Colophon

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Delft, September 2010

A digital version of the Delft Design Guide is available on the Internet: TU Delft OpenCourseWare: http://ocw.tudelft.nl

Introduction

The Delft Design Guide

The design methods presented in this book can be very useful for you as a designer, both during your time as a student and as a practitioner. Our aim is that you will use it as a source and reference during and after your design education to gradually build a repertoire of different ways of approaching the design of products.
It is crucial to be aware of two issues before starting to use the Delft Design Guide:

First, design methods are not recipes for success, just like strictly following a cooking recipe is not a guarantee for good food. Methods will help to bring structure to your thinking and actions (so you will be reminded of essential steps, work efficient, achieve your goals without too many detours, communicate with your team or client more easily, so you will not drown in the complexity of designing). Reflecting critically on the path you choose to take and the methods that you use is a competence that you mostly learn by experience.

Second, there are many ways to accomplish something. You yourself will need to learn how to find an appropriate approach for each new situation that you will encounter. To be able to perform well, you need to adapt any method to the specific situation that you are dealing with. The selection of an appropriate approach depends on your goal or task, the circumstances, your personality, background and experiences, etc. For every combination of designer, design problem and environment there will be multiple applicable methods that all have their own benefits and limitations. The more methods you have experienced, the better you know which way(s) of working fit you and thus the better you will be able to approach design problems effectively and efficiently.

Designing is changing existing situations into preferred ones

Designing in the widest sense of the word, is "changing existing situations into preferred ones" (Simon, 1996 pp.111). This means that designing is a way of thinking and acting that is aimed at understanding and intervening in the world around us through the design of products that aim to help satisfy people's needs and wishes. Characteristic for design education in Delft is the focus on the design process. By teaching design methods we aim to educate designers that have a fluent control of design processes and through that can come to successful design projects.

Designing is dealing with uncertainty

Designing distinguishes itself from other disciplines by the combination of a number of activities, for example: visualizing, creative thinking, empathizing with the user, reasoning from function to form (innoduction). But in essence, designing is an activity that is supposed to lead to new possibilities and an embodiment of those possibilities. That means that designing asks you to deal with uncertainty – to play with possibilities – to come to new insights that can lead to innovations. As a designer you have the difficult task to understand the world around you and at the same time to create new products that change the current world. How does that work? You could ask yourself a number of questions like:

- Is there a specific way of thinking of designers? How is their mind set?
- How do I need to act to come to good results? Which steps do I take? Which phases will I go through?
- How do I determine the boundaries of the context I am designing for?
- How can I map the 'world' of the user?
- When can I stop analyzing and start creating?
- How do I generate solutions?
- When is my design proposal good enough to present to others?
- How do I choose between a variety of solutions?

Design methods and tools can help you answer these and many other questions. The Delft Design Guide contains most methods that are used in the education in Delft and that often have been developed in Delft!

Designing is situated

Why do we need so many different design methods? Why is there not one method that fits all? Although designing is a distinct type of activity – i.e. different from accounting, or construction, etc - design processes can have different forms (Visser, 2009), depending on the specific combination of a designer and the designer's situation. A designer that is designing a surgical instrument for the Dutch market with a series size of one hundred will show a different process than an interdisciplinary team of nine people that is developing the new customer experience for Schiphol airport. This is something you will probably recognize from experience: on a detailed level every design process is different. But as we zoom out, more and more commonalities between design processes become visible. For example, both designers will probably start with analyzing the problem, both will subsequently start generating possible solutions, simulate and evaluate these solutions, and so forth. Although we admit that some – usually experienced - designers do not always start analyzing extensively but immediately come up with a preliminary design. If we zoom out to a more abstract level, we can see specific activities and ways of thinking that might be valuable to apply in other design situations as well.

The field of study that focuses on these issues is called design methodology. It aims at understanding the complex discipline of designing and develops methods that can help in teaching and supporting designers. It aims to study and describe the structure of design processes that is common to successful performance. That knowledge can then be used to develop methods. In turn, these methods can help designers to understand and execute design projects in efficient and effective ways. Although many methods can be used in multiple domains, they are often intended for a class of activities, for example for product design or service design or architecture.

However… it is important to understand that a method exists on paper only. A method is an abstract description of a possible structure that can be applied to one's thinking and actions. They are not recipes that tell you exactly what to do; rather they enable you to focus your mind on certain activities and information - in a certain order - to bring structure to your actions. Ultimately, you will be the one that acts. You can apply a method to guide your thinking and steer your actions, but a method is not the same as your activities or your thinking.

The function of the Design Guide

The curriculum at the faculty of Industrial Design Engineering has been organized in such a way that you will experience a number of different situations that you might encounter in practice,

and a number of methods that can help you to structure your thoughts and actions appropriately in those situations. It is a school that aims to produce designers that are capable of designing complex products (or services) through a thorough understanding and control of design processes. Of course there are many topics that you learn about, for example ergonomics, mathematics, material science, production technology, etc. but most of the design related courses teach you various aspects of designing through methods.

The Delft Design Guide is a collection of methods that is developed to help you to be ready for many new situations that you will encounter in the future. We would like you to be able to fluently act upon those situations through a mastery of a variety of methods. The collection of methods can help you to stage effective processes to come to radical – or incremental – innovations that humanity and our planet needs. In short: the more you know about these methods, and the more you have experienced them, the better you will be able to deal with the complex problems of our time.

The Delft Design Guide is first and foremost intended for teaching designers such as our students. It is complementary to the teaching material in design courses and the books and readers that accompany them. These include the yellow book by Roozenburg and Eekels, Integral Product Development by Buijs and Valkenburg, papers on the ViP method by Hekkert and van Dijk (their book is forthcoming), Order and Meaning in Design by Muller and many more. Part of the content of these sources has been used throughout this guide.

Next to that, the guide is intended for design tutors: to give an overview of the methods that are available within the Delft curriculum. Tutors can use the guide to make a selection of methods for a specific course. Finally the guide is also intended as a reference guide for design practitioners.

References

Simon, H. (1996). *The sciences of the artificial*. (pp. 111), MIT press.

Visser, W. (2009). Design: one, but in different forms. *Design Studies*, vol. 30 (3), pp. 187-223.

Guide for readers

The editors of this guide are aware that this collection of methods is not complete, since new methods are being developed right now!
The design of this guide facilitates additions.

Part 1 – Approaches to Product Design in Delft

Part one describes the processes of product design and innovation that are used in Delft. These models mostly originated within the faculty, but they draw on wider (international) research on product design and new product development. The topics addressed are:

1 Product Design in Delft
2 The Product Innovation Process
3 The Basic Design Cycle
4 Engineering Models of Product Design
5 The Fish Trap Model
6 Vision in Product Design
7 Emerging Design Methods

Part 2 – Design Methods

Part two presents a variety of design methods, which can be used in the product design process. The design methods present¬ed here are categorised according to the activity for which they can be used:

1 Creating a Design Goal
2 Creating Product Ideas and Concepts
3 Decision and Selection
4 Evaluation of Product Features

Part 3 – Generic Competences in Designing

Part three presents techniques and tips that support the development of your competences and skills needed throughout a design project. The follow¬ing areas will be covered in this section:

1 Planning & Design
2 Communicating & design
3 Reflection & Design
4 Traps, Tricks and Strategies & Concept Development
5 Teamwork & Design
6 Finding Information & Design

Overview

Part 1 Approaches to Product Design in Delft

- 1.1 Product Design in Delft
- 1.2 The Product Innovation Process
- 1.3 The Basic Design Cycle
- 1.4 Engineering Models of Product Design
- 1.5 The Fish Trap Model
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  - The Brainstorming Method
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  - Morphological Chart
  - Roleplaying
  - Storyboard
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  - Design Drawing
  - Three-dimensional Models
  - Biomimicry
  - Contextmapping
- 2.3 Decision and Selection
  - C-Box
  - Itemised Response and PMI
  - vALUe
  - Harris Profile
  - Datum Method
  - Weighted Objectives Method
- 2.4 Evaluation of Product Features
  - Product Simulation and Testing
  - Product Concept Evaluation
  - Product Usibility Evaluation

Part 3 Generic Competences in Designing

- 3.1 Planning & Design
- 3.2 Communication & Design
- 3.3 Reflection & Design
- 3.4 Traps, Tricks and Strategies & Concept Development
- 3.5 Teamwork & Design
- 3.6 Finding Information & Design

Part 1
Approaches to Product Design in Delft

In part one, descriptions of the processes of product design and innovation that are used in Delft are presented. These models mostly originated within the faculty, but they draw on wider (international) research on product design and new product development.

Part 1 Approaches to Product Design in Delft

1.1 Product Design in Delft

What is Product Design?

The word 'design' has various meanings. This guidebook focuses on the designing of material products. For that purpose we define 'design' here as 'to conceive the idea for some artifact or system and to express that idea in an embodiable form'. But this does not mean that the methods and tools presented in this guidebook are applicable only to designing material products. Much of the content of this guidebook is useful for the designing of other products too, such as services, strategies, programs, and brands.

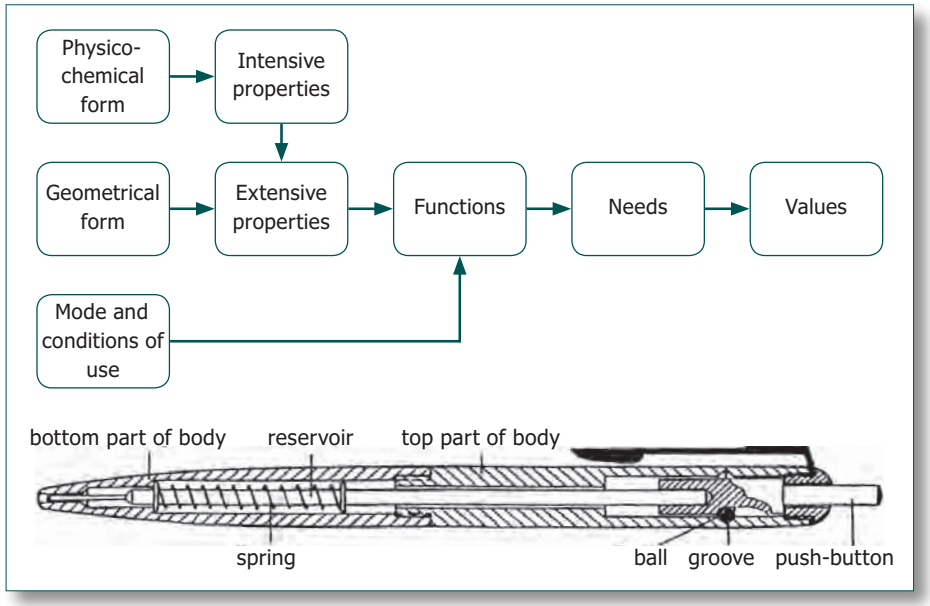

fig. 1.1 Model of reasoning by designers. (Roozenburg and Eekels, 1995)

Products are designed and made because of their functions. To design a product is to conceive of the use of the product and to find a suitable geometrical and physico-chemical form for the product and its parts, so that the intended function, or functions, can be fulfilled. Seen this way, the kernel of designing a product is reasoning from function to form and use. In order to understand the nature of product design one must understand the nature of that reasoning process. Therefore, by means of an example, we shall take a look at the relationships between the function, the properties, the form and the use of products.

Form

Figure 1.1 shows a ballpoint pen. A ballpoint pen can be seen as an assembly of different parts. Each part is defined by its form. By the form of a part we mean the geometrical form (geometry or shape including size) as well as the physico-chemical form (the material).

Properties

Due to their form the parts have particular properties. Some of these properties depend on the physico-chemical form only. These are called the intensive properties. Examples are the hardness of the writing ball, the density of the body and the viscosity of the ink. Other properties, the thing properties, are a result of the intensive properties plus the geometrical form. For example the weight of the body of the pen depends on the density and its volume. Rigidity of the body parts and ink flow smoothness are other examples. These properties are called the extensive properties.

Designers are particularly focused on the extensive properties, as they most directly determine the

functioning of a product. By choosing for a material, a designer sets many intensive properties all at once so to say, both good and less desirable ones (steel is stiff, but it is heavy and rusts; aluminum is light and does not corrode, but is less stiff). The art of designing is to give the product such a geometrical form that it has the desired extensive properties, given the intensive ones.

Function

Due to its properties a product can perform functions. In our example: the function of a ballpoint pen is 'writing'. A function is the intended ability of a product to change something in the environment (including ourselves) of that product. Some process should run differently than it would without the product; e.g. a coffee mill changes beans into ground coffee, a chair prevents one from becoming tired, and a poster provides information (decreases uncertainty).

Properties and functions have in common that they both say something about the behavior of things; they differ in that products *have* particular properties irrespective of the purposes of people. So statements on properties are objectively true (or false). This is not so for functions. Functions express what a product is for, its purpose, and this depends on intentions, preference, objectives, goals and the like, of human beings. So different persons might see different things as the function of a product.

Needs, Values

By fulfilling functions products may satisfy needs and realise values. For instance 'writing' may provide for a need to express oneself and thereby realise aesthetical or economical values.

In figure 1.1 developing a product proceeds from right to left. The more to the right one starts the more open-ended the design process will be (ballpoints are by far not the only things that can help realizing aesthetical values). But often designers start from an initial idea about function(s) for a new product and for the remainder of this section we shall assume that this is the case.

The kernel of the design problem

Now one can think up all sorts of functions and try to design a product for them, but will that product really behave as intended? Of course the functioning of a product depends on its properties and hence on it's geometrical and physico-chemical form. But there is more to it. For instance a ballpoint will write only if being used as anticipated by its designers: one must hold the pen in a certain way, one can write only on a more or less horizontal surface (on vertical surfaces ballpoints do not work) and the air pressure in the environment should neither be to low nor to high (in space capsules normal ballpoints do not work). So not only the form but also the mode and conditions of use determine how a product will actually function. Said differently: the context of use counts as much as the product itself and therefore designers should equally pay attention to both of them.

In many cases, especially for innovative products, the mode and conditions of use are not given facts for the designer, but are thought up - together with the form of the product - and hence form an essential part of the design. So designing a product involves more than designing the material thing; it also includes the design of its use.

Figure 1.1 shows how the functioning of a product depends on its form and its use. The arrows indicate causal relations. This means that if you know the geometrical and physico-chemical form of a product (i.e. the design of the ballpoint) you can in principle predict its properties. And if you also know in which environment and how the product will be used you can predict whether it will work or not. This kind of reasoning is often called 'analysis'. For designers analysis is an important form of reasoning, because it is the basis for all sorts of simulation.

But for designers the essential mode of reasoning is to reason from function to form. Before something can be analyzed, designers should first think up the form and its use as a possibility, and this in such a way that, if users act in accordance with the usage instructions, the intended function is realised. This is the kernel of the design activity.
Reasoning from function to form is usually called 'synthesis'. The descriptions - represented in whatever manner - of the form and the use of the product make up the design.

Now there is an important difference between these two modes of reasoning. The reasoning from form and use to functioning – 'analysis' – is based on deduction. Deduction is a *conclusive* form of reasoning, because in principle there is only one

answer: the product has or has not the required properties and will or will not function as intended. But we cannot infer conclusively the geometrical and physico-chemical form from the function, even if we would know everything about the laws of nature that govern the required behavior of the product. And in principle there are always different possibilities.

Here lies the challenge for designers, for in designing the most decisive step is not to predict the properties of a product already thought up, but the preceding step of conceiving of the form and use of that product. In a rather poignant contrast to this stands the fact that for the transition from form and use to function much scientific knowledge and methods are available, while the transition of function to form depends largely on the creative abilities and insight of the designer.
This does not mean that scientific and technical knowledge does not play a part. Causal models indicate the direction in which main choices can be made (choice of material, choice of shapes, choice of one or more key dimensions). Yet these models never lead to an unambiguous answer. The number of possible solutions to a design problem is in principle even innumerable.

The foregoing explains why in product design intuition and creativity have an indispensable role to play. Notwithstanding the importance of scientific knowledge, systematic approaches and modern possibilities for simulation, without intuition and creativity design processes would come to a stand still. A design cannot be deducted from a description of a problem, nor from a function or a performance specification. A design must be created in the true sense of the word. Knowledge only is not sufficient to design a product. Producing new ideas for products requires intuition and creativity, not only in the domain of product design but also in all design domains.

