of time. The figures specified are laboratory values that can be determined with ambient air and also with a 100% pure gas. The values given are the averages obtained from three processes: diffusion of the gas in the foil, the transport of the gas through the foil, and the exit of the gas out of the foil. While a linear calculation of the specified values gives a reasonable picture of the situation that can be anticipated, it is still risky and testing is recommended. The ambient conditions under which the values were determined and the conditions under which any tests have been carried out must also be taken into consideration, given that these can have an enormous influence on the processes described above. In general, certain standard conditions are used which are set out in DIN standards, British Standards (BS) and American Standard Test Methods (ASTM). Frequently used circumstances for the permeability of moisture are:

- ASTM F1249: 38°C, 90% Relative Humidity
- BS 3177: 25°C, 75% Relative Humidity
- DIN 53122: 23°C, 85% Relative Humidity

and for the permeability of oxygen:

- ASTM D3985: 23°C, 0% Relative Humidity
- DIN 53380: 23°C, 75% Relative Humidity

Rules of thumb used to calculate the amount of gas that passes through a foil are:

- The permeability is inversely proportionate to the thickness of the film. The thicker the film, the less gas passes through.
- There is a relationship between the permeability (P) of separate layers and a multilayer combination of the same layers. This is as follows:

$$\frac{1}{Pt} = \frac{1}{Px} + \frac{1}{Py} + \frac{1}{Pz}$$

in which the permeability factor of the total Pt is the sum of the reciprocal values of the permeability factors of the separate values. It is easy to see that the calculations will show that a thin layer with good barrier properties is sufficient to bring about a substantial reduction in the permeability of the total.

- There is no relationship between the water vapour permeability and oxygen permeability.
- The relationships between the permeability of oxygen, carbon dioxide and nitrogen are reasonably constant for most films:

  $P(CO_2) / P(O_2)$ = approx. 4.5

  $P(N_2) / P(O_2)$ = approx. 0.3

- There is no relationship between a film's permeability regarding oxygen or water vapour compared with that for aromas.
- The barrier properties of polyamides and cellulose acetate depend on the ambient conditions, particularly Relative Humidity.
- If the temperature rises, permeability also increases; however, the extent to which this occurs greatly depends on the sort of material and the type of gas that is being used.
- The barrier properties of metallized films depend to a large extent on the substrate used. The quality of the process, the amount of vacuum-evaporated metal, the type and sort of film, especially the surface conditions, and the adhesion of the metal layer on the film are major determinants of the barrier properties.
- Most films offer only moderate protection from UV light. Only metallized films reduce the level of permeability to a large extent. Depending on the thickness of the layer and the layer dispersion over the foil, only up to about 10% of the light is able to penetrate the foil. A good barrier against light can be quickly obtained by using sufficiently thick paper or aluminium foil. Another option is to incorporate pigments in the plastic film.
- Tests show that storage at 21°C and 60% Relative Humidity simulate the normal Dutch indoor and outdoor climate reasonably well. Storage at 25°C and 75% Relative Humidity can cause an increase in permeability by a factor of 3. Comparing data at 23°C and 85% Relative Humidity, and at 38°C and 90% Relative Humidity, can give a difference of a factor 4.
  These data do not apply in the case of materials which are sensitive to water, such as polyamides, cellulose and ethylene vinyl alcohol. These materials tend to lose their gas-barrier properties quickly once they become moist.

Appendix B - Step-by-step plan for determining buffers

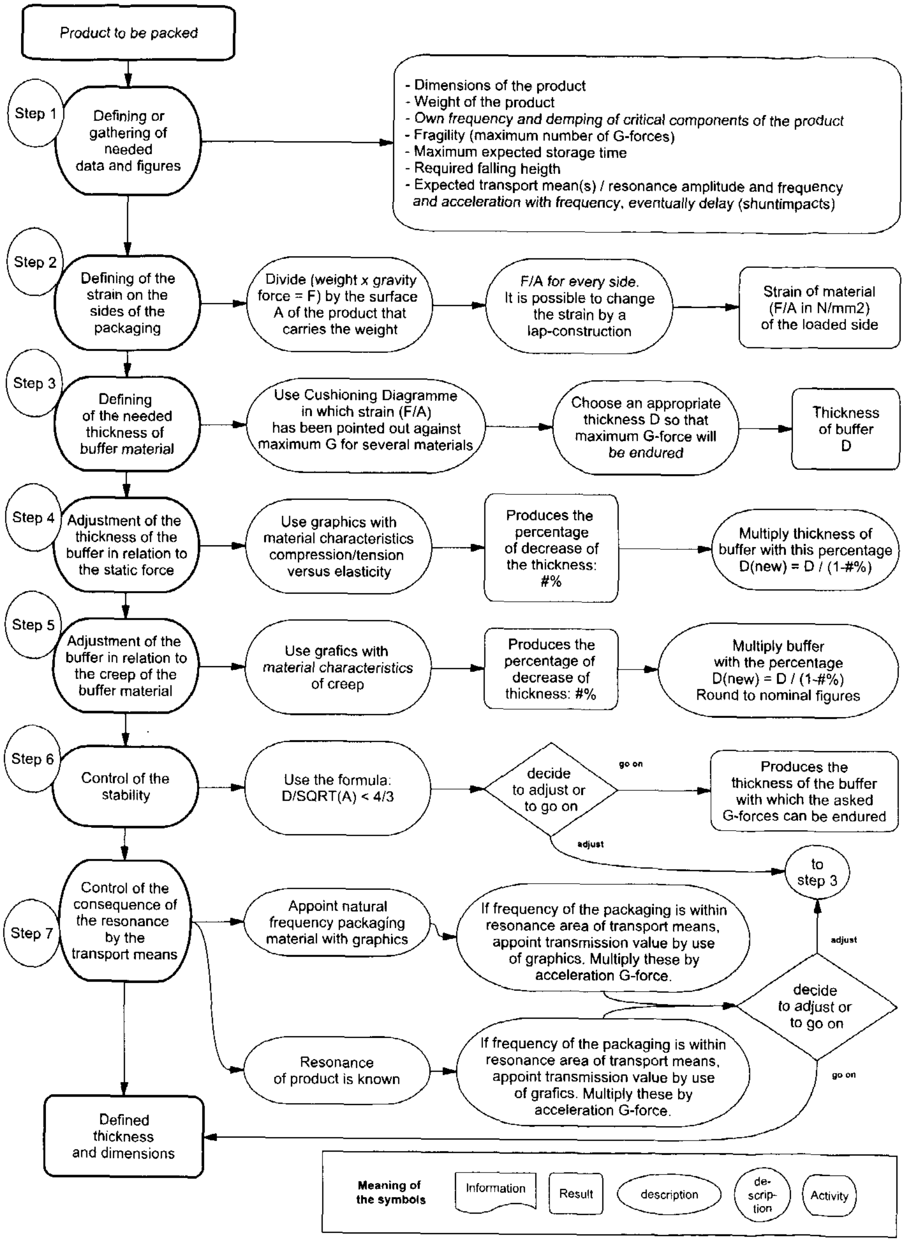

Table B.1 Step-by-step plan for determining type and thickness of buffer materials for mechanical vulnerable products (mainly from the product categorie durables)

Appendix C - Dutch translation of the cards

Hieronder is schematisch de volgorde en de teksten van de kaartjes weergegeven. De kolommen geven de drie ontwerpcycli weer. Volgens de ideale gedachte wordt in de linker kolom bovenaan begonnen en wordt de kolom van boven naar beneden afgewerkt, dan de middenkolom in dezelfde richting en vervolgens zo de rechter.