Product Design: a Multidisciplinary Approach

In the preceding analysis much has been left out in order to highlight the kernel of designing. In reality product designers have to deal with a variety of interests and stakeholders in the design process. Therefore, in addition to the function(s) many other factors must be considered when designing a product. Consumers look upon a product as something to be bought and used. To the design engineer it is a technical-physical system that has to function efficiently and reliably. Production engineers have to manufacture it, often in large numbers, preferably fast, cheaply, accurately and with the lowest possible number of faults. A marketer considers it a commodity with added value, something that people are prepared to buy. Entrepreneurs invest in new products and count on an attractive return. People that are not directly involved may see above all the reverse side of the coin: the undesirable and often even harmful side effects of production and use. To every point of view there are corresponding requirements that must be taken into account. Product design, therefore, demands a multidisciplinary approach. Which disciplines have to contribute largely depends on the characteristics of the product to be developed, but engineering design, industrial design, ergonomics, marketing and innovation management are nearly always involved.

References and Further Reading

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Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product-Ontwerpen: Structuur en Methoden*, Utrecht: Lemma, pp. 59-93

1.2 The Product Innovation Process

How can you structure the Product Innovation Process?

In a modern industrial company the design of a new product is not an isolated activity. Product design is embedded in a larger process, which is called 'product development'. Product development includes the development of a new product together with the plans for its production, distribution and sales. This larger process is also called 'new business development'.
Product development in turn is part of the product innovation process. Product innovation encompasses all activities that precede the adoption of a new product in a market. Thus, innovation comprises the development as well as the realisation of a new product or production process by a company.

Which part does product design play in the product innovation process, and how can we systematically approach this process? In this chapter we shall outline two models of the product innovation process that provide answers to these questions.

Product Innovation according to Roozenburg and Eekels

A company that wants to innovate must know very well what it wants to achieve. It must produce fruitful ideas for innovation, work them out skilfully into comprehensive plans for action and then realise those plans tenaciously yet flexible. Figure 1.2 shows a very simple model of this process; in figure 1.3 this model is worked out in more detail.

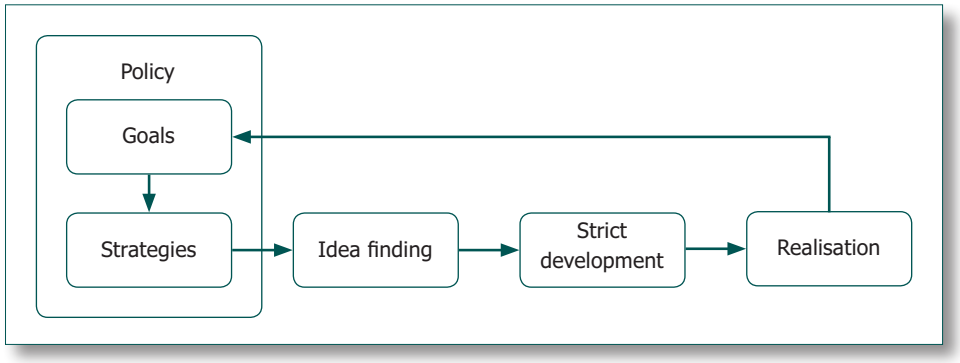

fig. 1.2 The structure of the innovation process (Roozenburg and Eekels, 1995)

Product Planning

The first part of the innovation process is called 'product planning'. In this phase it is decided what product(s) will be developed and when. Product planning has two parts: 'policy formulation' and 'idea finding'.

What a company wants to achieve is shown by its policy. Proclamation of goals only is not enough for a proper policy formulation. What are the strategies for fulfilling the goals? That is the complimentary part of the policy. In product development the product-market strategy (or 'product-market scope') lays down the kinds of products the company is going to apply itself to, now and in the future, and the markets it is going to attend.
A proper crystallised policy is the basis for the next activity: 'idea finding'. Before a product can be developed, someone has to come with the idea for it. In a new product idea two elements come together: a technical possibility and a market need. The discussion whether the development should be market-pull or technology-push is in this context less important; both elements are needed.

How does a company find new product ideas? Simply put, this comes to:

1. Keeping informed about markets and consumer needs (external research, opportunities and threats).
2. Investigating the strengths and weaknesses of the company (internal investigation).

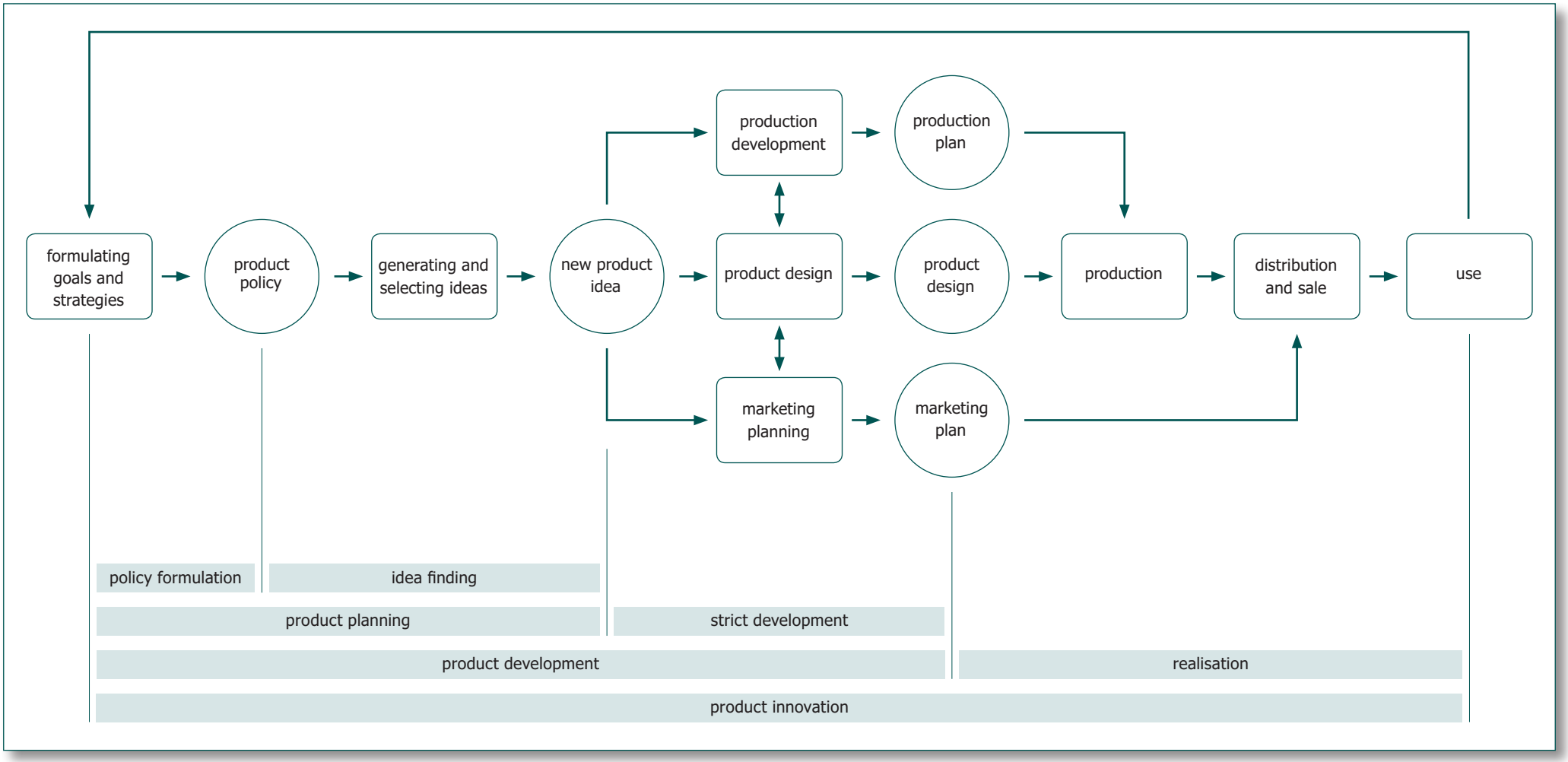

fig. 1.3 The phases of the product innovation process (Roozenburg and Eekels, 1995)

3 Getting inspired by those studies and generating new product ideas.
4 Selecting the most promising product ideas and formulating them into an assignment for further development.

When searching for new product ideas it is wise not to search at random, but first to demarcate the areas in which you want to be active. These areas are called 'search fields'. A search field is a strategic idea of future activities of a company, which is based on knowledge of external opportunities and awareness of internal capabilities (strengths). Idea finding has much in common with exploration. Its success depends on the activity itself, but also strongly on luck and chance. The product policy directs the idea-

finding process and provides normative information for making choices in that process.

Strict development

Promising ideas for new products must be worked out into detailed plans for the product, the production and the sale. This phase is here called 'strict development'. The plans are developed with the new business idea, as point of departure and it is very important that the plans are properly attuned to one another. To that end the product development process must be arranged 'concentrically'.

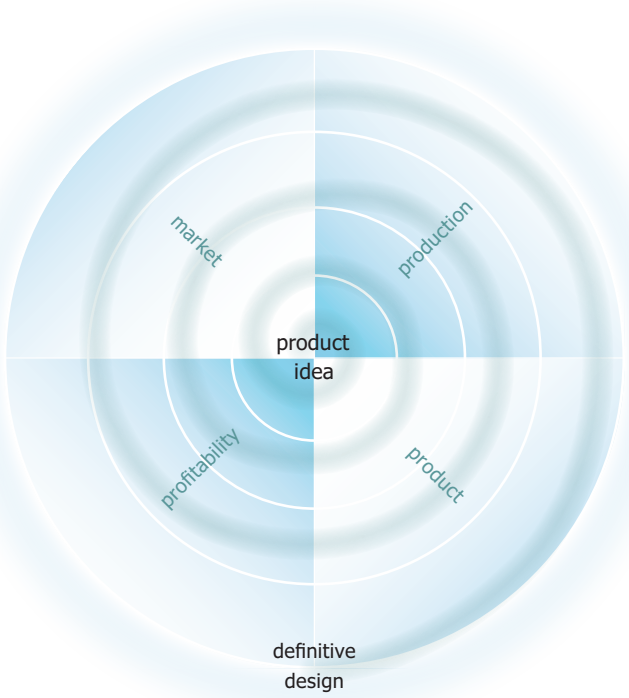

fig. 1.4 Concentric Development

Concentric development means that at first all plans are worked out in outline, to be able to estimate the technical and commercial feasibility of the new business activity as a whole. Whenever a product idea survives the first round, the plans are further worked out in a second round, etc., until they are completed and fit one to another (see figure 1.4). Of course the number of rounds is arbitrary. Essential is that in each round all aspects of the new business activity (function, appearance, use, manufacturing, cost, environment, etc) are taken into consideration. Other names for this fundamental methodological principle are 'integrated product development', 'simultaneous engineering' and 'concurrent engineering'.

By concentric development two important things are achieved. Concentric development prevents that more time and money is spent in the development of eventual 'non-successful' product ideas than necessary. Besides that, as concentric development stimulates the interaction between product design, production development and marketing planning, it raises the quality of the product and shortens the lead times.

Realisation

In this phase the detailed plans out of the strict development phase are transformed into reality. This phase includes production, distribution, sales and the actual use of the product.

The model of the product innovation process in figure 1.3 shows how product design is embedded within the larger industrial innovation process. Product design is preceded by product planning activities that define the kind of products to design and it proceeds in interaction with production development and marketing planning. The development of a new product will be successful in so far as these activities are properly attuned.

Product Innovation Process according to Buijs

J. Buijs (see figure 1.5) introduced a four-stage innovation model based on the assumption that the product innovation process is similar to an (experiential) learning process (Buijs, 2003). Coming up with new products and services is the response of a company to its changing competitive environment. The four-stage product innovation model consists of:

1 Strategy formulation (i.e. policy and strategy formulation).
2 Design brief formulation (i.e. idea finding).
3 Product development (i.e. strict development).
4 Product launch and use (i.e. realisation).

From this point of departure Buijs and Valkenburg (2000, 2nd ed.) developed a more detailed model of the product innovation process consisting of 17 steps in a given order (see figure 1.6). This model puts more emphasis on the first phase of the product innovation process, the Strategy Formulation (or product planning). For the explanation of product

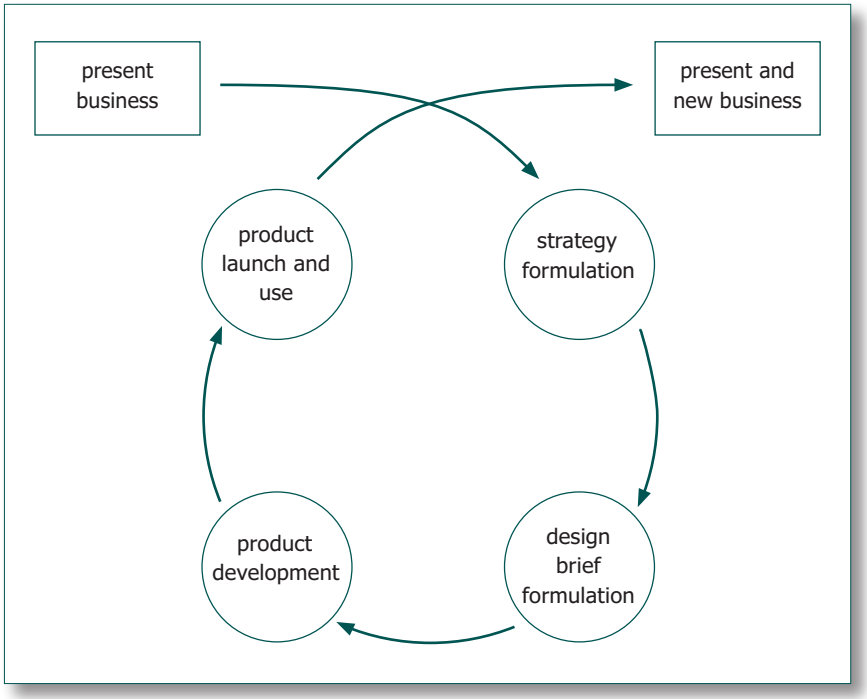

fig. 1.5 Four stages Product Innovation Model (Buijs and Valkenburg, 2000, 2nd ed.)

innovation in relation to the corporation, its brands and the kind of new product the company should develop, a very detailed description of the first stage of the innovation model is presented.

The strategy formulation stage is subdivided into six activities:

1 analysis of the present situation, which leads to the strategic situation of the company;
2 internal analysis;
3 external analysis;
4 search area generation;
5 search area evaluation; and
6 search area selection.

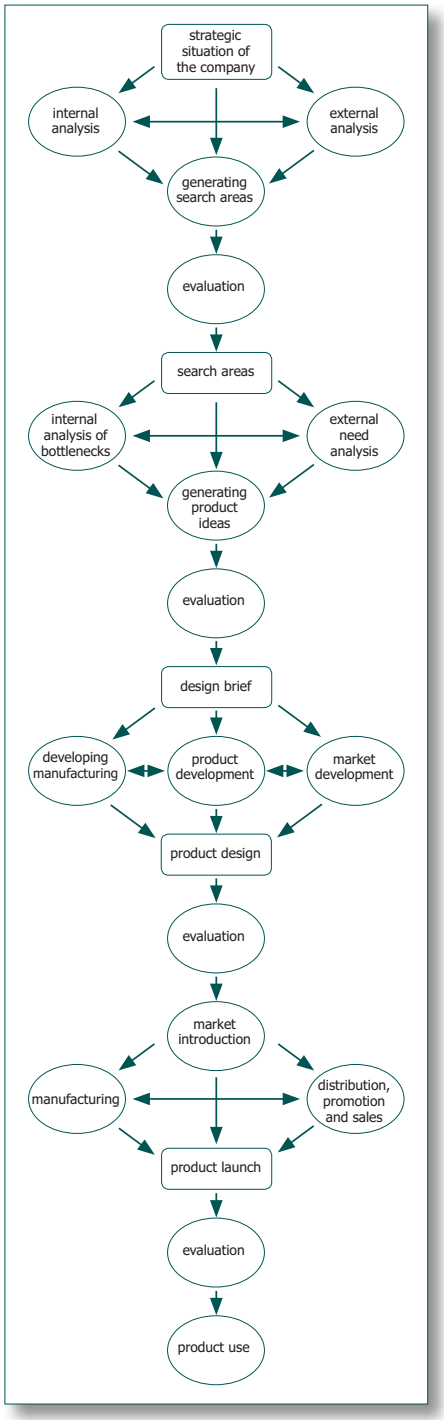

fig. 1.6 Model of the Product Innovation Process (Buijs and Valkenburg, 2000, 2nd ed.)

Based on an analysis, the strategic situation of the company is formulated. The strategic need for innovation is made explicit by estimating the future corporate situation when no strategic changes are made. During the internal analysis, the strategic strengths, the core competences are defined. In the external analysis, the competitive environment is analysed and the opportunities and threats are made explicit. Search areas are strategic ideas for innovation and potential new business opportunities. A search area is a combination of a strategic strength and an external opportunity. During search area evaluation, the strategic innovation ideas are checked with the outside world by interviewing experts, looking at patents, observing potential clients/users, etc. In search area selection, a definite choice is made. The selected search areas form the starting point for the next phase: design brief formulation.

Circular Chaos: the Delft Innovation Model

Inspired by the circular four-stage innovation model, the linear and sequential 17-step model was adapted (see figure 1.7). Product innovation processes are intended to help companies design and introduce new products, which customers are willing to buy and use. Therefore, in product use the innovation process ends, but at the same time this forms the starting point of a new product innovation process. Visualizing the innovation process as a circular model suggests that there is neither beginning nor end, which is true in the sense that introducing a new product on the market will lead to reactions from competitors. These in turn will cause the original innovating company to start the next new product innovation process in order to regain its competitive advantage.

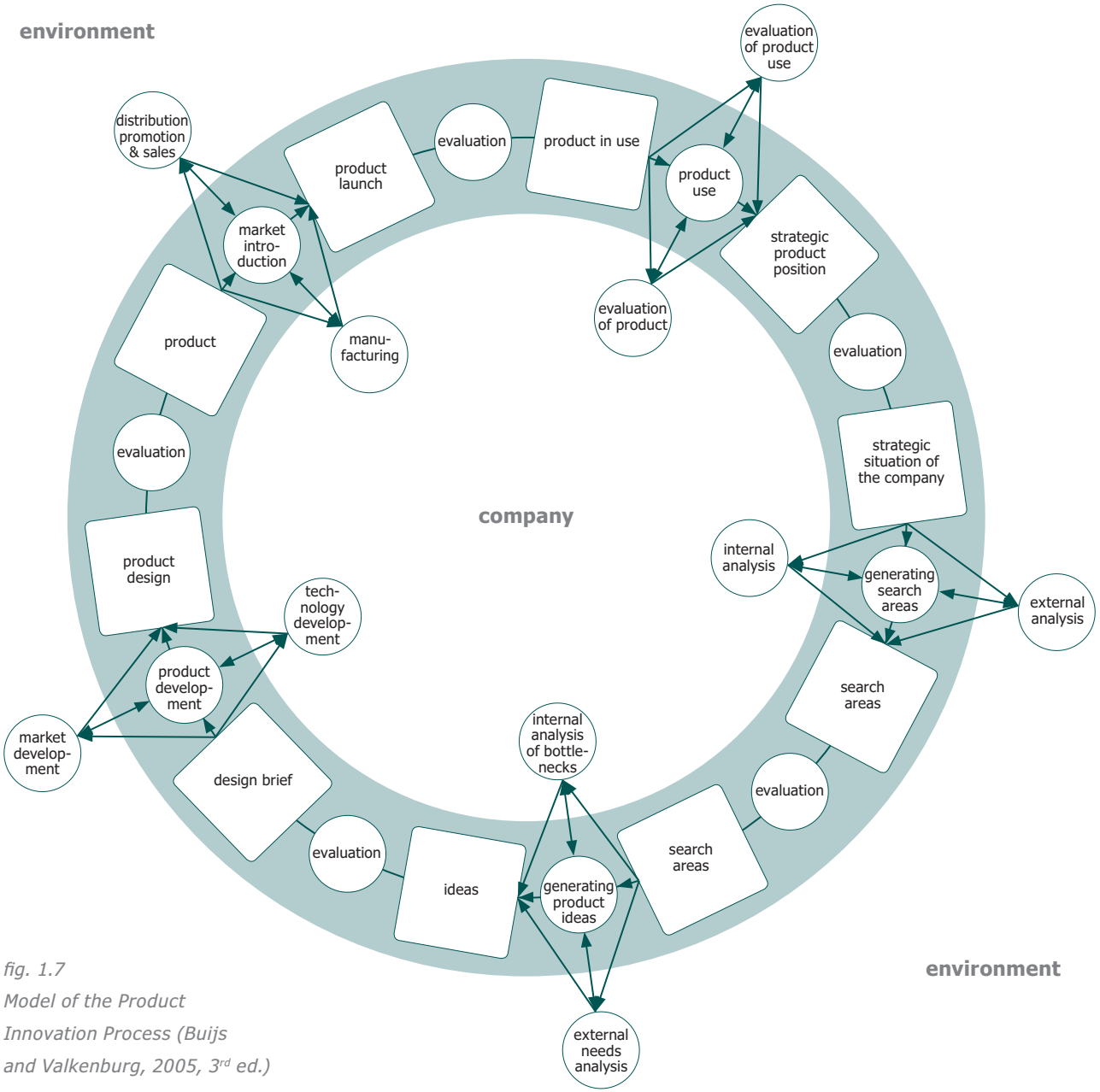

fig. 1.7
Model of the Product Innovation Process (Buijs and Valkenburg, 2005, 3rd ed.)

References and Further Reading

Buijs, J. and Valkenburg, R. (2000, 2nd ed.) *Integrale Productontwikkeling*, Utrecht: Lemma.

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Buijs, J., (2003) 'Modelling Product Innovation Processes: from Linear Logic to Circular Chaos', *Creativity and Innovation Management*, Vol. 12 (2), pp. 766-93.

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1.3 The Basic Design Cycle

How do you think when designing?

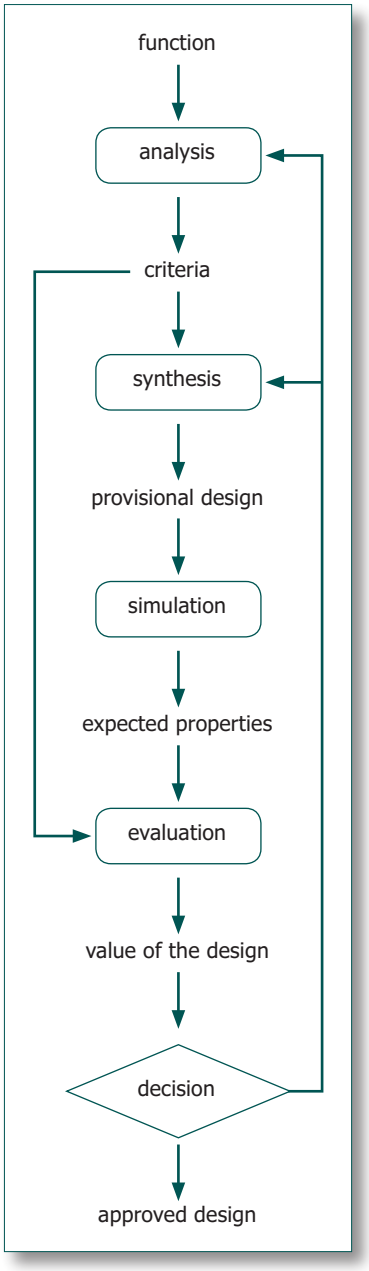


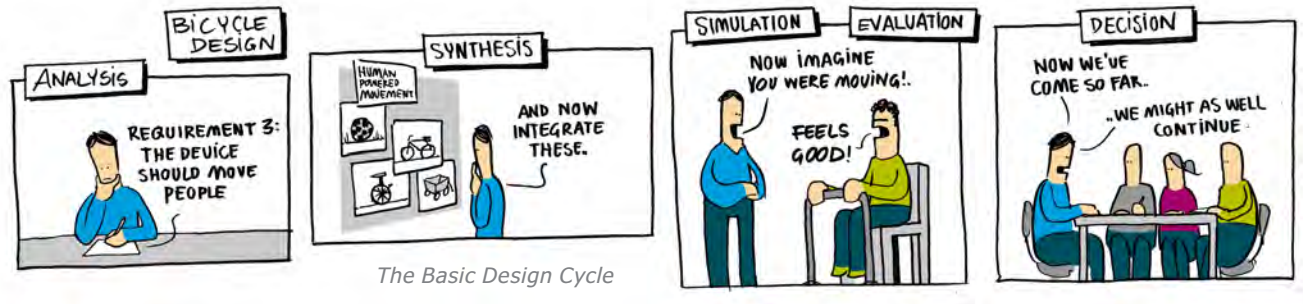
fig. 1.8
The Basic Design Cycle (Roozenburg and Eekels, 1995)

In section 1.1 we saw that the kernel of designing is reasoning from functions to form (geometrical form and physico-chemical form) and use of a new product. It is not possible to deduce the form and the use of a product from its function(s) and in principle many different for a particular function can exist. Therefore in essence design a *trial-and-error* process that consists of a sequence of empirical cycles. In each cycle by experience, intuition and creativity provisional solutions are generated, which are to be tested for their qualities by theoretical simulations and practical experiments.
In this trial-and-error process the knowledge of the problem and of the solution(s) increases spirally.
Roozenburg and Eekels have called their model of this cycle 'the basic design cycle' (see figure 1.8). They claim that the basic design cycle is the most fundamental model of designing, because this cycle can be found in all phases of the design process and is applicable to all design problems, whatever their nature! Someone who claims to have solved a design problem has gone through this cycle at least once.

Analysis

Point of departure in product design is the function of the new product, i.e. the intended behaviour in the widest sense of the word. We do not only include the technical function, but also the psychological, social, economic and cultural functions that a product should fulfil.
The function need not be laid down in all detail - this is even impossible -, but broad statements on the function must have been made, otherwise the designer does not know what has to be designed.

In section 1.2 we saw that product design is preceded by a product planning phase, which should yield one or more product ideas with, among other things, statements on the functions to be fulfilled. In the analysis phase the designer forms an idea of the problems around such a new product idea (the problem statement) and formulates the criteria that the solution should meet, first broadly and in later iterations more accurately and complete. The list of criteria is called the 'performance specification' or 'program of requirements'.
Like the design itself a performance specification cannot be 'deduced' from the problem. It is part of the perception that the client, the designer and other 'stakeholders'



The Basic Design Cycle

have of a certain problem. A specification comprises all sorts of decisions as to the direction in which solutions will be sought; writing a specification is therefore already a genuine design activity. One can, therefore, arrive at different, equally good specifications for one and the same problem.

Synthesis

The second step in the basic design cycle is the generation of a provisional design proposal. The word 'synthesis' means: the combining of separate things, ideas, etc., into a complete whole. Synthesis is the least tangible of all phases of the cycle, because human creativity plays the most important part. But the origination of ideas, seen as a psychological process, cannot be localised in a particular phase of the basic design cycle. The synthesis step is the moment of externalisation and description of an idea, in whatever form (verbally, sketch, drawing, model, etc.)
The result of the synthesis phase is called a *provisional* design; it is not yet more than a possibility, the value of which can only become apparent in the later phases of the cycle.

Simulation

Simulation is a deductive sub process. Simulation is: forming an image of the behaviour and properties of the designed product by reasoning and/or testing models, preceding the actual manufacturing and use of the product. Here, the whole array of technological and behavioural scientific theories, formulas, tables and experimental research methods is available to the designer. Yet, in practice many simulations are based merely on generalisations from experience. Simulation leads to 'expectations' about the actual properties of the new product, in the form of conditional predictions.

Evaluation

Evaluation is establishing the 'value' or 'quality' of the provisional design. To do so, the expected properties are compared with the desired properties in the design specification. As there will always be differences between the two, it will have to be judged whether those differences are acceptable or not. Making such a value judgment is difficult, for usually many properties are involved. Often a design proposal excels in part of these properties, while it is weak in others.

Decision

Then follows the decision: continue (elaborate the design proposal) or try again (generate a better design proposal). Usually the first provisional design will not be bull's eye and the designer will have to return to the synthesis step, to do better in a second, third or tenth iteration. But you can also go back to the formulation of the problem and the list of requirements.
Exploring solutions appears to be a forceful aid to gain insight into the true nature of a problem: you might therefore often want to adjust, expand, or perhaps sharpen up the initial formulation of the problem. The design and the design specification are thus further developed in successive cycles and in a strong interaction, until they fit one another.

This iterative, spiral-like development of the design and the performance specification has been reflected in figure 1.9 The design process comprises a sequence of intuitive (reductive) steps and discursive (deductive) steps. Between the two, there is always a comparison of the results attained so far and the desired results. The experience gained in the cycle is fed back, both to the design proposal and to the formulation of the problem and the list of requirements.

References and Further Reading

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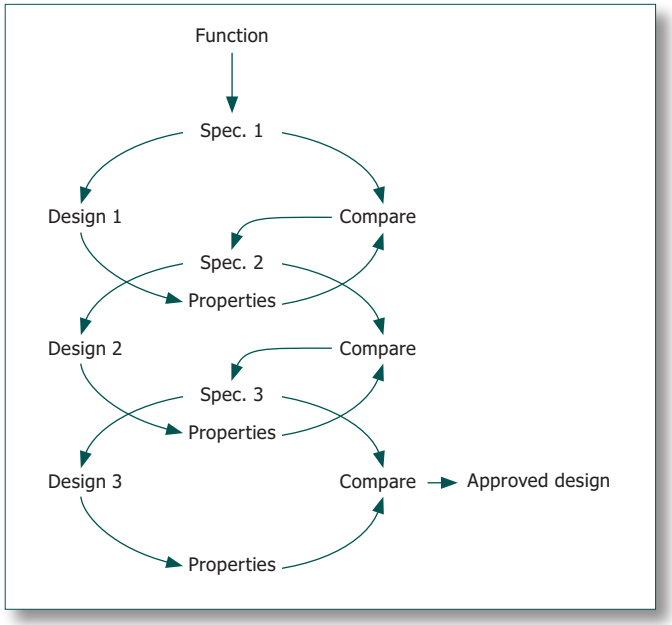

fig. 1.9 The iterative structure of the design process (Roozenburg and Eekels, 1995)

1.4 Engineering Models of Product Design

How can you structure engineering design processes?

Models of the design process have been developed since the early nineteen-sixties. In engineering design, this development has converged to what might be called a consensus model. Typical examples of this model are the model of Pahl and Beitz and the VDI-model (Verein Deutscher Ingenieure). These models are also called phase-models or procedural models.
The engineering models are fundamentally derived from the way in which engineering design problems are conventionally perceived and modelled. Products are seen as technical systems that transform energy, material and information. The functional behaviour of a technical system is fully determined by physical principles and can be described by physical laws. The engineering design problem is to find and define the geometry and materials of the system in such a way that the required prescribed physical behaviour is realised in the most effective and efficient way.

Engineering models are based on the idea that a design-in-the-making can exist in three different ways:

1. As a *function structure;* this is a representation of the intended behaviour (the functions) of a product and its parts.
2. As a *solution principle;* this defines the working principle, or mode of action, of a product or a part thereof. It specifies (in generic terms) the function carriers or 'organs' of which a product should be built up, to fulfil its internal and external functions.