Ontwerpcyclus beschermen/conserveren	Ontwerpcyclus distribueren	Ontwerpcyclus Informeren
Wetgeving product/verpakking Opstellen van eisen en formuleren van consequenties die voortkomen uit wegeving m.b.t. product en/of de verpakking	***Eisen afnemer*** Bepalen wat voor eisen de afnemer en/of het afzetkanaal stellen voor wat betreft maatvoering en uitmonstering	***Vormgeving*** De verpakking vormgeven (vorm, kleur, textuur, verhoud ing van afmetingen, ...)
Opstellen beschermingseisen Aan de hand van een analyse van de kwetsbare delen van het te verpakken product (mechanisch, fysisch, chemisch, biologisch) eisen stellen aan de verpakking	**Distributie/transport eisen** Eisen formuleren die voortkomen uit het ontworpen/bepaalde distributie- en transportsysteem, zoals gangbare maatvoeringen, gewichten en volumina en te vermelden informatie	**Gebruik optimaliseren** Optimaliseren van de gebruiksmogelijkheden vanuit ergonomisch standpunt zoals vasthouden, openen, sluiten, wegzetten, etc.
Materiaalkeuze Materialen voor de verpakking vaststellen	**Eisen transportwetgeving** Opstellen van eisen en formuleren van consequenties die voortkomen uit wetgeving m.b.t. transport van het product en/of de verpakking	**Product aanpassen voor verkoop** Het product wijzigen om verkoopbevordering van de product-verpakkings-combinatie te optimaliseren
Constructie Bepalen van de optimale materiaalverdeling vanuit sterkte en stijfheid	**Distributie/transportsysteem** Ontwerpen/bepalen van het distributie- en transportsysteem	**Bepalen informatie** Bepalen welke informatie op de verpakking moet worden aangebracht (recepten, informatienummers, samenstelling, andere wijze van gebruik, etc.)

Ontwerpcyclus beschermen/conserveren	Ontwerpcyclus distribueren	Ontwerpcyclus Informeren
Keuze productietechniek Productietechniek van de verpakking bepalen/kiezen/uitwerken/vaststellen	**Dimensies vaststellen** De maatvoering van de (om) verpakking afstemmen op het distributiesysteem	**Informatie aanbrengen** De wijze(n) van aanbrengen van informatie bepalen/kiezen/ ontwerpen/vaststellen (drukken, printen, etiketteren, stickeren, etc.)
Product aanpassen Overwegen het product te wijzigen om het beter te kunnen verpakken om zodoende de meest geschikte product-verpakkings-combinatie te verkrijgen, teneinde het product optimaal te kunnen beschermen	**Dimensies product** De maatvoering van het product aanpassen om de product-verpakkingscombinatie beter af te stemmen op het distributiesysteem	**Grafisch ontwerp** Grafisch ontwerp maken van de verpakking waarin alle te vermelden gegevens zijn meegenomen
Producthoeveelheid De hoeveelheid te verpakken product(en) bepalen	**Handling transportverpakking** De transportverpakking (die verpakking waarin de afstand van producent tot gebruiker wordt overbrugd) optimaliseren voor wat betreft handling (oppakken, neerzetten, afmetingen, gewichten, e.d.)	**Specialties** Speciale toevoegingen (premiums, naamgeving, stickers, etc.) verwerken in het ontwerp
Kiezen verpakkingssysteem Ontwerpen/bepalen van de wijze van vormen, opzetten, vullen, sluiten, houdbaar maken (food), transporteren op de verpakkingslijn, etc. (in zijn totaliteit wel aangeduid als verpakkings-systeem)		
Tussentijds toetsen Tussentijds toetsen van het resultaat aan het programma van eisen	**Tussentijds toetsen** Tussentijds toetsen van het resultaat aan het programma van eisen	**Toetsen eindconcept** Toetsen van het eindconcept aan het programma van eisen

Appendix D - Participants of the testing and of the pilot test

The experts that took part in the testing

June 1997

Name	Company/organization
Mevr. Ir. F. Asberg	Heineken Technical Services
Ir. H.J. van de Bergh	Heye Glas Nederland
Ir. M. Collignon	Pré
J.E.E.P. van Dinter	Philips Display Components
J.H. Flamand	Honig Merkartikelen
P.J. Geerts	Industrial Packaging Support
D.A. de Koning	Schut Superflex
Ir. J.J. Laarhoven	Trapac Plastic Crates
W.J.G. van de Molengraft	Nederlandse Philips Bedrijven
Ir. S.F. Schilthuizen	TNO Industry
prof. Ir. J.L. Spoormaker	Delft University of Technology, Subfaculty Industrial Design Engineering
Ir. V. Swinkels	Van Leer Services
Ir. G.P.J. Tweehuysen	DSM / Pack Point
Mevr. Ir. H.J.H.M. Walravens	Unilever / selfemployed
P.M.Th. Wijnen	Digital Equipment
W.H. Witteveen	Bolletje
A.R. van der Zwan	United Biscuits Verkade

Participants pilot test

May 1997

Ir. H.N. Steenwinkel	Graduated on a packaging design
Mevr. Ir. G. Zijlstra	Graduated on a packaging design
Mevr. Ir. A.G.C. van Boeijen	Counselled a student completing his studies on a subject concerned with an ecologically-sound packaging
Mevr. Nathalie Hendriks	Student
Mevr. Claudia van Riet	Student

Appendix E - Assignment description of the experiments

Exercise 1

Design process of a packaging

You are asked as an expert to make clear how you would prosecute the design process, by using the set of cards. The goal of the process is to end up with one or more manageable packaging concepts, in an efficient and effective way.

Assignment
An assignment for a new packaging for a certain product has been formulated.

A short programme of requirements has been set up for the product. A number of requirements for the packaging has been formulated.

Requirements
The formulated requirements involve:
- the shelflife of the product,
- the product should be in sight,
- the design (shape, appearance)
- the convenience,
- the costs of the packaging (including the process).

A team of designers started the packaging design process and introduced some proposals and ideas.

Ideas
The ideas are presented as follows:
- a description of the shape, based on the image of the product,
- the way the package can be opened,
- improvements of the present packagings concerning:
    - design (shape, appearance) and
    - costs

  by using some new production techniques.

- a number of ideas to develop a new packaging with new materials and material combinations.

Now it is up to you to continue and end this design process by using the cards.

Way of working:

- Put the cards in the right order, in front of you on the table, according to your opinion and insights. You can do this by:
  - . Clustering of the cards which belong to each other.
  - . Add missing steps within each cluster, if wanted.
  - . If there is a kind of hierarchy between the clusters, do present it (cause and effect, input-output relations).
  - . Order the clusters according to the relationship, if there is one.
  - . Present the clusters as a time schedule if they would be used to design a packaging (certain decisions have to be taken before another activity can be undertaken).
- Present the order of the cards on the sheet of Exercise 1. Use the codes which are presented on the cards. With arrows and lines you can set out the mutual relations of the cards.
- Explain, as far as possible, what the basis is for the way you presented the cards (motivation, background). *(End of the description of the exercise.)*

Before the exercise has been handed out, the first part of the design process is presented by using sheets with flow-charts untill the activity as formulated on the cards. The reason for this is to avoid the confusion which had been created during the pilot test. A picture of the flow-chart of the first part of the design process which has been presented is taken up hereafter.