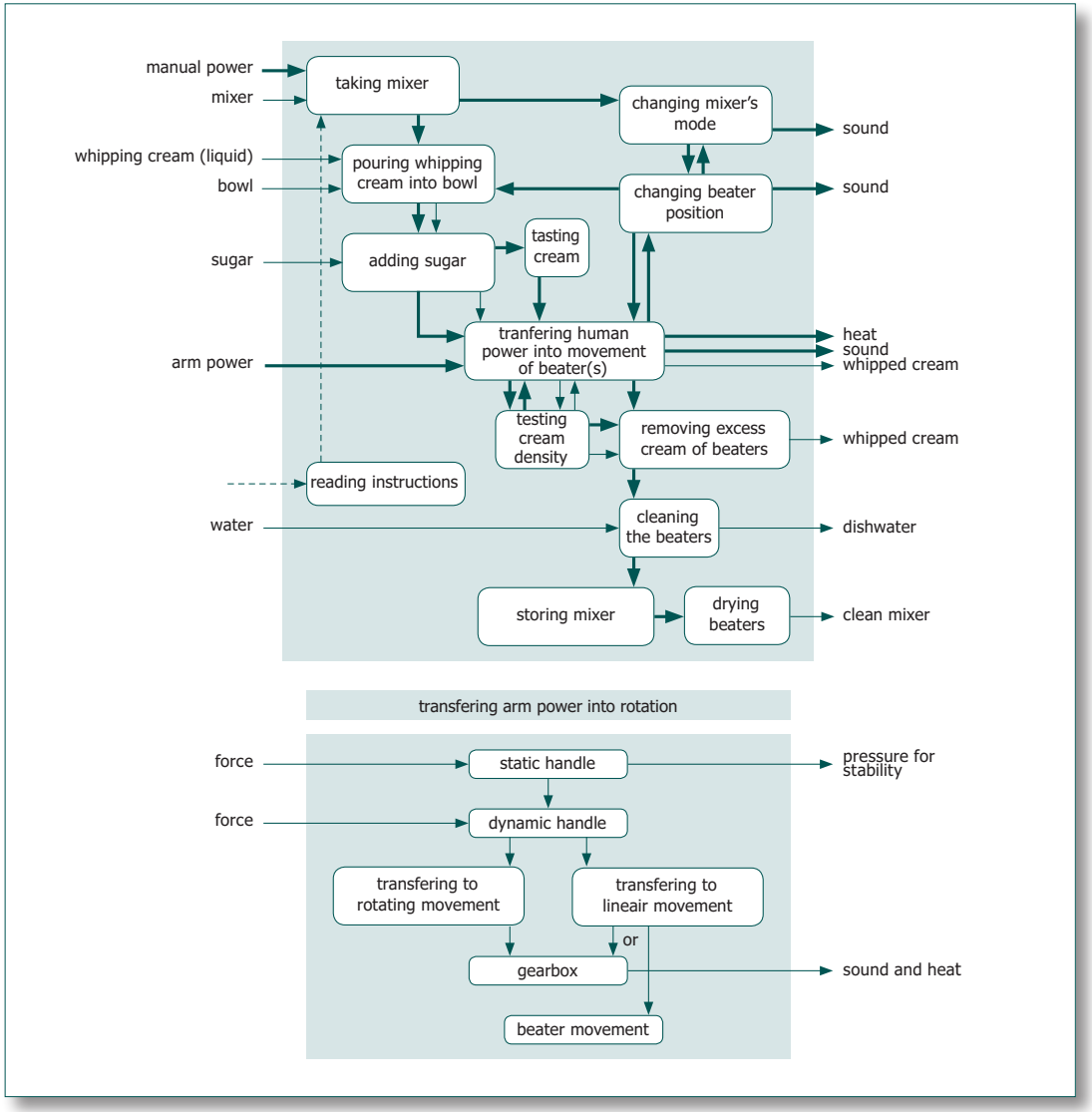

fig. 1.10 Example of a function structure (from student report)

3 As an *embodied design;* this is a design in the more usual meaning of the word. It is a description, usually as a drawing, of the geometrical and physico-chemical form of a product and its parts.

The Function Structure

In a function structure (see figure 1.10), the product and its components and parts are represented by their functions. It is an abstract representation that does not refer to concrete shape and material of the physical parts of the system.
The function structure is an important methodological tool; it provides an aid for thinking about the mode of action of a product, without enforcing premature decisions on its embodiment.

The Solution Principle

A function structure is a model of the intended behaviour of a material system; it shows what internal functions must be realised by (not yet concretely defined) elements, so that the system as a whole can fulfil its external overall function. Designers try to realise this behaviour by thinking up concrete parts and components for the internal functions. For each part its place in the whole is established, as well as its precise geometry and materials. A solution principle (see figure 1.11) is an idealised (schematic) representation of the structure of a system or a subsystem. The characteristics of the elements and the relations are qualitatively determined. Yet a solution principle already establishes essential characteristics of the form of the product. Just as the overall function of a system is the resultant of a number of sub-functions, a solution principle for a product as a whole arises from the combination of solution principles for its parts. The overall solution principle, which is chosen for further development, is called the *principal solution*.
The core of designing - reasoning from function to form - is especially evident in the creation of a principal solution, for the principal solution marks the transition of the abstract functional structure to the concrete material structure of the product to be developed. Reasoning from function to form does not lead to a unique answer. Any function can therefore be realised with different physical effects, and these can be worked out into different solution principles and an overall principal solution.

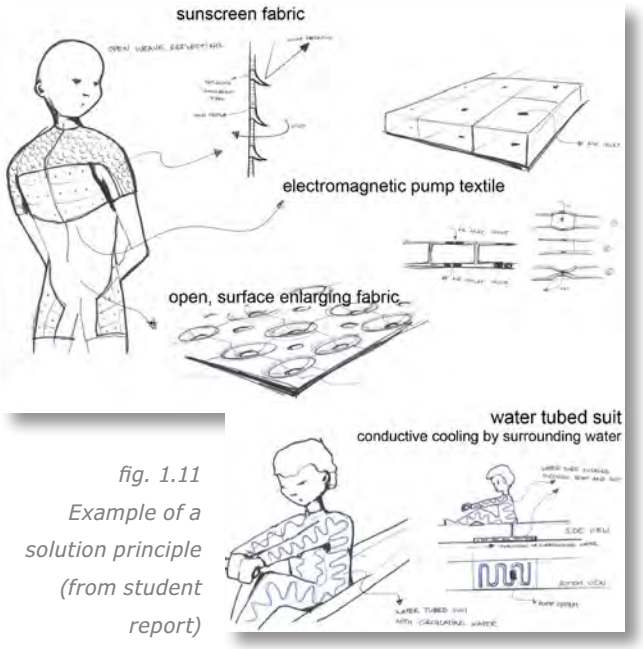

fig. 1.11 Example of a solution principle (from student report)

The Embodied Design

A principal solution is already a first design proposal, because it embodies decisions on the geometry and material of the new product. It is, however, not more than an outline design proposal, which deals with physical feasibility only. It is a technical possibility that has to be worked out to some extent, before it can be evaluated against non-technical criteria as well. The development of a principal solution to a *embodied design* (see figure 1.12) can be seen as a process of establishing increasingly accurate, and more numerous characteristics of the new product, in particular: (1) the structure of the entire product (the arrangement of the parts) and (2) the shape; (3) the dimensions; (4) the material(s); (5) the surface quality and texture; (6) the tolerances and (7) the manufacturing method of all the parts.
A product design is ready for production once all the design properties have been specified definitively and in all required detail. Usually many properties have to be considered, and the relations among them are complex. Therefore the development of a principal solution into a detailed definitive design usually requires some stages in between. Typical intermediate stages are the *design concept* and the *preliminary design* (or *sketch design*).
In a design concept a solution principle has been worked out to the extent that important properties of the product - such as appearance, operation and use, manufacturability and costs – can be assessed, besides the technical-physical functioning. One should also have a broad idea of the shape and the kinds of materials of the product and its parts.

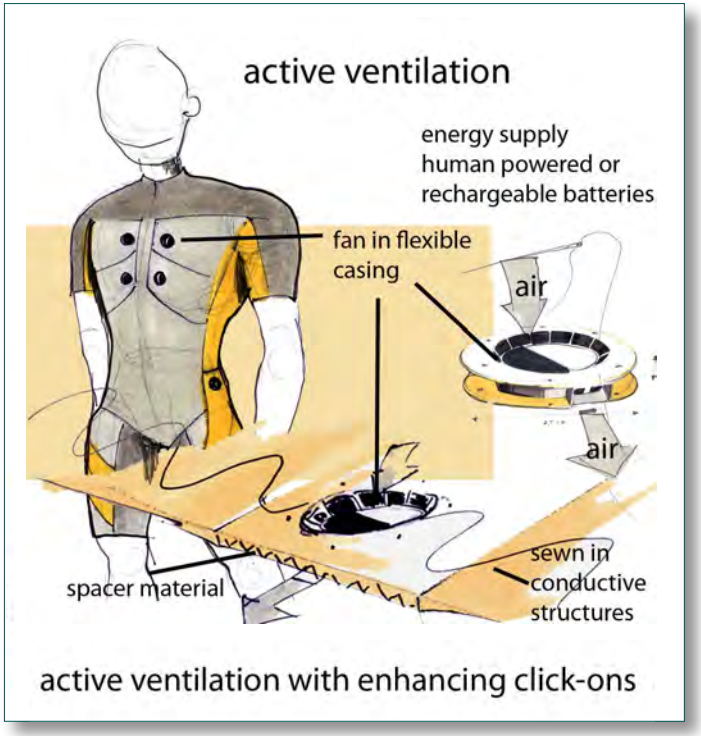

fig. 1.12 Example of embodied design (from student report)

A preliminary design is the following stage and also the last stage before the definitive design. It is characteristic of this stage that the layout and shape and main dimensions have been established for at least the key parts and components of the product, and the materials and manufacturing techniques have been determined.

The modes of existence of a design proposal as described above, enable designers to explicate their thoughts about a design, and to judge and further develop them. Often there corresponds a more or less usual form of representation to each stage, such as flow diagrams for function structures, diagrams for solution principles, sketches for concepts, layout drawings for preliminary designs and standardised technical drawings for definitive designs. Such documents mark a stage in the development of the design and a phase in the design process.

The model of Pahl & Beitz

A typical example of this 'consensus model' is the model of Pahl & Beitz (figure 1.13). Their model has four phases:

- clarification of the task ('Aufgabe klären')
- conceptual design ('konzipieren')
- embodiment design ('entwerfen')
- detail design ('ausarbeiten')

Broadly speaking, the phases involve the following activities:

Clarification of the task

In this phase the problem, handed over to the designer by the product planning department or an external client, is analysed, and information on the problem is collected. Based upon that information a *design specification* (or *programme of requirements*) is drawn up. The specification defines the functions and properties that are required for the new product, as well as the constraints placed upon the solution and the design process itself, such as standards and date of completion.
The specification directs the work in all other phases of the design process. Work done in later phases may change ones understanding of the problem and new information may become available. Therefore modification and refinement of the initial specification should be undertaken regularly. This is indicated by the feedback loops in the models.

Conceptual design

Given the specification, broad solutions are to be generated and evaluated, that provide for a suitable point of departure for embodiment design and detail design. Such broad solutions are called concepts (Pahl & Beitz) or *schemes* (French). Normally they are documented as diagrams or sketches.
The conceptual phase starts with determining the overall function and important sub functions to be fulfilled and establishing their interrelationships (function structure). Next *solution principles* ('Lösungsprinzipien'), also called *working principles* ('Wirkprinzipien'), for sub-functions or sub-problems are generated and integrated into overall solutions, in accordance with the function structure. Such a combination of solution principles has been called a *principal solution* ('Prinzipielle Lösung'). A principal solution defines those physical-technical characteristics of a product, that are essential for its functioning.
However, the choice for a particular principal solution is not to be based upon technical criteria only. Criteria relating to use, appearance, production, costs and others, must also be taken into account. To that end principal solutions have to be worked up into concept variants that show already part of the embodiment of the principle. A concept, or scheme, should be carried to a point 'where the means of performing

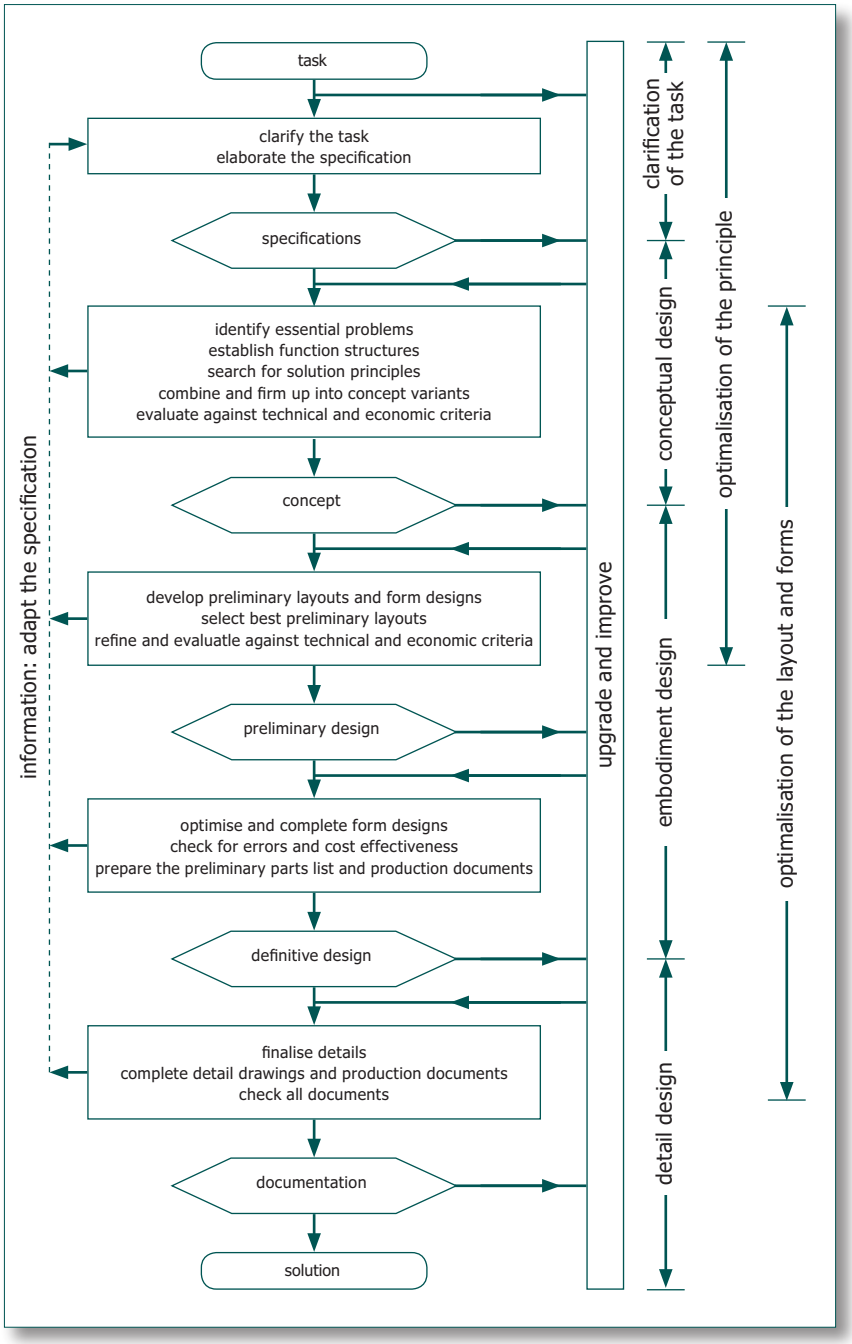

fig. 1.13
Phase model of the Product Design Process by Pahl and Beitz (Roozenburg and Eekels, 1995)

each major function has been fixed, as have the spatial and structural relationships of the principal components.
A scheme should have been sufficiently worked out in detail for it to be possible to supply approximate costs, weights and overall dimensions, and the feasibility should have been assured as far as circumstances allow.

A scheme should be relatively explicit about special features or components, but need not go into much detail over established practice. Conceptual design is commonly seen to be the most important phase of the design process, because the decisions made here, will strongly bear upon all subsequent phases of the design process. A weak concept can never be turned into an optimum detailed design, so to speak.

Embodiment design

In this phase the chosen concept is elaborated into a *definitive design*, also called *definitive layout*. The definitive design defines the arrangement ('layout') of assemblies, components and parts, as well as their geometrical shape, dimensions and materials ('form designs').

Contrary to what the phrase 'definitive' may suggest, the definitive design need not be completely worked out into full detail. The configuration of the product and the form of the parts are to be developed up to the point where the design of the product can be tested against all major requirements of the specification, preferably as a working model or prototype.

The decisions to be taken about the layout and form of the components and parts are strongly interrelated. Therefore, more than conceptual design, embodiment design involves corrective cycles in which analysis, synthesis, simulation and evaluation constantly alternate and complement each other. Embodiment design is essentially a process of continuously refining a concept, jumping from one sub-problem to another, anticipating decisions still to be taken and correcting earlier decisions in the light of the current state of the design proposal. It proves therefore difficult to draw up a detailed plan of action for this phase, that holds in general.

In Pahl and Beitz' model embodiment design is subdivided into two stages. The first stage is leading to a *preliminary design*, in which the layout, form and material of the principal function carriers are provisionally determined. In this stage several alternative embodiments of a concept are often worked up in parallel in order to find the layout. In the second stage, then, the best preliminary

design is elaborated, up to the point where all major decisions about the layout and form of the product are taken and tests of its functionality, operation and use, appearance, consumer preference, reliability, manufacturability and cost can be carried out. Normally at the end of this phase the design is represented by layout drawings, made to scale and showing important dimensions, and preliminary parts lists.

Detail design

In this final phase the geometrical shape, dimensions, tolerances, surface properties and materials of the product and all is individual parts are fully specified and laid down in assembly drawings, detail drawings and parts lists. Also instructions for production, assembly, testing, transport and operation, use, maintenance and the like, have to be worked out now. All these documents fall under the heading of the 'product documents'.

The VDI Model (Verein Deutscher Ingenieure)

Of a more recent date than the model of Pahl and Beitz is the Guideline VDI 2221, Systematic Approach to the Design of Technical Systems and Products. This guideline aims for a general approach to design, which is applicable to a wide variety of tasks including product design, and transcends specific branches of industry.

To demonstrate its potential, examples are given for mechanical engineering, process engineering, precision engineering (mechatronics) and software engineering. Yet, the ideas presented in the guideline seem to be more closely associated with mechanical engineering design.

The general approach is divided into seven stages, correspondingly producing seven results (figure 1.14). Either all or some of the stages are to be completed, depending on the task at hand. Individual stages can be combined into design phases, in order to assist the overall planning and management of the design process. It is stated that the way stages are grouped into phases can differ depending on the branch of industry or company.

Apart from stage 4, in which a so-called *module structure* ('modulare struktur') is to be established, all stages and results can be recognised in the Pahl and Beitz model as well. The module structure takes more or less the place of the concept in the Pahl and Beitz model. The module structure specifies the division of a principal solution into realisable parts, components or assemblies, which has to be undertaken before starting the process of defining these modules in more concrete terms. Such a breakdown is particularly important for complex products, as it facilitates the distribution of design effort in the phase of embodiment design.

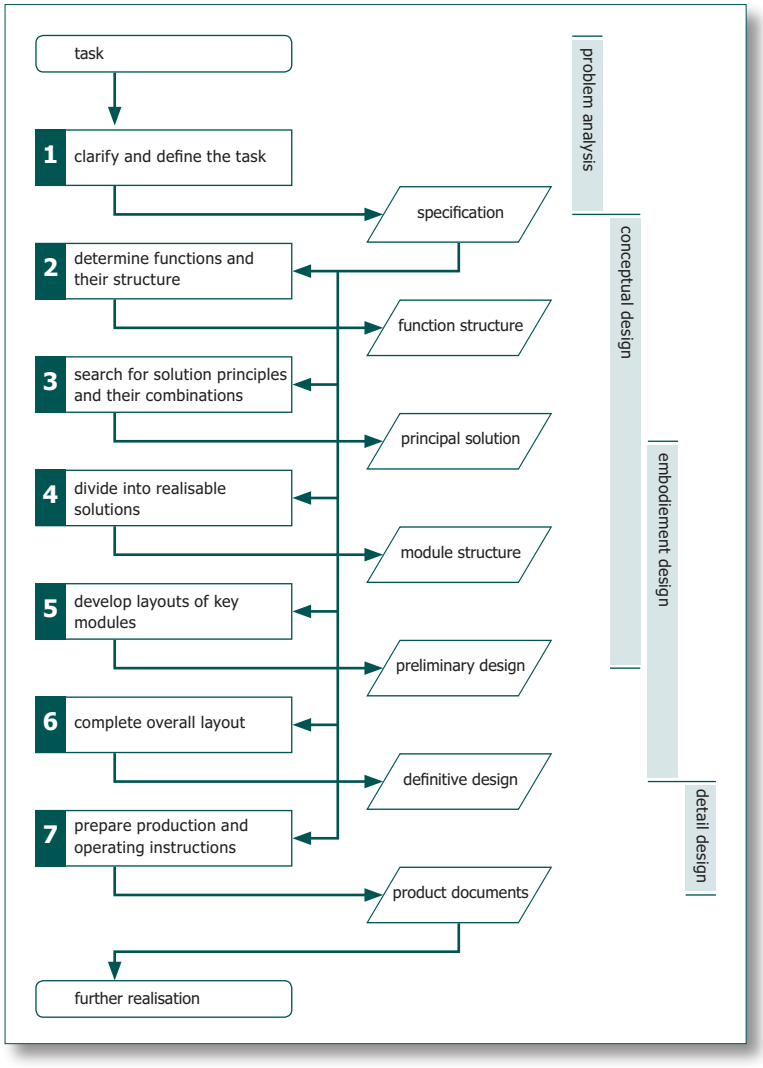

fig. 1.14 Phase model of the Product Design Process by VDI (Roozenburg and Eekels, 1995)

Some comments on phase-models

- First, it is stressed by all authors of phase-models that sharp divisions between the phases cannot be drawn, and that the stages and phases do not necessarily follow rigidly one after the other. They are often carried out iteratively, returning to preceding ones, thus achieving a step-by-step optimisation.
- Second, a phase-model does not show the problem-solving process, by which solutions for the design problem are generated and refined; in each phase the designer will go through the basic design cycle, often more than once.
- Third, in each phase alternative solutions can be thought up. Working out all solution variants through all phases would lead to an explosion of the number of possibilities to be studied. On the other hand, restricting oneself to one track only within the network of possibilities is dangerous, because, then, the better or best alternatives may be overlooked. One is therefore urged to diverge and converge in each phase.
- Fourth, the models have been developed with the designing of new, innovative technical systems in mind. Therefore they pay (too) much attention to the conceptual design phase, at the expense of the phases of embodiment design and detailed design. In practice many design projects can do without inventing new technical principles, and start from known, proven, concepts. However the phase models offer little procedural advice concerning embodiment and detail design. It has even been questioned whether more detailed procedural models for these phases may exist (but see the 'Fish-Trap' Model in section 1.5)
- In phase-models the end of each phase can be taken as a decision point. Herein lies the importance of phase models. At the decision points you look back on the work performed, and you weigh the results obtained against the goals of the project. Phase models therefore urge a regular evaluation of the project: reject, do a step back, or continue to the following phase.

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VDI 222, *Systematic Approach to the Design of Technical Systems and Products*. Düsseldorf, VDI, 1987.

1.5 The Fish Trap Model

How can you generate form concepts?

"The Fish Trap model (see figure 1.15) *is a method for generating and developing a form concept for a product up to sketch plan. As such, the approach is intended to cover the form-creation phase. The method is prescriptive, meaning that it indicates how a concept should be developed"* (Muller, 2001, pp 196). Motivation for the development of this method rose from experiences with students; they were confronted with the difficulty to just start designing and to give direction to their search for design solutions. Methods that may steer this form creation phase were not available.

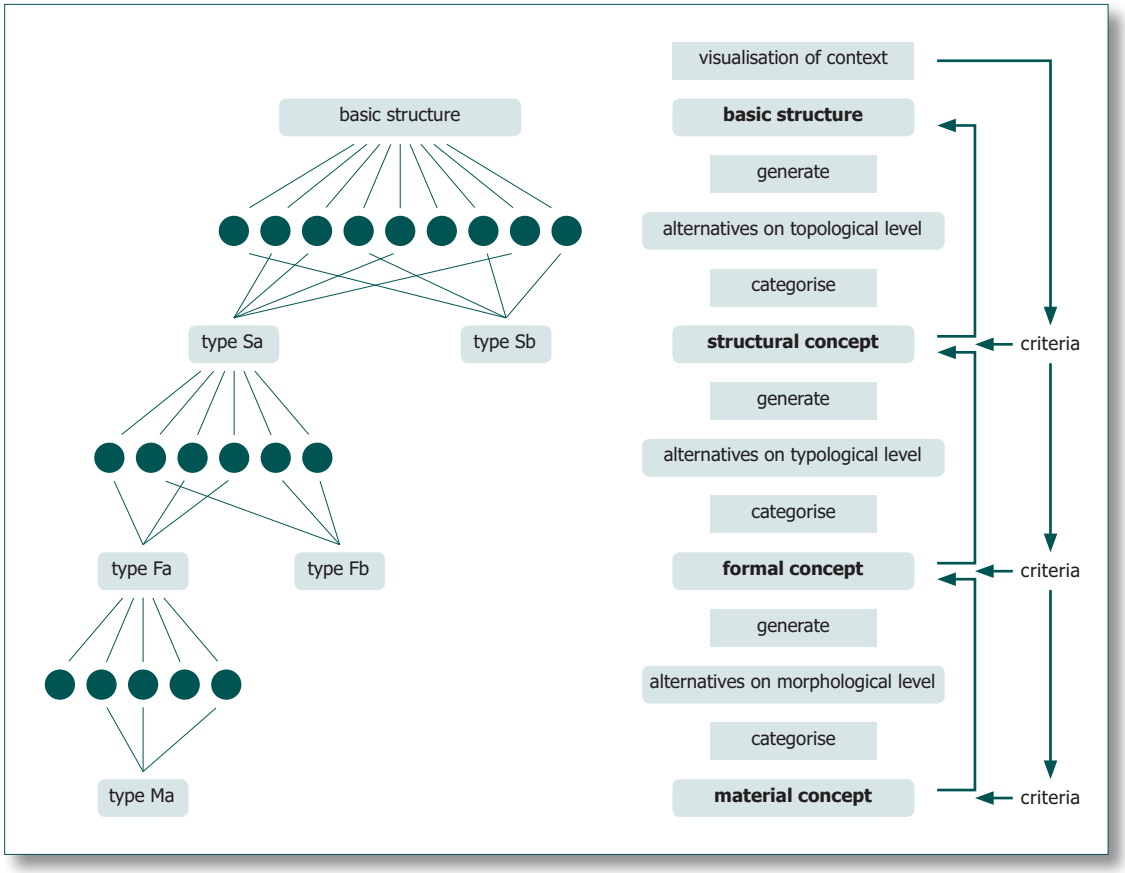

fig.1.15 The 'Fish Trap' Model describing the form-creation phase up to the sketch-design (Muller, 2001)

The Fish-Trap Model in the Product Design Process

The Fish-Trap Model starts at the stage of the design process when a basic structure of the functional components required for the primary function fulfilment is known. According to Muller the starting point in the Fish-Trap Model is an intermediate stage between the *function structure* and the *solutions principle* and ends with the stage of the *material concept (sketch plan or preliminary design)*.

The Fish Trap Model process in short

Development of Criteria

Design criteria (see also 'Design Specification (criteria)' in section 2.1) form an important starting point for the exploration of possible concepts.
In this model they are derived from a visual exploration and analysis of the context (intended users, usage and the environment). The criteria are developed simultaneously with the development of the concepts (see fig. 1.15). Muller emphasises the role of visio-spatial thinking, imaging and exploration by sketching that is essential to develop the criteria. Therefore the exploration is done by means of both visualisation techniques such as sketching & collages and three-dimensional sketch models or mock-ups (see also 'Three-dimensional models' in section 2.2).

A Systematic Process: Levels

The Fish-Trap model is a systematic process of designing a product form. The model is systematic because it forces the designer to explore alternatives on three subsequent levels of increasing detail and meaning: (1) topological level, (2) typological level and (3) morphological level. Exploring alternatives on each of these levels yields three types of concepts: (1) a *structural concept*, (2) a *formal concept* and a (2) *material concept.* On each of these levels, large variations of design alternatives (or variants) are generated, clustered in groups and evaluated. After a selection of the most promising concepts a new generation phase starts on a more detailed level.

Converging, Diverging and Categorisation

In figure 1.15, *"the Fish-Trap Model is depicted in two ways; on the right, according to the normal representation of the process by phases, on the left, through a diagram to visualise the divergence and convergence, and to indicate the occurrence of various solution types at each concept level. Because the last depiction shows a visual analogy with a fish-trap which can be metaphorically understood as 'to catch' a final solution, the method is called 'fish-trap model"* (Muller, 2001, pp.197).

The generation of variants is a diverging process and should be done with an open attitude and the curiosity about new possibilities. After creating many possible variants the diverging stage can start; the variants are categorised according to their *solution type*. Then, one or more representations of a category will be developed into a concept. Those concepts, representing a specific *solution type*, will be evaluated against the criteria. One or more concepts need to be selected for the next diverging stage on a new, more concrete, level.

Topological Level: The Structural Concept

For the development of a structural concept (figure 1.16) you need to define the basic functional components in advance. These components, or *ordering elements*, can exist of the technical parts that are needed for the working principle (such as batteries and printed circuit board) or the parts that represent the functions that are needed for product use (such as visual feedback and one-hand control). With the components you can compose as much as possible variants that differ compared to their *topology;* the spatial ordering of the components. This can for instance result in an 'open', a 'compact' or a 'horizontal structural' variant. In his book Muller

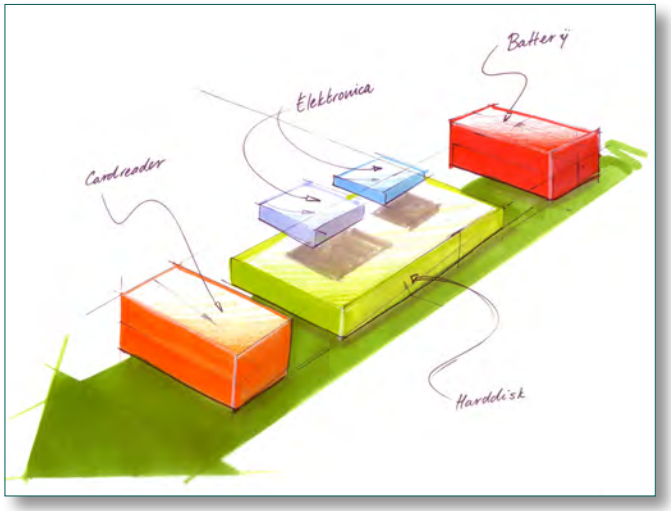

fig.1.16 Structural Concept (from student report)

presents an overview of possible ways of ordering and the meaning they may articulate (Muller, 2001, pp.122). After this stage of diverging, variants of the same 'type' need to be clustered (converging stage) and a representative variant should be developed into a structural concept. Selection of one or more structural concepts will be done by evaluation with the criteria. Important is that the structural concepts need to be 'put into context' and evaluated by imagining the possibilities for the interaction with the intended user. By doing so new ways for the product-user interaction may appear.

Typological Level: The Formal Concept

For the development of a formal concept (figure 1.17), that has a concrete *form* of 'flesh and blood', we start with one or more selected structural concepts. In this stage we focus on the global form of the concept. A variety of possible geometric constructions lead to different classes of form; form *typologies.* In order to explore freely the possible form solutions, in the diverging stage, not so much attention should be paid to the form criteria and to production requirements. Though it is useful to explore forms in relation with their possible technical constructions since they will co-define the final form (e.g. scale division of an injection moulded body, open skeleton construction from tubes). Exploration takes place by sketching. In the converging stage the sketches need to be evaluated on their viability (related to construction, integration of components, needed material) and categorised in groups with the same form type. During this stage improvements can still be made, together with textual explanation and

fig.1.17 Two Formal Concepts (from student report)

comments. Subsequently each form type needs to be evaluated against the criteria. Promising solutions should be further developed into one or more formal concepts, which clearly show the formal features and the typical intended interaction with the intended users. This interaction includes the abstract meaning that the design may elicit (such as 'cool', 'childish', 'playful').

Morphological Level: The Material Concept

The development of a material concept (fig. 1.18) includes the further materialisation of one or more formal concepts. A diverging process of exploration takes place again, looking for solution on a rather detailed level, concerning the *morphology* of the variants. Manufacturing, assembly, specification of materials, finishing, texture and colours should be explored and in the converging stage defined. And although the number of alternatives may be narrowing down slightly, feedback to the criteria is also in this stage of importance.

Remark: This explanation of the Fish-Trap Model is in short and does not honour the richness of it. Please, read about this model and more in Wim Muller's book.