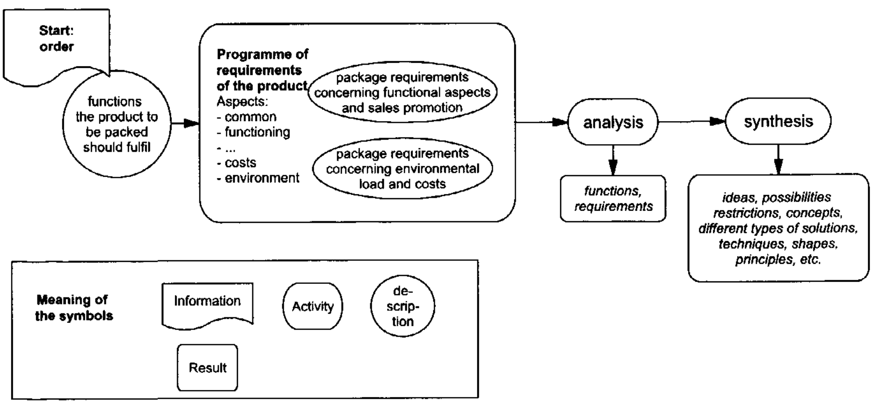

Figure E.1 First part of the packaging design process

Exercise 2

Additional questions with cards - The influence on the design process for packaging in general

Method

- Check the way you ordered the cards for the products/packagings listed hereafter and change the order according to your insights (use the order as presented in Exercise 1).
  Products:
  - (Consumption unit of) French beans
  - transistorradio
  - large packaging for cocoa (800 kg)
  - paperclips (100 pieces)
  - shoeshine
  - smoked sausage
  - oranges
  - furniture
  - washing machine
  - paint

  Packagings:
  - bundle packaging for a number of primary packagings
  - transport packaging
  - bulk packaging

- If, according to your insights, the order changes, can you explain the reason of the transformation? You can describe or present this by using the cards and by noting the codes of the cards.
- Can you explain why the order of clustering, the hierarchy, the mutual order, etc. has been changed?
- Are there other kind of products or packagings for which the order will also change? *(End of the description of the exercise.)*

Exercise 3

Additional exercise with cards - Reduction of the number of cards

- Please answer the following questions, also taking into account the order of the cards of exercise 1.
  - Are there cards which are not essential?
  - Can you remove these cards?
  - Can you reduce the number of cards down to the minimum required in this way?
  - Is it possible that the activities as formulated on the removed cards still are executed after the activities which you think are the most important?

- Present on the sheet of Exercise 3 the codes of the cards:
  . the essential steps,
  . the mutual relations,
  . the activities that can be executed after the essential steps.

(End of the description of the exercise).

Exercise 4

Falsification of the method by propositions

A number of propositions specific to the method is presented. With these propositions it is examined if it is possible to falsify the method and if so on what grounds.

To support the propositions examples are presented.
Every time the following two questions are being asked:

a. Do you or don't you agree with the proposition in this specific case?
b. Can you give examples by which the proposition can be rejected? If so, please, describe these examples?

Limitation

The developed method appoints to the phase of convergence, e.g. the phase in which ideas, concepts, principles, detail solutions, etc. Are systematically reduced to a few workable solutions.

However, this will not mean that it is impossible to come up with new ideas or insights during this phase. Therefore it is possible to start with the method without a phase of idea generation.

It has to be assumed that a number of project requirements has already been specified.

At last: the objective of this examination is to develop a method by which the design process of packaging becomes more efficient and effective.

Way of presenting the results

Please, present your ideas and insights underneath every proposition.

Proposition 1

A packaging design process is more effective and efficient when undertaken in the order as shown, and when each step is succeeded with a go-no-go decision:

- design a packaging concept that, if wanted, protects the product;
- work out the packaging concept for distribution of the product;
- work out the packaging for sales promotion.

Example

Step 1 - protection of the product

For the concept to protect a dairy drink with fruits, a three-layer plastic bottle has been chosen. In the middle of the plastic is a black layer to protect the product from UV-light. The plastic bottle is covered with an aluminium foil which is sealed on the bottle and which is covered by a plastic cap.

Step 2 - make the design appropriate for distribution

For optimal distribution of the products the dimensions of the area are chosen in such a way that twelve bottles fit exactly in a box which is tuned to the collomodule system (dimensions of the box are equal to or fit in 40x60 cm). The boxes are dimensioned in such a way that they are stackable so that an optimum load of the pallet can be realised.

Step 3 - promote sales

To accelerate sales, the bottle is designed carefully and attention will be paid to the label of the bottle.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Example

Step 1

To protect a television a PE-bag against dust, polystyrene foam parts against shocks and a carton box to keep the parts togeher, are chosen.

Step 2

The packaging concept is engineered in such a way that sideclamp trucks can pick up the televisions and load them easily for transport or stack them for storage.

Step 3

The box does not play an important role to accelerate sales. The brand and the type of television are being printed on the box, besides the information needed for distrubution.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Proposition 1, rejection

Can you find examples or arguments to reject proposition 1?

Proposition 2

When designing a package the product must (also) be seen as a variable, otherwise it is impossible to achieve the best possible situation in terms of engineering, costs and the environment.

Example
Common electronic equipment puts heavy requirements to the mechanical buffering which the packaging should realize. A monitor has been for sale which was considerably less vulnerable because of some simple changements to the construction by which the most vulnerable components inside the monitor were protected. The cathode tube was hung elastically inside the frame and the prints were fixed on top of small parts of polyethylene foam. The amount of packaging material and the volume of the packaging were thus strongly reduced.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Example
Many foods can be made fit for packaging in which it otherwise could not have been packed with the guarantee of the wanted quality, by changing the ingredients or components. Some examples are given hereafter.

Extra carbondioxide is added to carbonated drinks to be able to pack it in plastic bottles and to compensate the loss of it during a certain time.

Dairy drinks with fruits which are packed in permeable plastic bottles, in which the taste changes slowly because of the oxygen which comes into the bottle, are mostly composed as cocktails in stead of mono tastes, so that it is hard to notice that the taste is changing.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Proposition 2, rejection
Can you find examples or arguments to reject proposition 2?

Proposition 3

With regard to perishable products, the amount packaged determines to a large extent the amount of environmental load.

Example
If the amount of packed product is not in keeping with the amount that is being used, spillage will be increased (left-overs that will be thrown away). Production of perishable goods (with production phases such as growing, pesticides, harvesting, processing, packing, sterilization, transportation, etc.) costs energy just as the packaging material and causes discharge of waste and emissions. Therefore it must be determined in an early stage how much product should be packed per package to reduce the environmental load to a minimum.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Proposition 3, rejection

Can you find examples or arguments to reject proposition 3?

Proposition 4

The choice of material, and everything associated with that choice (such as production technique, design options and options relating to dimensions, the packaging system, construction), determines whether an adequate guarantee can be given in terms of required product quality.

Example
The packaging concept to protect a television consists of a construction made form a material with buffering characteristics, for example polystyrene. The possible production techniques and the possibilities to construct the package are strongly limited by this choice.

Another packaging with buffering qualities can be proposed. For example, a bag which surrounds the television. To guarantee a shelf life of two years, the bag has to be made out of several layers from which one of them should have barrier qualities. With these aspects possibilities for choice of material, related production techniques for bags, possible dimensions, the way of packing and the type of construction, are defined to a great extent.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Example

A packaging concept for dairy products with fruits consists of a laminate with the materials: cartonboard-polyethylene-aluminium-polyethylene and guarantees a shelflife of nine months.

A packaging concept of three layers of polyethylene with a dark layer in the middle to block UV-light guarantees a shelfl life of six months for the same product.

A packaging concept with a polyethylene monolayer guarantees a shelflife of three months for the same product.

The materials in the three different packagings for the dairy drinks with fruits are known and therefore the possibilities for dimensions, shape, construction, way of filling and the way to preserve the product.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Proposition 4, rejection

Can you find examples or arguments to reject proposition 4?

Proposition 5

If the possible methods of protecting the product are known, and the concepts have been adapted to feasible methods of distribution and points of sale, then the exterior dimensions (height, breadth, depth) will be known.

Example

To pack rice a cardboard box has been chosen. The box must fit into the collomodule system, as required by the distribution channel. A rectangular box is chosen. The amount of product is adapted to the amounts being used, and some concepts are produced. After calculations for possible configurations in the transport packaging, the outer dimensions are defined.

Do you agree with the proposition in this specific example? (please encircle)

Do agree   Do not agree

Comment:

Proposition 5, rejection

Can you find examples or arguments to reject proposition 5?

Summary

I

Media and politicians often refer to packaging as being rather superfluous or even unnecessary. However, studying the literature and research in this field shows that packaging is very useful and, as a rule, is indispensable. Various sources show that assessments as to the use of packaging are complicated by the number of aspects that play a role in the realization and actual functioning of packaging. There is specific training, education and research on the subject of packaging, but it is not as large as would be expected in view of the magnitude of the market. There is apparently no explicit design method nor specific training in this field, at least not published. Especially concerning the step from designing an image to the realisation of the packaging little or no systematics can be found. It is quite possible that designers each follow their own methods in practice.

We believe that a documented method for the design of packaging can be of benefit to the practice and training of designers of combinations of products and packaging. A method could enable them to follow a more efficient design process, to achieve both ecological and financial savings, to make good use of innovative opportunities. An explicit method could also help decision-makers by providing them with a tool for integrally tackling packaging problems. The underestimated complexity of packaging, the short time-to-market, the limited tests that are executed on packaging concepts, the restriction of costs of packaging materials, are reasons to look for a more detailed model of the design process.

The central research question of our study is: What method can packaging designers use to design packaging effectively and efficiently such that it incorporates all the essential functions, and as many of the desired functions as possible.

To answer this question we will do research of literature and new empirical investigations on methods of packaging design, development and innovation.

2.

Research into design methods is executed at several universities. At Delft University of Technology, Subfaculty of Industrial Design Engineering (DUT-IDE) research is done on the way designers think (f.i. Dorst, 1997) and about the integration of ecological aspects in the design process, called eco-design methodology. About a dozen students annually (7%) finish their MSc study by designing a packaging and they produce detailed reports about the process and results at DUT-IDE . Several of these MSc projects concern environmental strategies. We analysed these reports and compared the findings with our own experience in packaging design projects.

According to the definition of Archer in 1974, an industrial designer is: *"One who is qualified by training, technical knowledge, experience and visual sensibility to determine the materials, construction, mechanisms, shape, colour, surface finishes and decoration of objects which are reproduced in quantity by industrial processes. The industrial designer may, at different times, be concerned with all or some of these aspects of an industrially processed object. The industrial designer may also be concerned with the problems of packaging, advertising, exhibiting and marketing when the solution of such problems requires visual appreciation in addition to technical knowledge and experience".*

Heskett (1980) stated that *"... the growing industrial design profession finds itself enmeshed in a complex web of problems."* (p.201), and mentioned the responsibility of the designer for problems like the depletion of finite material resources and the increase of environmental pollution. Dorst (1997) concluded that design can be understood as consisting of 'objective' and 'subjective' interpretative activities.

Students at DUT-IDE are trained according to the above mentioned descriptions. They work systematically, mostly using the basic design cycle (Roozenburg and Eekels, 1991) consisting of the stages analysis, synthesis, simulation, evaluation. The students use many tools which are available for each stage. The emphases are on: "creating products for people", on the programme of requirements, aspect completeness, creativity techniques and on techniques to ensure the best possible evaluation of the design proposals. No specific method, however, is taught for packaging design. The eco-design approach is a recent and more system-based, supplementary approach. Our analysis of the Masters theses on packaging also showed that a way to dictate a hierarchical structure of functions for adequately dealing with the requirements is not taught, and there is little or no steering of the requirements on the basis of prior choices. Projects do not always provide the opportunity to design a combination of product and packaging and Eekels and Roozenburg's methods fail to indicate how changes in the starting points of a project must be dealt with. Also noticeable in the MSc projects is that specific packaging knowledge is rather meager or even completely lacking.

The mistakes made in the packaging design projects outside university, in practice, show that in many projects technical aspects are not integrated and/or the knowledge is missing and/or management aspects are often neglected. These data from industry confirm the data found in the MSc projects.

3

To set requirements, a hierarchical structure of functions is needed. To set out the functions of packaging, a distinction is crucial between 'use functionality' - the intention of the user - and 'product functionality' - strategic choices on how the use functionality is interpreted.

By analyzing functions of packaging in history a definition of packaging is formulated:

Packaging is the fulfiller of functions, added to a product, to bridge the aspects of time and distance at acceptable cost and acceptable environmental impact, ensuring acceptable quality of the product for the end user.

By elaborating on this definition an enumeration of possible packaging functions has been set up as a tool for packaging designers. Three main groups of functionalities are distinguished: protecting/conserving, distributing and informing.

To protect/conserve a product the main funtions are determined by bridging time and distance. To distribute a packed product the main functions are fixed by the distribution channel and the information system used. To inform all the users of the packed product, the total chain has to be analysed. Every step in the chain usually has specific users needing specific information. Legislation may be relevant for every functionality.

4

To achieve optimum packaging, first the product's vulnerability needs to be assessed. The next step is chosing the material, or combination of materials, that is expected to counteract that vulnerability. Hence the most essential properties of the packaging materials and the product vulnerabilities are specified. These vulnerabilities and materials are summarized in a table. The products are divided into the categories: food, medicinal drugs and medical products, non-food non-durables, durables, industrial packaging and bulk goods.

The vulnerabilities are divided into the basic processes that cause loss of quality of the products to be packed: biological, biochemical, chemical, physical and mechanical. Important material characteristics are among others: barriers against gasses, humid, flavours, fragrances and UV light, buffering capacity, temperature resistance, whether it gives off flavour and, finally, recycling possibilities.

Subsequently, attention is focused on the influence of the amount of product to be packaged, the absolute and the relative dimensions of a packaging, and the influence of the packaging shape on the amount of material used.

Legislation can be very coercive in terms of how packaging is produced or which process is used to pack the product. This chapter also contains an overview of various, relevant facets and laws which apply in the Netherlands.

In order to harmonize the various regulations governing packaging and packaging waste within the EC, regulations were adopted in 1994 by the EC which have priority over the national legislation of the Member States. Attention is focused on this in general; the characteristic way in which some of the individual nations have translated EC legislation is focused on in particular. With these data from literature and experiences from best practice the preparatory parts of our study, aimed at establishing a background for design methods, are concluded.

5

A core question of our study is to find out emperically how packaging designers work in practice. A method of approach is therefore developed. We have chosen for a framework within which a thinking process is literally mapped out, based on the definition of packaging and the enumeration of functions as presented in chapter 3.

A design method is set up, based on Matchett's Fundamental Design Method (in Gregory, 1966) and on Systems Design (many sources, see section 5.3.3). Functions are the start of every design project (Roozenburg and Eekels, 1995), but ways to describe or analyse functions was not presented by them. To compensate for this, Matchett's Fundamental Design Method is chosen. The peculiarity of the design of packaging is that a packaging can hardly ever be designed in isolation from the product to be packed. In contrast, many products can be designed isolated from the surroundings in which they have to function. Systems design is concerned with the design of complex systems in which separate subsystems can be distinguished. For this reason the approach of systems design was chosen for our empirical investigations.

In the developed method three design cycles are distinguished. The first is aimed at finding a concept which protects the product. The second starts with the concept and tries to fit this into a distribution channel in such a way that the product can efficiently reach the customer. In the third design cycle the goal is to provide the wanted and required information. At the end of each cycle, the concept is tested against the goal of this design cycle and then against the goals of the project. Whether the product can change in such a way that the product-package combination can function more effectively and efficiently, should be examined within each design cycle.

6

Our study can be characterized as the development of a method and also as an orienting study. Its aim is more to generate than to test hypotheses. Nevertheless, it was decided to test the developed method, as much as feasible, by using a set of explicit hypotheses.

The entire method is set out on cards, each card containing a brief formulation of an activity that must or may be carried out in the design process in a certain stage and in a certain order, with the freedom to make additions, changes, etc.

A pilot test with the cards was done, before assigning 17 participating subjects to test the cards and the design method itself.

The participants for the experiment were selected in association with the Dutch Packaging Centre and DUT-IDE. In order to test the method, it is essential that the group of participants is representative for the field, and that there is variation within the group in terms of field of activity, job, background, etc. These requirements seem to have been adequately met.