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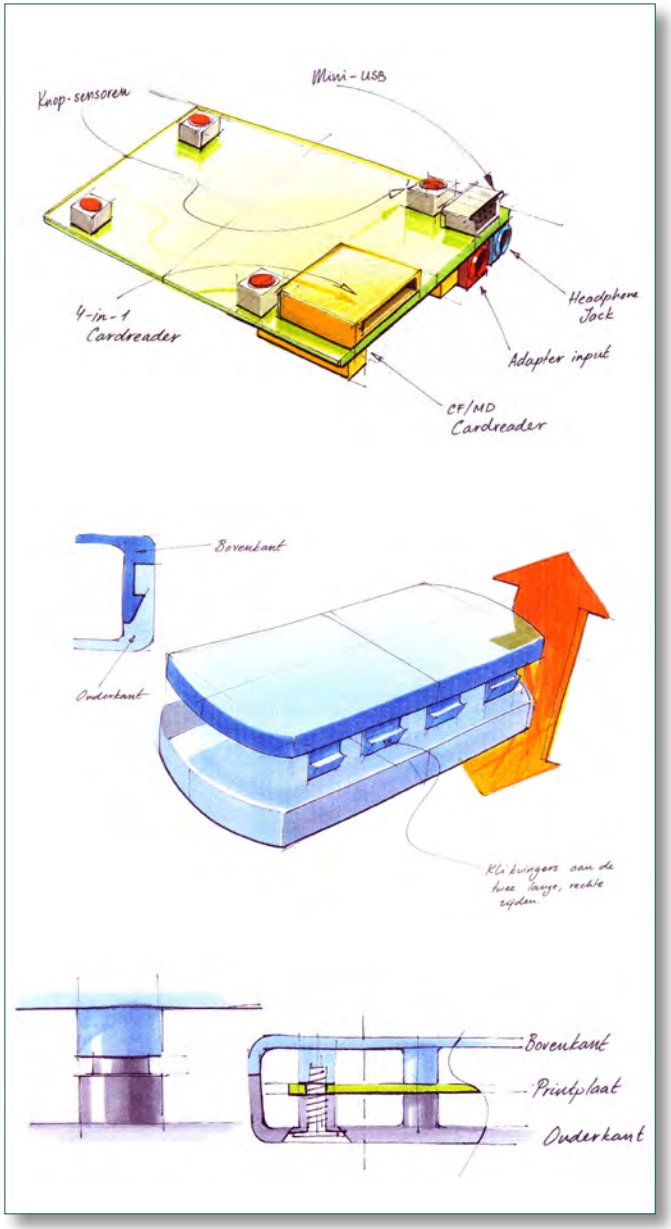


fig.1.18 Aspect of material comcept (from student report)

1.6 Vision in Product Design

Watch interview with Jeroen van Erp (Fabrique) via the OpenCourseWare version of this guide: http://ocw.tudelft.nl

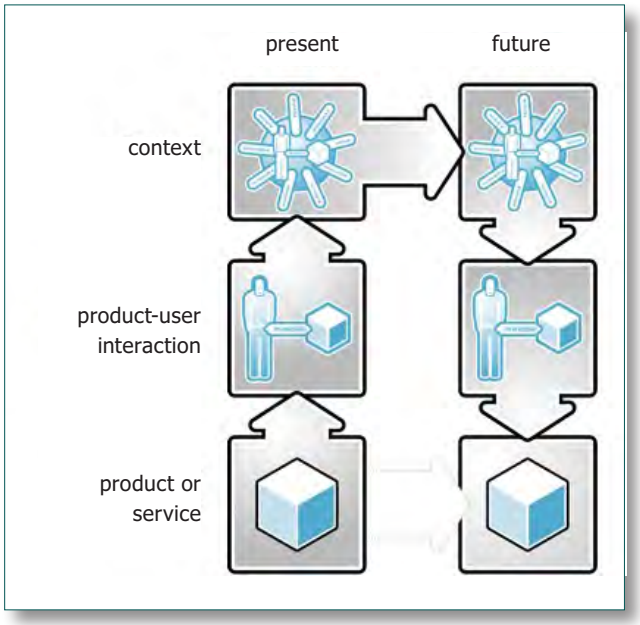


fig.1.19 The VIP Process: deconstruction phase (left) and construction phase (design) (right) (Hekkert, van Dijk and Lloyd, 2009)

Since 1995, Matthijs van Dijk and Paul Hekkert have been working on a design approach, coined Vision in Product design (ViP). At that time, their main goal was to bring the designer back into the process, thereby enforcing that the final result would be more than just appropriate and fulfilling user needs. They aimed at designs with a soul, authentic products that would reflect the vision and personality of the person responsible for them: the designer. Thanks to the support of many colleagues and students, ViP has grown into a mature approach that has left its traces in the design world and, hopefully, in many designers. Together with Peter Lloyd, they are currently writing a book about this approach and expect it to be published in 2009.

In 2003, an article was published in the Dutch design magazine ITEMS about the design approach Vision in Product design, entitled 'Dream projects in progress'. Many designers from practice were in this way introduced to the approach for the first time.
The response heard most often was "But that's the way we always work!". That was a big relief. The goal of ViP has always been to touch the core of designing in a coherent framework and systematic approach in order to pass it on to students of design. Now, after more than ten years of experience with ViP in graduation projects and courses at the Faculty of IDE, as well as in workshops and projects for design firms and the industry, it is clear that ViP appeals to students, designers, and product managers, and fills a need among them to deal with design problems differently.

The basic thought behind ViP is deceptively simple: designing always starts with the selection of a set of starting points or factors, ideas, observations, beliefs, or obsessions, that will finally determine the product-to-be-designed.[1] These starting points must be relevant for the domain for which possibilities

1 If the design assignment is such that it automatically refers to existing solutions, the first step preceding the new context is one of 'deconstruction' (see fig. 1.19). In this step the designer asks herself/himself why the existing products are as they are, to free herself/himself from preconceived ideas and to unveil the former context. To answer this question a designer needs to distance himself/herself from the world of products and shift from thinking about the what to thinking about the why. The deconstruction phase helps to take a wider view of the world of products in three ways. First, to understand that there are three levels of description (product, interaction, context) to ViP and also the relationships between these levels. Second, to get rid of any preconceptions one might have about products in a certain domain. Third, in finding factors that are obsolete or no longer make sense, a designer can already begin to have a feeling of new opportunities for the design phase that follows. Once a designer has gone through the deconstruction phase a few times he/she will be able to do it quickly, almost without thinking. In fact it is a way of thinking about things.

Example 1: Tak Yeon, Lee

(from student report)

The assignment of the ViP elective 2004/2005 was to improve the experience of passengers in long-distance KLM flight.

Context

1. **Contrast makes dynamic movements**
   If a single drop of ink is dropped into clean water, it makes dynamic shapes for a limited time. This moment represents an exciting moment that people can remember.
2. **Experiences are changed by repetition**
   1. Arousal gets lower. A flight experience is very new and exciting at the first flight. But experiencing it again and again, it makes less of an impression than before.
   2. Independence gets higher. Some people who have travelled a lot know how to spend their time. For example, drinking alcohol and sleeping are good for skipping the entire flight experience.
   3. Profound understanding about in-flight situation. Repetitive flight experiences can teach some sensitive passengers about inherent concerns of in-flight services.
3. **Subjective perception of time**
   Perception of time in the human brain is very subjective. Speed and length of a certain moment are dependent on what happened at that moment.

   From these three context factors, one statement was established:
   "I want to create afresh contrasts that can influence people's subjective perception of time."

Vision of Interaction

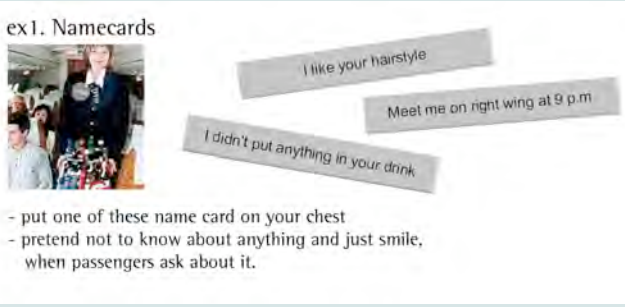
1. **Against common sense, rules and reasoning**
   Where everything is well-regulated and secure without question, to make afresh contrasts, the interaction radiates something going against common sense, rules, and reasoning.
2. **Arousing Curiosity**
   The interaction is characterised by its purposeless. The only purpose is making people curious.
3. **Treasure hunting**
   The interaction does not expose itself to the public. It is hidden and there is just a little clue.
4. **Silent sensation**
   Like a droplet of ink in clear water, interactions are merely noticeable when they are started. However, subsequently the interaction creates a long-lasting sensation in a person's mind.

Product vision

1. **Subtle Absurdity**
   The product creates a little bit of an absurd atmosphere, not a distinctly humorous atmosphere in the airplane.
2. **Almost Hidden**
   Based on the interaction visions, 'Treasure hunting' and 'Arousing curiosity', the product is almost hidden.
3. **Double twisting**
   Twisting a certain situation can be funny, but it is too prominent. By twisting the joke again it becomes more obscure and intriguing.

Concept

The product is a toolkit that can be used by the steward(ess). It contains dozens of small gadgets, performance instructions, video contents, and so on. When the stewardess needs to create a subtly absurd situation, she can use any of them.



Vision in Product Design

are sought. Domain is a deliberately open concept, unconstrained in its type or formulation, provoking an open-minded process. Everything can be a starting point, trends in the behaviour of (groups of) people or social, technological, or cultural developments, principles about human needs, their functioning or thinking, and laws of nature. A systematic discussion of these starting points can be found in the paper 'Designing from context' (Hekkert and van Dijk, 2003) in which it is also explained that the context factors must be combined into a unified whole in order to come up with a general statement or opinion that will further function as the goal or 'leitmotiv' of the project.

The selection of starting points has big implications for the final design and should therefore be the first step in the design process. Within ViP this step is called the design of a new context (see figure 1.24). This may not sound very revolutionary: after all, in every design process many starting points play a role. Often, however, this is very implicit. Take for example the deeply rooted, albeit disputable, point of view that people like to do something with a minimum of effort. In many cases, this (implicit) starting point automatically leads to a design goal like 'ease of use', whereas the use could also - and easily - be 'interesting', 'fascinating', or 'stimulating'. For this to happen, the starting point must be defined differently.

By making the selection of starting points very explicit, the designer is confronted with all kinds of considerations. What starting points are interesting and which ones are relevant? What facts lend support to my context and to what extent do I allow personal motives, interests, or intuition to play a part? Where and how do I involve the mission of my client and/or developments in the market? ViP does not provide answers to these questions, but ensures first and foremost that the designer makes these decisions deliberately, sees what their consequences will be, and makes sure that they are made in freedom and are not enforced by conventions or biased views. Only in this way can designers stand by their product and take full responsibility for it. Given the big impact of products on our society and daily life and well-being, we consider this responsibility to be essential.

A distinctive characteristic of ViP is that this context is not directly translated into product features which the new product has to embody, but that this transition goes via the interaction between user and product. Products are just a means of accomplishing appropriate actions, interactions, and relationships. In interaction with people, products obtain their meaning. This is why ViP is interaction-centred. Without knowing what they are going to design, designers have to conceptualise a vision of the interaction, an image of the way the product is going to be viewed, used, understood, and experienced. This interaction must, of course, follow from the starting points or, stated differently, fit into the context.

Conceptualising an interaction is not an easy task. Here ViP makes a strong appeal to a designer's skill of conceptual and abstract thinking, sometimes looking like word games. They are not. The designer must feel what interaction is possible and reflect on whether this is 'right'; the designer argues what interaction fits and is sensitive to its consequences. On the basis of the vision on the interaction between user and product, the designer defines the product's meaning, i.e. the qualitative characteristics that the product has to embody.

The context - interaction- and product vision do not fully define a product concept, but well-defined visions almost automatically lead to such a concept. Although many concept ideas can be tried and tested,

Example 2: Eliza Noordhoek, Femke de Boer, Marjolijn Weeda and Tuur van Balen

(from student report, Team Tape)

The theme of the 2004 Microsoft Research Design Expo contest was "people to people" and the teams had to design "something about communication". Team Tape used the ViP approach to find a focus within the broadness of this assignment.

Context

Looking at today's communication, it occurred to us that ways of communication and communication in general grow exponentially but their *accuracy* decreases tragically. What is the value of an e-mail or an SMS in a world where we receive hundreds of them a week? The second factor in our context is the development that it seems to be harder for people to deal with *unpredictability* in this over-regulated society. The next factor is a principle we called *"the joy of giving".* It says that giving a present not only pleases the receiver but also gives joy to the giver. The last factor is the principle of *"collecting memories".* People tend to look after material representations for their memories, for example that particular stone found on a vacation with your best friend. Vision of Interaction

In this context Team Tape wanted to design a product which changes the way people communicate from fast and practical to personal and valuable.

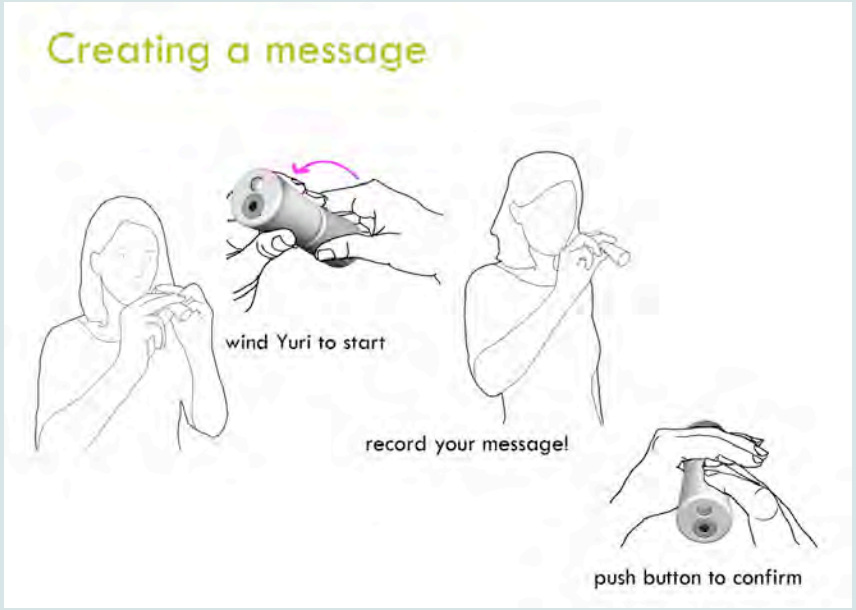
Vision of Interaction & Product Vision

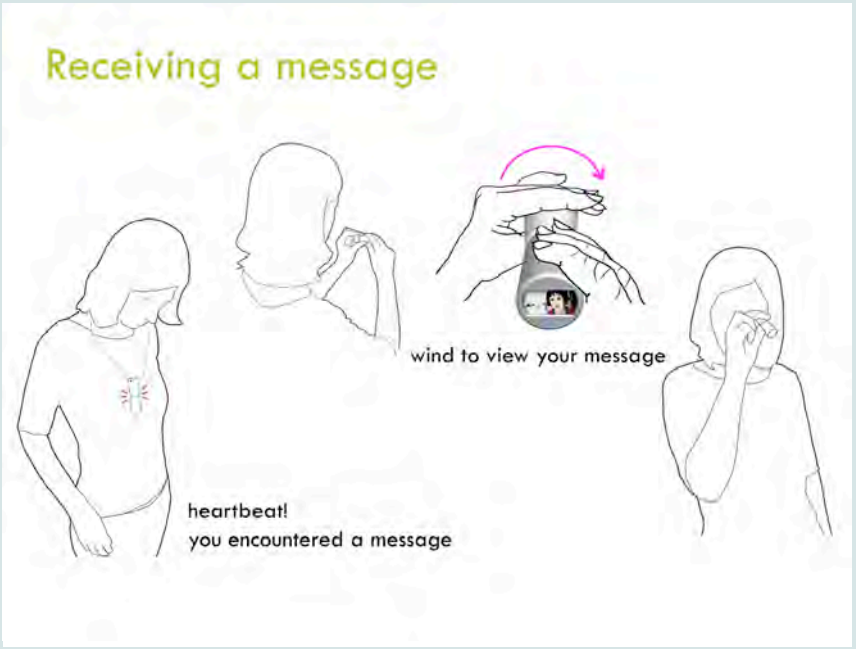
We described the interaction as "Souvenirs of timeless communication", characterised by *intimacy, excitement, creativity* and *limited control.* The product therefore must be surprising, reliable and lo-fi.

Concept

Yuri allows you to create short photo-sequences with sound/voice. Afterwards you leave these "souvenirs" behind, for your friend to find. While dropping it in the air you can set the radius of the "souvenir-area". For instance leaving it in your favourite bar by the table where you and your friend always drink your Friday night beer. Knowing you left some kind of gift behind for your friend, gives you a feeling of excitement and joy. When your friend passes through that area his Yuri sends out a heartbeat by sound and pulse. Your friend is pleasantly surprised when he sees and hears your message. After watching it in his Yuri, he saves it.

Both sender and receiver have limited control over the time it takes for the message to arrive. Therefore this communication becomes timeless. This reflects on the content of the messages: the communication shifts from practical and fast to personal and valuable. "Souvenirs of a timeless communication" are unpredictable gifts that elicit joy in both sender and receiver.





designers quickly feel whether an idea fits and is worth pursuing. This prevents them from working out a range of concepts that must finally be eliminated. When all steps are taken adequately, the properties of the final design can be perfectly traced back to selected factors at the context level. The degree to which the final product is a reflection of the vision, however, depends on constraints or requirements that are also taken into account (as late as possible), such as price, standardisation, available production techniques, etc.