7

The tests showed the following results:

- Participants can use the 23 cards to express their views on methods of packaging design sufficiently, completely and structurally.
- There is a professional, more or less uniform design method for packaging.
- The more-or-less uniform design method used by the 17 people with packaging skills is not completely in line with the design method developed in this study. The sequence of the various steps is right, but the phasing indicated is not always completely correct. The different working areas of the participants probably explain the preference of other phasing.
- The design method is convincingly applicable on many categories of products and packaging. One exception is display packaging.
- When both the packaging and the product are designed interdependently and synchronously, both effectiveness and efficiency of process and outcome benefit.
- Designers searching for innovative solutions work in a different manner than designers developing a packaging within a limited time, based on proven techniques.

The exercise using the set of cards was repeated at four seminars on Pollution Prevention and Innovation in Packaging. The conclusion could be drawn that the method of using the cards is operational and that there is probably a high level of acceptance of the method in the packaging world. The central research question can be answered now.

The starting point when developing/innovating/redesigning packaging is that it will be added to a product in order to provide that product with economic benefits. The preferable method assumes that both the product and the packaging are developed synchronously and interactively, given that they are strongly connected, both physically and functionally. Dirken (1999) recommends drawing a conceptual sketch of the solution before moving on to draw up a programme of requirements.

The analysis stage
Dirkens's model (2000) is used for the systematic elaboration of the functions into use functionalities and product functionalities. The use functionality is divided into three main functionalities: preserving/protecting, distributing and informing; these are then subdivided into sub-functions, functional aspects and into potential requirements.

The synthesis stage
Solutions are generated and devised in the synthesis stage. Several creativity techniques can be used for this purpose. To find the most appropriate material to offer optimum protection, the product vulnerabilities and the possibilities offered by the chosen packaging material should be well matched.

The simulation stage
First and foremost an attempt must be made to estimate whether the concepts meet the specified criteria, particularly those concerning the starting point and the ultimate use of the product. If it seems certain that a concept is unable to meet the criteria, then, obviously, it should be eliminated. If there are doubts, and depending on the number of concepts, the decision can be taken to either still include it for the time being or to eliminate the concept.

The evaluation stage
Preliminary conclusions can be drawn about the feasibility of the concepts and about the possibility to reach the formulated goals. Conclusions are drawn in this stage about continuation of the project, and if so, with which concepts, or about stopping the project or maybe even about redefining the goals.

The detailing stage
The three aforementioned groups of use functionalities form a hierarchy in which preserving/protecting has priority above distributing which, in turn, has priority above informing. At first the concept is detailed in such a way that it can meet the specified criteria on preserving/protecting, that it can be produced, and that the product can be packaged or the packaging can be filled. All uncertainty as to these aspects should be eliminated. Next the concept can be tested against the remaining goals and starting points of the project, for instance: those relating to costs and environmental impact.

The ability to actually use the product, which is the ultimate goal of the packaging, must be tested exhaustively.

The remaining concepts are the starting point for the next design stage, in which the objective is to ensure that the product is able to reach the required destination at the required time and with a quality suitable for use. Also after this stage, the concepts can be tested against the remaining goals and starting points. A similar exercise can be repeated for the third group of use functionality: informing the different users.

Always it should be certain that the product can be used as intended. Subsequently, the remaining concepts can be tested against the requirements specified and a comparison can be made on the basis of the differences. In each of these three stages is has to be taken into account if product and packaging can be adjusted to each other to find a better solution.

The design method developed can be applied in a variety of ways. If practical solutions need to be found in a reasonably short time, mainly involving routine work, called redesign, the three design cycles can be carried out in parallel. Known solutions are combined and the designer more or less visualises the solution. In the case of innovation it is quite likely that certain functional aspects are dealt with more in depth. This implies that the three stages of the method will be undertaken more sequentially, although it is quite feasible for two of them to be carried out in parallel. In reality it will usually be a question of many intermediate forms between innovation and redesign.

9

Conclusions

Packaging is not superfluous, in general, but it is in most applications indispensible. Yet excess of packaging sometimes occurs, being consequences of inadequate designing. There is an underestimation of the complexity of functions of packaging and underuse of knowledge in this field. Packaging designers actively engaged in this field implicitly use a method of thinking that uses a hierarchy of functions. The method developed and tested in this study is a first version of a documented method for packaging design. This method also may fill the gap between graphical packaging design and three-dimensional packaging design. The method still to be further developed promises to improve the efficiency and effectiveness of the design of combinations of product and packaging. The method is acceptable for people active in this field and it may be expected that other designers, teachers, product developers, etc. can also benefit by using it.

Recommendations

It is recommended:

- to do research on wider application of the experiments with cards to analyse design processes in other areas of product development;
- to set up a manual for packaging designers to improve the efficiency and effectiveness of design projects;
- to do research into the opportunities of information- and communication technology to augment the accessibility and background of the design method;

- to investigate whether ISO 14000 is appropiate to enhance the acceptability of the design method for trade and industry;
- to examine systematically in practice the method developed in this study, to obtain more details and more insight into how processes of different types of packaging design are carried out;
- to enhance and detail the list of vulnerabilities of products to be packed;
- to build a databank for lists of the properties of materials used for packaging;
- to develop mathematical models to optimize shelf life, product buffering, etc. in the form of software, to help a designer in determining packaging materials and related dimensions;
- to collect keyfigures for costs and amount of packaging materials in relation to the product packed;
- to build up systematic research into different areas of packaging to improve packaging functions and to develop a professional body of knowledge and methods, typical for a mature discipline;
- to gain insight into a decision structure for setting up a machine configuration based upon characteristics of the product to be packed;
- to make lists of all relevant national and international (EU, USA and other important countries for export) laws and regulations and their amendments, on a regular basis;
- to list software programs for calculating optimal palletizing, plus optimization of the amount of material used for primary and secondary packaging;
- that governments play a role in a more differentiated judgement and communication about packaging. And, as a last recommendation: governments ought to catalyse the improvements of R&D in neglected areas, which are of substantial relevance for national policies, such as policies on packaging and sustainable development.

Samenvatting

I

Verpakkingen worden door de media en de politiek vaak aangeduid als overbodig of zelfs onnodig. Uit literatuur- en veldonderzoek blijkt echter dat verpakken zeer nuttig en gewoonlijk onmisbaar is. Uit diverse bronnen blijkt dat het beoordelen van het nut van verpakkingen bemoeilijkt wordt door de hoeveelheid aspecten die een rol spelen bij het tot stand komen en functioneren van een verpakking. Onderwijs in het vakgebied verpakken wordt door verschillende instituten verzorgd, er wordt aan onderzoek gedaan, maar deze activiteiten lijken niet in verhouding te staan tot de marktomvang. Een ontwerpmethode specifiek voor het ontwerpen van verpakkingen is niet bekend, althans niet in beschreven vorm. Vooral betreffende de stap in het ontwerpproces van een gewenst (meestal grafisch) beeld tot een gerealiseerde verpakking is weing systematiek te vinden. Het is goed mogelijk dat ontwerpers in de praktijk impliciet een eigen methode volgen.

Wij denken dat een beschreven methode voor het ontwerpen van verpakkingen voordelen kan bieden voor ontwerpers en producenten van verpakkingen. Een dergelijke methode stelt hen in staat om het ontwerpproces efficiënter te laten verlopen, om ecologische en financiële besparingen te behalen, om innovatieve mogelijkheden goed te kunnen benutten. Een methode voor het integraal ontwerpen van verpakkingen biedt beslissers een hulpmiddel voor het oplossen van verpakkingsontwerp problemen. De onderschatte complexiteit, de korte tijd voor marktintroductie, het slechts in beperkte mate testen van verpakkingsconcepten, de beperking op kosten van verpakkingsmaterialen, zijn redenen om meer gedetailleerd het ontwerpproces te beschrijven.

Onderzoeksvragen zijn geformuleerd met als centrale vraag: Met welke methode kunnen ontwerpers van verpakkingen, verpakkingen effectief en efficiënt ontwerpen zodat deze alle vereiste en zoveel mogelijk van de gewenste functies vervullen.

Om deze vraag te beantwoorden doen we literatuuronderzoek, onderzoek naar het verloop van verpakkings ontwerpprojecten en doen we nieuw empirisch onderzoek naar ontwerpmethoden.

2

Onderzoek naar ontwerpmethoden wordt uitgevoerd op verschillende universiteiten. Op de subfaculteit Industrieel Ontwerpen van de Technische Universiteit Delft (TUD-IO) wordt onderzoek gedaan naar de manier waarop ontwerpers denken (bv. Dorst, 1997) en naar de wijze waarop ecologische aspecten geïntegreerd kunnen worden in het ontwerpproces, genaamd eco-design methodologie. Ongeveer een dozijn studenten van TUD-IO studeert jaarlijks af op het ontwerpen van een verpakking (ca. 7%). Ruim 20% betrekt ecologische aspecten betrekt in het ontwerpproces of heeft deze als uitgangspunt. Het proces en de resultaten van deze projecten zijn gedetailleerd beschreven in hun afstudeerrapporten. We hebben deze rapporten geanalyseerd en vergeleken met onze bevindingen van ontwerpprojecten in de praktijk.

Volgens de definitie van Archer uit 1974 is een industrieel ontwerper: *"Iemand die gekwalificeerd is door training, technische kennis, ervaring en het visuele gevoel heeft om materialen, constructie, mechanismen, vorm, kleur, oppervlakte afwerking en decoratie van objecten vast te stellen, welke in kwantiteit gereproduceerd zijn door middel van een industrieel proces. De industrieel ontwerper kan, op verschillende momenten, zich bezig houden met alle of enkele van deze aspecten van een industrieel geproduceerd object. De industrieel ontwerper kan zich ook bezighouden met de problemen van verpakken, reclame, exposeren en verkopen wanneer de oplossing van zulke problemen visuele waardering in toevoeging tot technische kennis en ervaring vraagt."*

De verantwoordelijkheid van ontwerpers voor meer dan esthetiek of commerciële aspecten, wordt ook door Heskett (1980) aangehaald in zijn beschouwing over de ontwikkeling van industrieel ontwerpen. Dorst (1997) concludeert dat ontwerpen gezien kan worden als een combinatie van activiteiten van objectieve en subjectieve aard.

Studenten aan TUD-IO zijn getraind te werken volgens de bovengenoemde beschrijvingen van industrieel ontwerpen. Ze werken systematisch, maken meestal gebruik van de basis ontwerpcyclus (Roozenburg en Eekels, 1991) die bestaat uit de fasen analyse, synthese, simulatie en evaluatie. De studenten maken veel gebruik van tools die in elke fase beschikbaar zijn. De nadruk ligt op: "creating products for people", het programma van eisen, volledigheid van de aspecten, creativiteitstechnieken en technieken die een zo goed mogelijke keuze van de ontwerpvoorstellen ondersteunen. Een specifieke methode voor het ontwerpen van verpakkingen wordt echter niet onderwezen. De eco-ontwerp benadering is een recente en meer systeem gebaseerde, aanvullende benadering.

Onze analyse van de afstudeerrapporten toont tevens aan dat studenten niet geleerd wordt een hiërarchische structuur van functies op te stellen om hierop eisen te baseren. In het ontwerpproces lijkt geen sturing plaats te vinden op basis van eerder gemaakte keuzes. De meeste projecten bieden niet de ruimte om product en verpakking gezamenlijk te ontwerpen. De methoden van Eekels en Roozenburg geven niet aan hoe in een project omgegaan moet worden met uitgangspunten die wijzigen.

Opmerkelijk is dat in veel afstudeerprojecten specifieke verpakkingskennis over afvullen, barrières, logistiek, e.d. ontbreekt.

Fouten zoals deze gemaakt worden in verpakkings ontwerpprojecten in de beroepspraktijk, tonen aan dat in veel gevallen technische aspecten niet of slechts in geringe mate geïntegreerd worden en/of dat kennis niet voldoende ingezet wordt en/of dat projectmanagement gebrekkig uitgevoerd wordt. Deze gegevens uit de beroepspraktijk zijn een bevestiging van de analyse van de afstudeerrapporten.

3

Om eisen te kunnen formuleren, is een hiërarchische structuur van functies noodzakelijk. Om functies van verpakkingen te kunnen beschrijven wordt onderscheid gemaakt tussen gebruiksfunctionaliteiten - de intentie van de gebruiker - en productfunctionaliteiten - strategische keuzes hoe de gebruiksfunctionaliteiten geïnterpreteerd moeten of kunnen worden.

Op basis van een analyse van verpakkingsfuncties in het verleden, is een definitie van verpakking geformuleerd:

Een verpakking is een functievervuller die wordt toegevoegd aan een product, om dit tijd en afstand te laten overbruggen tegen acceptabele kosten en acceptabele milieubelasting, om de eindgebruiker een product van acceptabele kwaliteit te garanderen.

In het verlengde van deze definitie is een opsomming van mogelijke verpakkingsfuncties gemaakt, die gebruikt kan worden door verpakkingsontwerpers.

Drie groepen van hoofdfunctionaliteiten voor verpakkingen worden onderscheiden: beschermen/conserveren, distribueren en informeren.

De hoofdfuncties van beschermen/conserveren worden bepaald door het overbruggen van tijd en afstand. De hoofdfuncties van distribueren worden bepaald door het distributiekanaal en de gebruikte informatiesystemen. Om alle gebruikers van de verpakking te informeren, moet de gehele keten geanalyseerd worden. Iedere stap in de keten kan vereisen dat specifieke informatie aangeboden wordt aan de specifieke gebruiker(s) in de desbetreffende stap. Wetgeving kan van belang zijn in iedere functionaliteit.

4

Voor het optimaal verpakken moet eerst de kwetsbaarheid van het product worden onderzocht. De volgende stap is om die materiaal of -combinatie te zoeken, waarmee naar verwachting de kwetsbaarheden beschermd kunnen worden. Daarom zijn de meeste, wezenlijke eigenschappen van de verpakkingsmaterialen vermeld. Kwetsbaarheden en materiaaleigenschappen zijn samengevat in een tabel. Producten

Daarom is de systems design methode gekozen om te gebruiken voor ons onderzoek.

In de ontwikkelde methode worden drie ontwerpcycli onderscheiden. De eerste gaat uit van het vinden van een verpakkingsconcept dat het product beschermt. De tweede gaat uit van dit concept en tracht dit in te passen in een distributiesysteem op een zodanige wijze dat het product de eindgebruiker efficiënt kan bereiken. In de derde ontwerpcyclus is het doel ervoor te zorgen dat de gewenste en vereiste informatie op de verpakking komt.

Aan het eind van iedere ontwerpcyclus wordt het concept getoetst aan de doelen van de cyclus en vervolgens aan de project doelen. Binnen iedere ontwerpcyclus moet onderzocht worden of het product gewijzigd kan worden op een zodanige wijze dat de product-verpakkings combinatie een effectievere en efficiëntere oplossing vormt.

6

Onze studie kan gekarakteriseerd worden als de ontwikkeling van een methode en eveneens als een oriënterende studie. Het doel is meer gericht op het ontwikkelen dan op het toetsen van hypothesen. Desondanks is besloten de ontwikkelde methode, voor zover haalbaar, te testen aan de hand van een aantal hypothesen.

De gehele methode is op kaartjes weergegeven, met op ieder kaartje een korte formulering van een activiteit die in een bepaalde fase van het ontwerpproces moet of kan worden uitgevoerd, met vrijheid van aanvulling, wijziging, weglating, etc.

Een pilot test met de kaartjes is uitgevoerd, voordat 17 participerende individuen gekozen zijn om de kaartjes en de methode zelf te testen.

De participanten voor het experiment zijn geselecteerd in samenwerking met het Nederlands Verpakkingscentrum en TUD-IO. Voor het testen van de methode is het essentieel dat de participanten representatief zijn voor het vakgebied, en dat er variatie binnen de groep is voor wat betreft soort activiteit, functie, achtergrond, werkterrein, opleiding, etc. Aan deze eis lijkt voldaan te zijn.