The designer in ViP is driven by possibilities and not by constraints. This can lead to innovative and surprising products, but this is not imperative and certainly not a goal as such. A good ViP-based product is clearly interaction-oriented and in all respects reflects the starting points as defined by the designer. Examples of ViP projects can be found in two papers, describing the design of a photocopier for Océ (Hekkert, Mostert and Stompff, 2003) and a hand-held device for Siemens Mobile (Belzer and Hekkert, 2005). Most of all, these projects show the diversity and, hopefully, authenticity this approach has to offer.

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1.7 Emerging Design Methods

The ZEN Design Method

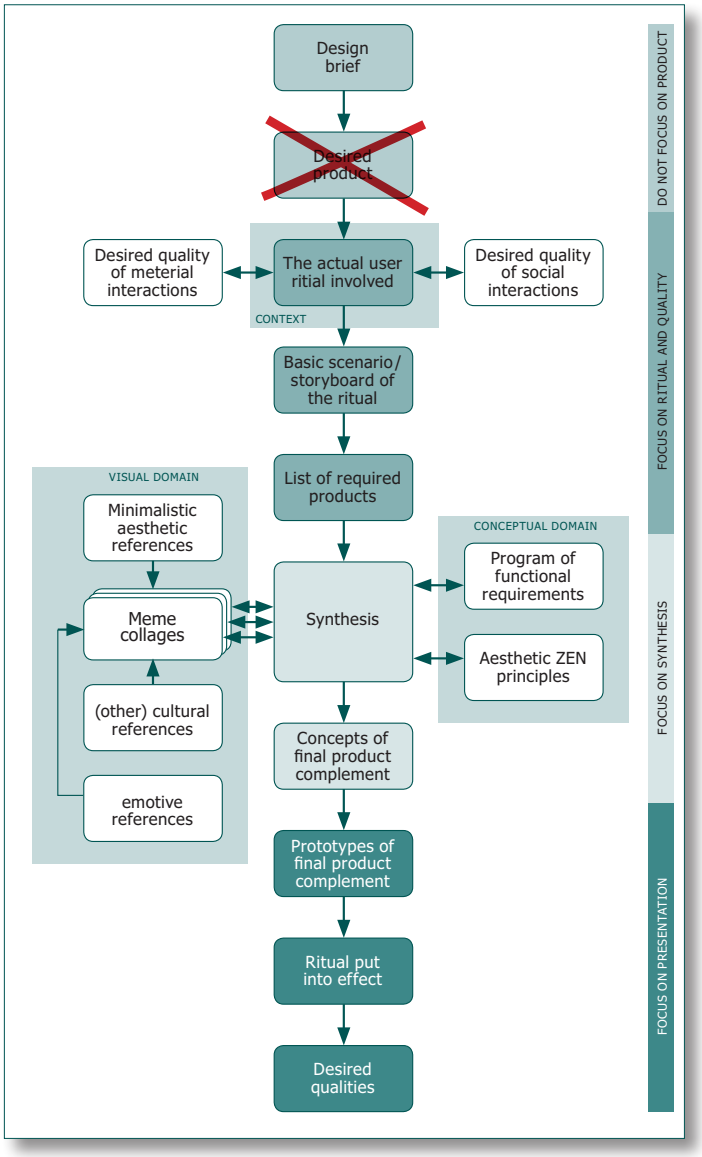


fig. 1.20
The ZEN design method
(Bruens, 2nd ed. expected 2011)

The basic principle of the 'ZEN' design method is: *'Do not focus on the desired product for quite some time'.* The primary focus should be on desired qualities, both in a material sense and in a social interaction sense. Thereafter, it is time to start thinking about problem solving, but only after moving the design brief away from the actual required product to a more abstract level. At this point it is good to identify the user ritual involved, for which a newer and richer scenario can be developed. Testing the validity of this "new" ritual can be done by acting it out, using existing products.

Now that the whole context of the desired product(s) in terms of its desired qualities (material(s) and interactions) is established, it is time to design the product(s) involved.

This is done using the basic design process, but with the information one has acquired this process takes place on a different level of experience. It has moved away from practical level to a more philosophical level: The *quality* domain.

Finally, after completing the design process, it is time to build models. The validity of the new ritual and its product(s) can now be tested by actually performing the ritual, using the products.

A more detailed explanation of the ZEN method

Ask a designer to design a toothbrush and you will end up ... getting a toothbrush. Usually the designer will first try to collect as much information as can be found about toothbrushes. Some research may be done about the desired quality of the brush and the ideal procedure of the brushing process. Collages with toothbrushes and happy smiling white toothed people may support this process. But soon, even after a vibrant ideation- and conceptualization phase, the designer will end up with concepts of ... toothbrushes.

Now, ask a designer to design a way to clean your teeth. The first question that comes to the mind may be: Why not a toothbrush? But soon the designer will get the hang of it and will come up with very unique and special ways to clean teeth. Who needs a brush? Why not a water jet? Or something you can chew on? Here, at this more abstract level of approach of the actual problem - sticky teeth - there is more room for innovation. The outcome may still be something like a toothbrush, but this time the whole concept will be based on a more solid foundation. And indeed, innovation as such (something totally new and desirable) may have a bigger chance.

Besides all these, there is one very important aspect that the ZEN design approach takes into account: The 'quality of the moment'.

The following example illustrates that our present wealth is also our poverty. We are used to getting a cup of coffee at work in the morning, spit out by some buzzing machine. We hear some clicks and some howling, and then a spur of hot coffee hits the plastic or paper cup, milk and sugar included at our desire. If we are lucky, the cup is printed with some memory of Grandma's teacups instead of a commercial advertisement. And after the absent minded drinking of the coffee during a phone conversation, we throw the cup away, never to relive that moment again

What are the qualities that are lost here? Earlier, there used to be a rich ritual around coffee drinking. There were porcelain cups involved, silver spoons, a sugar bowl, a wooden tray and a special tin canister with the smell and sound of real coffee beans. There was the grinding of the coffee by hand, the boiling of the water in a kettle on a stove accompanied by the anticipation due to the aroma of fresh coffee. The sharing of such an experience in the company of some nice people - enhancing social interactions - has been lost completely in the solo coffee machine ritual and what remains of the original ritual is hardly gives satisfaction. It is like taking a medicine.

Rituals

All of us have small daily rituals that guide our existence. The way one gets out of bed, followed by the way one takes a shower, the coffee break at work, the cigarette after sex, the exchange of presents during Christmas, the eating of a biscuit with sugar sprinkled over when a child has been born (which is a typical Dutch ritual), all those short or longer rituals can make a moment more special. Routine is broken, social interactions are guided; the sheer quality of existence is enhanced.

There are many fields where we have lost the basic qualities of life, too hasty as we are to live it. Think of the consuming of fast food instead of a meal of fresh ingredients at a well-laid table, think of playing computer games instead of board games. Think of emails instead of hand written letters in colourful envelopes, think of preparing your own jam or smoking your own fish instead of buying it. And how about baking your own bread?

Many qualities have been lost and perhaps, it is time to treat the lost accompanying rituals like we treat endangered species! We ourselves *are* the endangered species in this respect.

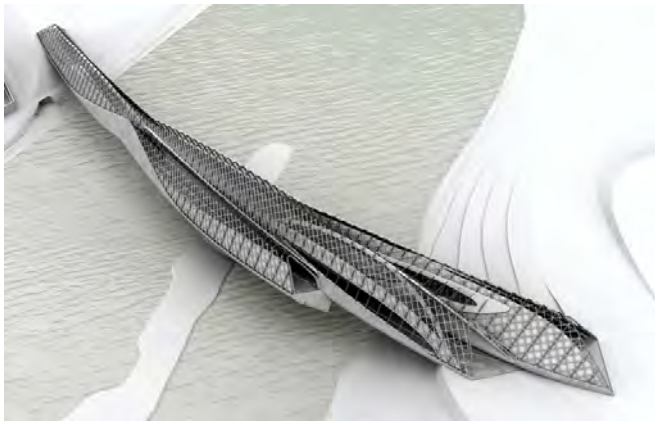
Why is it called the ZEN design method? Has it got something to do with Buddhism?

This design method has been developed by Ger Bruens, over a period of 15 years during the Master elective course called `ZEN' (working title). The full name of the elective is: *'ZEN and the art of design',* and it refers to the book by Robert Persig (1974): *'Zen and the art of motorcycle maintenance'*. This philosophical book was a cult book in the seventies as it sold over 4 million copies in 27 languages. The story is about a man on a motorbike trip through different states of the USA with his young son on the back seat. He is searching for the meaning and concept of *quality.* The book is filled with philosophical observations related to mechanical problems that occur during the trip. It is a great book which talks about a personal crisis, the search for truth and the meaning of quality. As the search for quality is the main focus of the elective too, quoting the title of the book for both the elective and the method developed there, seems appropriate.

When do you apply the ZEN method, is it suitable for solving all design problems?

According to our experience, the ZEN design method is applicable for all kind of design briefs. Even a mechanical designer building a bridge may find it useful, as a bridge does not only facilitate efficient passage from A to B but it also touches our imagination and experience on other levels. Colour and material contribute to that. The desired quality of the bridge to be built is more than what can be

fig. 1.21 Zaha Hadid Architects' proposal for a Bridge Pavilion, Zaragossa, 2008



captured in a list of requirements. To handle this design process, the ZEN method holds a promise.

In short:

The ZEN design method with its primary focus on rituals and qualities may be the preferred method for designers who would like to achieve innovation in terms of functionality, culture and social interaction.

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See for more examples http://blackboard.tudelft.nl
The elective course 'Formstudy 4' in 'Course Documents'.

Multi Sensory Design

Designers who intentionally try to create specific experiences for people, such as delight, trust or the feeling of being cared for, are more likely to succeed if they are aware of the messages conveyed by the different sensory channels and of their contribution to the overall experience. Such a multisensory approach enriches the product experience, avoids unwanted conflicting messages, and results in products that are also comprehensible for users with sensory impairments.

Each sensory modality is sensitive to a different type of energy and is stimulated by different product properties. As a consequence, the modalities usually provide different pieces of product information, which may or may not overlap (Schifferstein & Spence, 2008).

For instance, a bus stop may look attractive and welcoming, but leave the waiting passenger standing in a cold breeze, next to a smelly trashcan, or with a lot of traffic noise. On the other hand, the colour, taste, and texture of ice cream, the look and feel of its- package, and the crispiness of the biscuit may all contribute to being completely immerged in savouring it. Therefore, the main challenge in Multi Sensory Design (MSD) projects is to come up with an integrated design, in which all sensory impressions support the expression of the product.

Hendrik Schifferstein initiated the development of the MSD approach at TU Delft. He developed the first MSD elective course for Master students in cooperation with Marieke Sonneveld and Geke Ludden in 2004. Since 2008 the MSD approach is also being used in projects for industrial companies

Outline of the MSD approach

1. **Selecting the target expression**

   MSD takes the expression of the object (e.g., eagerness, cheerfulness, innocence) as the design starting point (Sonneveld et al., 2008). In a business context, the target expression may be provided by the marketing department on the basis of consumer research. Alternatively, you may start out from the effect you want to achieve among future users (e.g., feeling safe, inspire), and determine which object and interaction qualities are needed to achieve the desired effect.

2. **Conceptual exploration**

   After the target expression has been selected, you need to develop an understanding of this expression. You may start out by writing down the associations that come to mind when thinking about this expression. Making a collage can support this process. What does the expression make you think of?

3. **Sensory exploration**

   Subsequently, you collect samples that seem to evoke the target expression (figure 1) for different sensory modalities (e.g., pictures, materials, fragrances, fabrics, computer sounds, foods, plants). How does the target expression feel, sound, smell, and look? While exploring the world, you should be curious about the sensory properties of objects, especially the ones people hardly ever seem to pay attention to: In what ways can you pick up or manipulate an object? What sounds can it produce? How does it feel if you touch it in different ways? What does it smell like? Try to go beyond obvious choices: objects that look tough may actually feel quite elegant!

4. **Sensory Analysis**

   In the next step you try to describe and understand the relationships between the perceived sensory properties and the product expression. Try to find out why certain samples seem related to a specific expression and try to determine the physical properties that evoke the target expression. During this process, you may discover that an expression can manifest itself in different ways: Elegance may be related to flowing, uninterrupted movements, but also to simple and straightforward solutions.

5. **Mind map**

   The results of the previous stages serve as the starting point for a mind map. This mind map organises the information that was acquired in the previous stages, while trying to maintain the richness of the data.

   The target expression is displayed in the centre of the map, where several outward branches connect

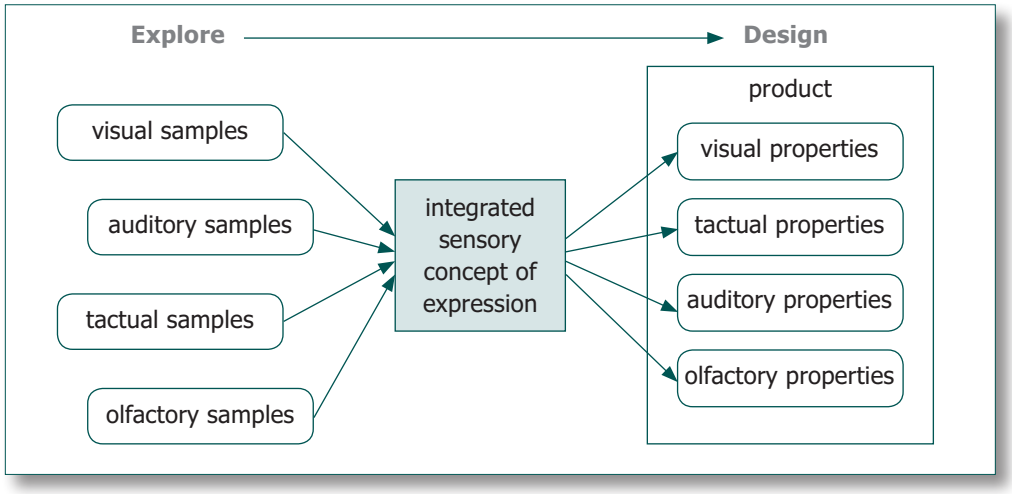
it to the main concepts defining the core of the expression. On their turn, these main concepts may be linked to other concepts, which may be linked to other concepts or sensory dimensions. From the centre of the map to the periphery, the descriptors in the map will become less conceptual, more concrete, and more sensory. New concepts may be added to the map if links seem to be missing or if a set of concepts can be summarised under a new label. In the end, the mind map should indicate how a particular concept may be translated into a perceivable product aspect that makes the concept physically tangible.

If the final design involves a branded product, brand associations can be added to the mind map, in order to make clear how the design can contribute to the brand image. You may decide to modify or disregard some parts of the map in the design process, if these conflict with the brand image.

6. User-interaction scenario

By developing an interaction scenario, the time dimension is included in the design process. The scenario describes the actions users perform, the feedback they receive from the product, the instructions users receive, and so on. A scenario is usually set within a certain context, defining a typical user and an environment in which the interaction takes place. In the MSD approach, scenarios are used to identify all the sensory touch points during the encounter: Which senses are stimulated when you pick up the product, when you unwrap it, when you use it, or when you store it? What does this contribute to the overall expression?

fig. 1.22
Framework for the Multi Sensory Design approach



7. Model making

Staying in touch with the physical counterparts of a specific product expression is a safeguard that enables you to develop an integrated user-product interaction that makes sense to prospective users and engages them. Actually sensing a specific property often differs from one's expectations when trying to imagine it. In an MSD process, visual sketching and digital modelling should be left to a minimum, otherwise visual impressions and cognitive reasoning will tend to dominate your design choices. You should try to 'sketch' in all your senses, in order to assess the sensory aspects of your concepts. You can make collages and explorative, physical models for the different senses, and assess their appropriateness in the proposed user context.

8. Multisensory presentation

In order to communicate the benefits of a Multi Sensory Design, the final design needs to be presented in a multisensory way; a set of slides will not suffice! If final prototypes are not yet available, you can show drawings, you can let the audience feel foam models, you can let them feel and smell materials, and you can play sound files. A storyboard can show the involvement of the various senses in the different stages of human-product interaction.