7

De toetsing heeft de volgende resultaten opgeleverd:

- Participanten kunnen de 23 kaartjes toepassen om hun visies weer te geven op ontwerpmethoden op een voldoende, volledige en gestructureerde wijze.
- Er bestaat een professionele, min of meer uniforme ontwerpmethode voor verpakkingen.
- De min of meer uniforme ontwerpmethode die toegepast wordt door de 17 participanten met ervaring op verpakkingsgebied stemt niet geheel overeen met de in deze studie ontwikkelde ontwerpmethode. De volgorde van de verschillende stap-

zijn ingedeeld in de categorieën: voedingsmiddelen, medicijnen en medische hulpmiddelen, niet voedingsmiddelen - niet duurzame goederen, duurzame goederen en industriële verpakkingen en bulkgoederen.

De kwetsbaarheden van producten zijn opgedeeld naar de basisprocessen die de kwaliteit van de te verpakken producten doen afnemen: biologisch, biochemisch, chemisch, fysisch en mechanisch. Belangrijke materiaaleigenschappen zijn onder andere: barrières tegen gassen, vocht, geur- en smaakstoffen en UV-licht, buffercapaciteit, temperatuurbestendigheid, het beïnvloeden van de smaak en als laatste, mogelijkheden voor recycling.

Vervolgens wordt aandacht besteed aan de invloed van de te verpakken hoeveelheid, de absolute en relatieve dimensies van een verpakking en de invloed van de vorm van een verpakking op o.a. de hoeveelheid toe te passen materiaal.

Wetgeving kan zeer dwingend zijn voor de wijze van uitvoeren van een verpakking of voor het proces waarmee het product verpakt is. Dit hoofdstuk bevat een overzicht van verschillende facetten en wetten die gelden in Nederland op basis van functionele gronden. Wetgeving die de laatste jaren van grote invloed is geweest op het verpakken, betreft verpakking en milieu. Om alle verschillende regelgevingen op het terrein van verpakking en verpakkingsafval binnen de EC te harmoniseren, is in 1994 regelgeving door de EC aangenomen die boven de wetten van de afzonderlijke lidstaten staan. Hieraan wordt aandacht besteed en enkele kenmerkende verschillen in hoe landen de EC regelgeving hebben ingevuld, worden behandeld. Met deze gegevens uit de literatuur en uit de praktijk, om een basis te leggen voor het uitwerken van een ontwerpmethode, wordt dit deel van het onderzoek besloten.

5

Een centrale onderzoeksvraag van onze studie gaat over de werkwijze van verpakkingsontwerpers in de praktijk. Om deze te bepalen is een aanpak ontwikkeld die zo is opgezet dat het ontwerpproces letterlijk in kaart gebracht kan worden, waarbij gebruik is gemaakt van de definitie van verpakking en de gemaakt opsomming van mogelijke verpakkingsfuncties uit hoofdstuk 3.

Een methode is opgezet, gebaseerd op de Fundamental Design Method van Matchett (in Gregory, 1966) en op Systems Design (vele bronnen, zie paragraaf 5.3.3). Functies zijn de start van ieder ontwerpproces (Roozenburg and Eekels, 1995), maar werkwijzes om functies te beschrijven of analyseren zijn niet door hen weergegeven. Om deze tekortkoming te compenseren is gekozen voor Matchett's Fundamental Design Method. Het bijzondere van het ontwerpen van een verpakking is dat dit nauwelijks geïsoleerd van het product uitgevoerd kan worden. Veel producten daarentegen, kunnen wel los van de omgeving waarin ze moeten functioneren, ontworpen worden. Systems design behandelt het ontwerpen van complexe systemen waarbinnen aparte subsystemen te onderscheiden zijn.

pen klopt, maar de aangegeven fasering is niet geheel correct. De verschillende werkterreinen van de participanten verklaren waarschijnlijk de voorkeur voor een andere fasering.

- De ontwerpmethode is overtuigend toepasbaar op vele categorieën van producten en verpakkingen. Een uitzondering betreft display-verpakkingen.
- Effectiviteit en efficiëntie zijn ermee gediend dat verpakking en verpakte min of meer synchroon en in onderlinge afweging worden ontworpen.
- Ontwerpers die op zoek zijn naar innovatieve oplossingen gaan anders te werk dan ontwerpers die een verpakking ontwerpen in een gelimiteerde tijd, gebaseerd op bewezen technieken.

De oefening met de set kaartjes is herhaald op vier seminars met als onderwerp Preventie en Innovatie van Verpakkingen. De conclusies die getrokken zijn uit deze oefeningen is dat het experiment met de kaartjes werkbaar is en dat de mate van acceptatie van de ontwikkelde methode binnen de verpakkingswereld hoog is. De centrale onderzoeksvraag kan nu beantwoord worden.

8

Uitgangspunt bij de ontwikkeling/innovatie/herontwerp van een verpakking is dat deze wordt toegevoegd aan een product, omdat dit economisch voordelen biedt. De methode gaat er vanuit dat product en verpakking tegelijkertijd en in nauwe samenwerking ontworpen worden, omdat ze fysisch en functioneel sterk aan elkaar verbonden zijn. Dirken (1999) geeft de aanbeveling, voordat wordt overgegaan tot het opstellen van een programma van eisen, een beeld te schetsen van de oplossing.

Analyse fase
Het model van Dirken (2000) wordt gebruikt voor het onderscheiden van gebruiksfunctionaliteiten en productfunctionaliteiten. De gebruiksfunctionaliteiten zijn opgesplitst in drie hoofdfunctionaliteiten te weten: conserveren/beschermen, distribueren en informeren, die zijn uitgewerkt en opgesplitst in deelfuncties, functionele aspecten en in mogelijk te stellen eisen.

Synthese fase
In de synthesefase worden oplossingen verzonnen. Er kan gebruik gemaakt worden van de vele creativiteitstechnieken die hiervoor beschikbaar zijn. Om geschikte materialen te vinden waarmee het product optimaal beschermd kan worden, moeten de kwetsbaarheden van de te verpakken producten en de eigenschappen van de verpakkingsmaterialen op elkaar afgestemd worden.

Simulatie fase
In eerste instantie moet getracht worden in te schatten of de concepten kunnen voldoen aan de gestelde criteria en in het bijzonder aan de uitgangspunten en aan de mogelijkheid om het product te kunnen gebruiken. Indien met zekerheid gezegd kan worden dat een concept niet kan voldoen, dan kan deze afvallen. Bij twijfel kan,

afhankelijk van het aantal concepten, besloten worden het concept mee te nemen of te laten vervallen.

Evaluatiefase
Voorlopige conclusies kunnen getrokken worden over de haalbaarheid van de concepten en over de mogelijkheden de gewenste doelen te behalen. Conclusies kunnen getrokken worden over het continueren van het project, en zo ja, met welk concepten, over het stopzetten van het project of wellicht over het herformuleren van de doelen.

Detailleringsfase
De drie hiervoor genoemde groepen van gebruiksfunctionaliteiten vormen een hiërarchie waarin conserveren/beschermen prioriteit heeft boven distribueren, hetgeen prioriteit heeft boven informeren. Het concept wordt eerst gedetailleerd op zodanige wijze dat voldaan wordt aan de gestelde eisen betreffende conserveren/beschermen, dat het geproduceerd kan worden, en dat het product verpakt of afgevuld kan worden. Hiermee zijn de onzekerheden met betrekking tot deze aspecten geëlimineerd. Vervolgens kan het concept (of de concepten) getoetst worden aan de andere doelstellingen en aan de uitgangspunten van het project, bijvoorbeeld de eisen op het gebied van kosten en milieu.

Het kunnen gebruiken van het product, zijnde het uiteindelijke doel van de verpakking, moet uitvoerig getoetst zijn.

De overblijvende concepten zijn het uitgangspunt voor de volgende ontwerpfase, waar het doel bestaat uit het ervoor zorgen dat het verpakte product de gewenste bestemming op het gewenste moment kan bereiken in de gewenste gebruikskwaliteit. Vervolgens kunnen de concepten wederom getoetst worden aan de doelstellingen en uitgangspunten van het project. Een zelfde exercitie kan herhaald worden voor de derde groep van functionaliteiten: het informeren van de verschillende gebruikers.

In elk stadium van het proces moet het zeker zijn dat het product gebruikt kan worden zoals gewenst. Daarna kunnen de resterende concepten getoetst worden aan de gestelde eisen en kan een vergelijking gemaakt worden op basis van de verschillen. In ieder van de drie ontwerpfasen moet gekeken worden of het mogelijk is om product en verpakking optimaal op elkaar af te stemmen.

De ontwikkelde methode kan op verschillende wijzen worden toegepast. Voor het vinden van practische oplossingen in een korte tijd, voornamelijk te ontwikkelen op basis van routine, genaamd re-design, kunnen de drie ontwerpcycli parallel verlopen. Bestaande oplossingen worden gecombineerd en de ontwerper ziet als het ware de oplossing voor zich. In het geval van innovatie is het aannemelijk dat dieper ingegaan wordt op bepaalde functionele aspecten. Dit impliceert dat de drie ontwerpfasen meer sequentieel uitgevoerd worden, alhoewel het voor te stellen is dat twee van de drie fasen parallel uitgevoerd worden.

In de praktijk zal er sprake zijn van veel tussenvormen van innoveren en ontwikkelen.

9

Conclusies

Verpakkingen zijn in het algemeen niet overbodig, maar in de meeste toepassingen onmisbaar. Desondanks komt overmatig verpakken zo nu en dan voor, als voorbeelden van onvoldoende ontwerpaandacht. De complexiteit van de functies van verpakkingen wordt in veel gevallen onderschat en er wordt onvoldoende gebruik gemaakt van in het vakgebied aanwezige kennis. Verpakkingsontwerpers die in de praktijk actief zijn, gebruiken impliciet een denkmethode waarbij een hiërarchie van functies gebruikt wordt. De in deze studie ontwikkelde en geteste methode, is een eerste versie van een beschreven methode voor het ontwerpen van verpakkingen. Deze methode kan een brugfunctie tussen grafisch en drie-dimensionaal ontwerpen van verpakkingen vervullen. De methode wordt geaccepteerd door personen die actief zijn in het vakgebied en het kan verwacht worden dat ontwerpers, onderwijzers, product ontwikkelaars, etc. eveneens baat hebben bij het gebruik ervan.

Aanbevelingen

Het wordt aanbevolen:

- onderzoek te doen naar bredere toepassing van de experimenten met de kaartjes om ontwerpprocessen te analyseren in andere gebieden van product ontwikkeling;
- een handleiding op te zetten voor verpakkingsontwerpers om de efficiëntie en effectiviteit van ontwerpprojecten te verbeteren;
- de mogelijkheden te onderzoeken van informatie- en communicatietechnologie om het gebruik te bevorderen en meer inzicht te verschaffen in achtergronden;
- te onderzoeken of de ontwikkelde methode opgenomen kan worden in ISO 14000;
- systematisch de toepassing van de ontwikkelde methode te onderzoeken in de praktijk, om meer inzicht in details en in het verloop van processen van verschillende soorten verpakkingen te verkrijgen;
- de overzichten met kwetsbaarheden van producten uit te breiden en te detailleren;
- een databank op te zetten voor eigenschappen van verpakkingsmaterialen;
- mathematische modellen te ontwikkelen voor het optimaliseren van houdbaarheid, buffering, etc. van producten, in de vorm van software om ontwerpers te ondersteunen in het bepalen van de verpakkingsmaterialen en gerelateerde dimensies;
- kengetallen te verzamelen betreffende verpakkingskosten en hoeveelheid verpakkingsmateriaal in relatie tot het verpakte product;
- systematisch onderzoek te doen naar verschillende terreinen van verpakken om verpakkingsfuncties te verbeteren en om een professioneel stelsel met kennis en methoden te ontwikkelen dat kenmerkend is voor een volwassen vakgebied;
- inzicht te verwerven in de beslissingsstructuur voor het kiezen/ontwikkelen van verpakkingsmachines en het opzetten van een verpakkingslijn in relatie tot de producteigenschappen;
- een overzicht te maken van alle relevante nationale en internationale wet- en regelgeving en bijbehorende besluiten (EU, USA en andere belangrijke landen voor export) dat regelmatig bijgehouden wordt;

- overzichten op te stellen van alle software programma's voor palletoptimalisatie en optimalisatie van hoeveelheid materiaal van primaire en secundaire verpakking;
- dat de overheden een rol spelen in het verkrijgen van een meer afgewogen oordeel en communicatie over verpakkingen. En als laatste aanbeveling: overheden moeten R&D verbeteringen in verontachtzaamde terreinen die van substantieel belang zijn voor nationaal beleid, zoals beleid betreffende verpakkingen en duurzame ontwikkeling, stimuleren.

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Besides the mentioned sources instruction material of the Netherlands Packaging Centre, which is used in the training OVK1 and OVK2, was used. The instruction material used concerns packaging materials and is available for public at the library of the Netherlands Packaging Centre, Stationsplein 9k, Gouda.

Acknowledgement

Since 1986, when I had searched the literature on cork and corkscrews, packaging has never ceased to draw my attention. At that time, different people held different opinions on packaging, opinions that were often contradictory. And yet very few of the people I came into contact with knew very much about the subject. Sources of scientific literature were few and hard to find. The quest for a plastic bottle for beer, my graduation project assignment at Delft University of Technology, subfaculty of Industrial Design Engineering, in 1987 made me realize that the actual activity of packing takes place somewhere between the product and the packaging. Sensitivity to beer depends on the type of beer, and the packaging must also satisfy other requirements depending on the type of beer. The experience I had gained was invaluable when judging the entries for the Netherlands Packaging Innovation and Design award *De Gouden Noot*, a competition organized periodically by the Netherlands Packaging Centre in Gouda. It was there that Hans Dirken pointed out the insight I had used when judging the many entries. It finally led to the idea of researching a method for packaging design. That idea ultimately presented me with the opportunity to go in depth on the ambivalence of public opinion on packaging, something that I had become aware of while reading Eliaan Schoonman's book on 'Issues Management'.

Because of the link between packaging and the environment, and because of legislation in the field of the environment, Han Brezet and Hans Dirken were prepared to act as my doctoral thesis supervisors; a most inspiring duo that neither spared me nor one another.

This study has given me an enormous amount of understanding of packaging problems, problems which I am now confronted with on a daily basis, and I therefore wish to express my gratitude to Hans Dirken and Han Brezet in particular. Besides that, Hans Dirken proofed to be a great translator.

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Delft, March 2002.

Roland ten Klooster

About the author

Graduated as MSc in Industrial Design Engineering at Delft University of Technology in 1987. He subsequently worked several years for Heineken Technical Services, where he also worked on his university graduation project, and then for Formaat engineers/designers. Together with Ton van Veen he founded Plato product consultants in February 1991, specialized in designing and giving advice on packaging.

Plato product consultants' clients are packers and producers of packaging, both large and small companies. Assignments can differ enormously, ranging from the organization of thematic workshops, feasibility studies, cost-saving projects, concept development, and all the various stages that run up to the actual concept realization.

Many trade journals in the field of packaging have published articles and interviews on his work and knowledge of this specific subject.

In 1991, 1994 and 1997 Roland ten Klooster was a member of the jury for the Netherlands Packaging Innovation and Design award *De Gouden Noot*. While engaged in packaging design he worked on the development of assessment tools to establish the environmental impact of packaging, and to advise the Eco-design projects turned out to be an interesting expansion of expertise. He has been advisor to several graduation projects of industrial design engineers at the Delft University of Technology, Subfaculty Industrial Design Engineering.

He has developed several tools for solving packaging problems better and faster. Writing this thesis would seem to be a logical sequel to that work.