Conclusion

The essential element of MSD is that perceptual knowledge obtained through explorations in all sensory modalities is explicitly incorporated in the design process (figure 1.21). The ultimate design challenge is to develop a product that provides users with an interesting, rich experience, and is nevertheless perceived as a coherent whole.

fig. 1.23 A cute socket set, developed through the MSD approach

Example

Figure 1.22 shows the results of a student project in which the assignment was to design a 'cute' hand tool. The socket set was developed for the feminine do-it-yourself handywoman, who wants to be reassured that the tools will not harm her.
The student wanted the tools to seduce the handywoman by their enthusiasm to do the job well, without showing any heavy-duty behavior in movements or sounds. The final socket set is characterised by a rounded, organic shape and soft, pastel colours. It is presented in a box that resembles a jewellery case. When opened, a sweet, comforting smell emerges.

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Part 2
Design Methods

This part presents a variety of design methods which can be used in the product design process. The design methods presented here are categorised according to the activity for which they can be used:

1 creating a design goal,
2 creating product ideas and concepts,
3 decision and selection
4 evaluation of product features

Part 2 Design Methods

2.1
Creating a Design Goal

- Strategy Wheel
- Trends Analysis
- Cradle to Cradle
- EcoDesign Checklist
- EcoDesign Stratey Wheel
- Collage Techniques
- Process Tree
- WWWWWH
- Problem Definition
- Checklist for Generating Requirements
- Design Specifications (Criteria)
- Design Vision

2.1 Creating a Design Goal

A product design process is preceded by a product planning process, as was explained in the first part of this reader. In the product planning process, policies are formulated based upon an internal and external analysis of the market and the company. The product planning process ends with the formulation of a design brief, which forms the start of the product design process. Sometimes the product ideas are already mentioned explicitly in the design brief, and sometimes the product design process starts with a search for relevant product ideas. In any case, the product design process always begins with a stage in which the design problem (or challenge) will be analysed.

A first description of the design problem is stated in the design brief. The analysis of the design problem serves the formulation of a design goal or goals. Hence this first section of design methods: creating a design goal. Design goals are broad declarations of intent that can be elaborated into more specific goals. For instance, the designer could study the motivation of the problem owner, the need in the market, the context in which the product is used, competitive products, user behaviour, the product's functions, the company's production facilities etc. After this analysis, conclusions are drawn, which are often in the form of requirements, a design philosophy, a mission statement, or a product vision.

In this section, creating a design goal, various methods are presented that facilitate the first stage of a design process: the analysis of the design problem, and the formulation of a design specification.

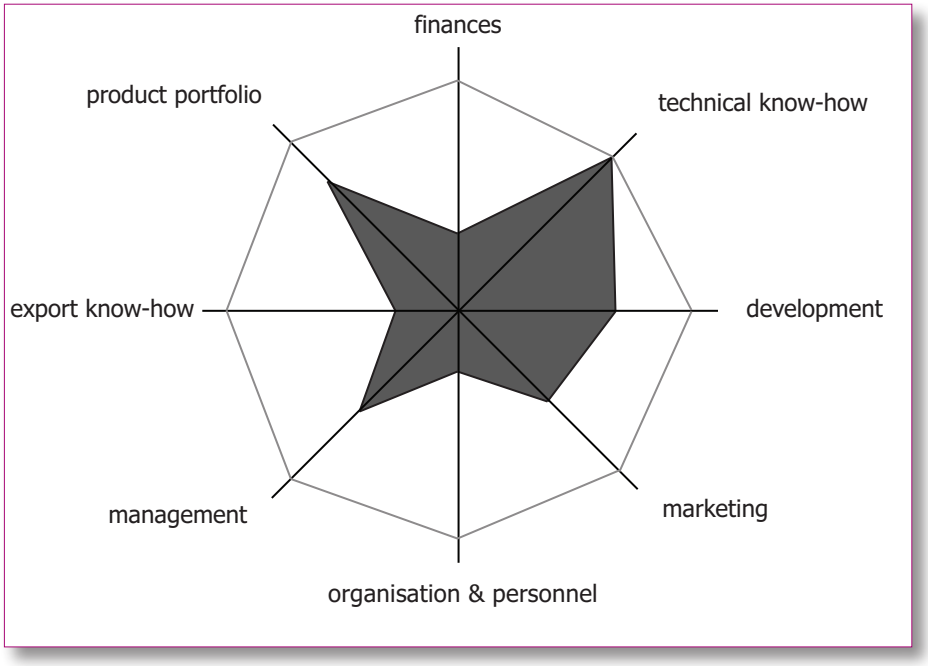
Strategy Wheel

Keywords
Strategic strengths
Competitor analysis
Marketing

What Is a Strategy Wheel?

A strategy wheel is a visual representation and a quick tool to review a company's strengths (see figure 2.2). A strategy wheel presents the company's competencies on the axes, and the scores of the competencies on those axes. By using the diagram, you obtain a quick understanding of the company's strategic strengths. Often it is useful to construct strategy wheels of a company's direct competitors. A product innovation process (see section 1.2) starts with a clear understanding of the current situation of a company. The need for a new product arises from an understanding of a company's strategic strengths and weaknesses, and the opportunities in the market. A thorough analysis of the current situation of a company yields an understanding of the company's strategic strengths (for example: technical know-how, product portfolio, development (capability), financial position, export know-how, marketing, organisation and personnel, management).

fig. 2.1 Strategy Wheel (Buijs and Valkenburg, 1996)



The strategy wheel is sometimes used to compare other things than a company's strategic position. For example, design concepts can be analysed and reviewed using the strategy wheel (see fig. 2.1). The axes represent design requirements on which the design concepts are evaluated. The strategy wheel then yields a visual representation of the scores of the different design concepts on the design requirements. Also, there are various adaptations of the strategy wheel (for example the 'EcoDesign Strategy Wheel', in this section).

When Do You Use a Strategy Wheel?

A strategy wheel is usually applied in the beginning of a new product development process in order to present the strategic strengths of a company.

How to Use a Strategy Wheel?

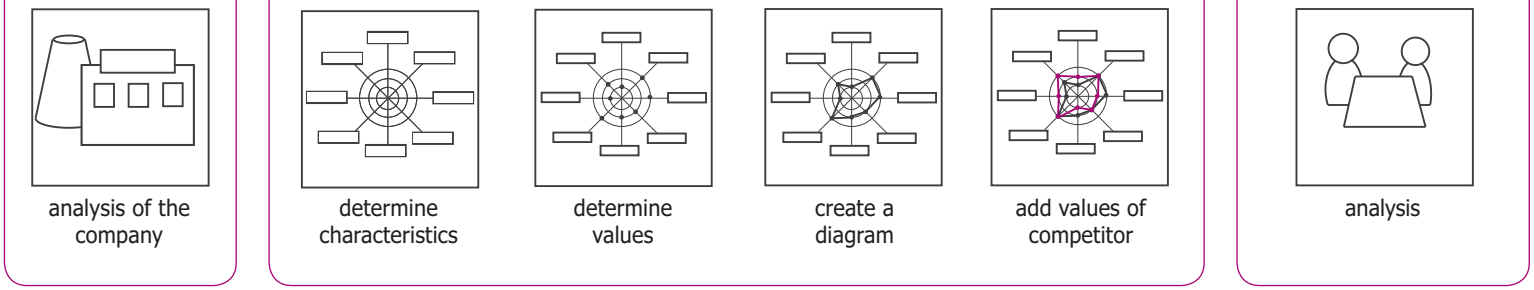
Starting Point

The results of an internal analysis form the starting point for the use of the strategy wheel: a clear understanding of the company's strategic strengths in relation to its direct competitors.

Expected Outcome

The outcome of the use of the strategy wheel is a visual representation and a better understanding of the company's strategic strengths.

How to
Strategy Wheel



Possible Procedure

1. Determine the company characteristics that you want to evaluate. Examples are: financial strength, in-house technology, knowledge (Research and Development).
2. Determine a value for each of the characteristics. These values are determined by comparing the company with its direct competitors.
3. Create a diagram, a strategy wheel of the scores on the characteristics.
4. Optionally, put down the values of the competitors' scores on the same characteristics in the same diagram, or in a similar diagram.
5. Analyse the diagram, the strategy wheel, to assess the company's strengths and weaknesses (in comparison with its direct competitors).

References and Further Reading

Buijs, J. and Valkenburg, R. (2005, 3rd ed.)
Integrale Product Ontwikkeling, Utrecht: Lemma

Trends Analysis

Keywords
Structuring
Trends pyramid
PESTED
Marketing

What Is Trends Analysis?

Trends are changes in societies that occur over longer periods of time (approx. 3-10 years). Trends are not only shifts in people's preferences (for example fashion or music), but are also shifts in larger areas such as the economy, politics, and technology. Trends are an important source of inspiration for thinking up new product ideas. Trends analysis is often used as part of a strategic planning process. Trends are used to identify customer/market needs, which a company can meet with new products or services. Trends analysis is preceded by trends watching, by which we mean the identifying, gathering and reporting of trend information without giving insight into the possible consequences.
Trends have the following characteristics:

1 a trend has already started and can therefore already be identified in some places;
2 a trend has a specific direction. A development that is constant over time does not bring any change with it and is therefore not a trend;
3 a trend will most likely continue for the next 3 to 10 years, so hypes and fashions, i.e. developments with a shorter time horizon, fall outside this category.

Trends analysis could be a rich source of inspiration, but could also determine the risks involved when introducing new products. Trends research is very complex, though. It is extremely difficult to identify and analyse future trends. Trends analysis tries to find answers to the following questions: what developments in the fields of society, markets and technology can we expect over the next 3 to 10 years? How do these developments relate to each other? Where do they stimulate each other and where do they block each other? How do trends influence the strategy of an organisation? What are the resulting threats and what are the opportunities? Which ideas for new products and services can we think of now on the basis of the trends?

For an analysis of the trends, a trends pyramid can be used. In a trends pyramid (see fig. 2.2), four levels are distinguished at which one can look at trends: The microtrend is on a product level and has a time horizon of 1 year. The miditrend is on a market level and has a time horizon of 1 to 5 years. The maxitrend is on a consumer level and has a time horizon of 5 to 10 years. The megatrend is on a societal level and has a time horizon of 10 to 30 years. Trends pyramids are set up with trends belonging to a single theme, for example political trends or technological trends (one could use the PESTED categorisation for example - see Possible Procedure below).
Examining trends in this way is useful for two reasons: it provides a tool with which the enormous amount of (trend) information generated can be processed and structured, and it makes it easier to

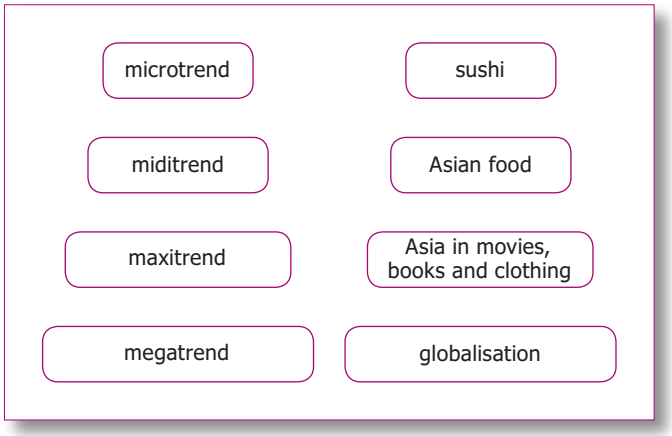
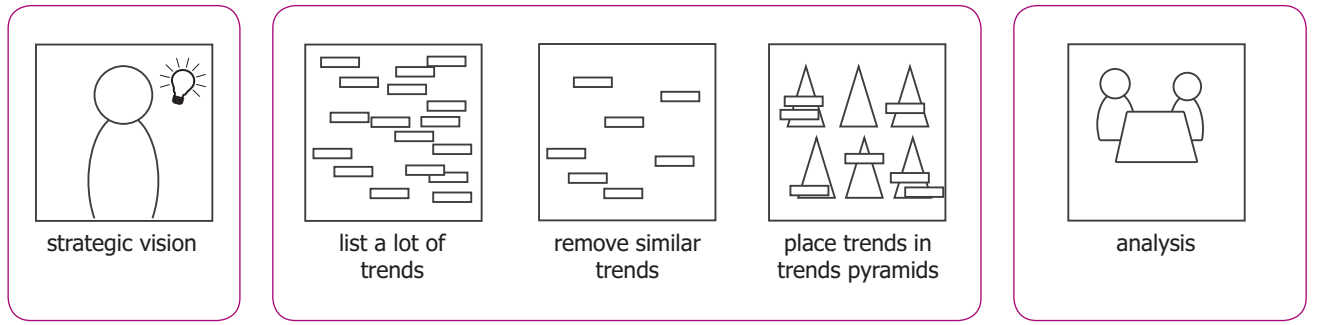


fig. 2.2 Trends Pyramid (Stappers et al, 2003)

How to
Trend Analysis



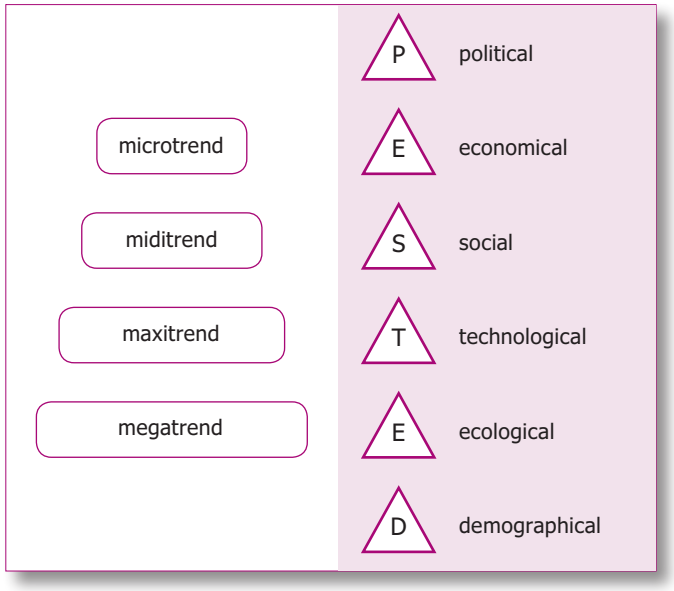


fig. 2.3 Trends Pyramid and PESTED categorisation

assess the consequences of trends. The different levels are related to each other and refer to the same developments but on a different level of abstraction or detail.

When Can You Use Trends Analysis?

A trends analysis is usually performed in the beginning of a design project or in the strategic planning process. With a trends analysis you can identify new business opportunities or new product ideas. You can also use it to identify preferences of the target group.

How to Use Trends Analysis?

Starting Point

Corporate/strategic vision.

Expected outcome

Potential customer/market needs for which new products and services can be thought up.

Possible Procedure

1 List as many trends as you can think up. Identify trends from newspapers, magazines, television, books, the Internet, etc. At this point it is important to list as many as possible; don't pay attention to redundant or similar trends.

2 Remove trends which are similar; identify hierarchy in trends. Identify whether trends are related and define this relationship.

3 Place the trends in a trends pyramid. Set up various trends pyramids according to the PESTED structure: P = Political; E = Economic; S = Social; T = Technological; E = Ecological; D = Demographic.

4 Identify interesting directions for new products or services based on trends. Also, combine trends to see whether new products or services may come about.

Tips and Concerns

- Try to combine trends as much as possible.
- Make as much use as possible of different sources.
- Try to visualise trends just like with scenarios (see 'Written Scenario' in section 2.2).

References and Further Reading

Buijs, J. and Valkenburg, R. (2005, 3rd ed.) *Integrale Product Ontwikkeling*, Utrecht: Lemma

Kotler et al. (1996) *Principes van Marketing*, Hemel Hempstead UK: Prentice Hall Europe.

van der Duin P. et. al. (2003), the worlds of futures research, In: dictaat context and conceptualisation, P.J. Stappers et al., August 2005.

Cradle to Cradle

Keywords
Sustainability
Product life cycle

What Is Cradle to Cradle?

Cradle-to-Cradle is positioned by the authors William McDonough and Michael Braungart as a manifesto for a new approach towards sustainable design: one which is based on the intelligence of natural systems. For McDonough and Braungart, this means we should stop drawing power from non-renewable fossil fuels, and turn towards the sun and other renewable energy sources for our energy supplies. And we should make all 'materials of consumption' become part of either the biological nutrient cycle or the technological nutrient cycle, meaning that materials should either be biodegradable, to be taken up in a natural cycle at the end of a product's life, or be 'upcyclable', and be reused indefinitely in a technological closed loop system. Their manifesto is written in a clear and optimistic style and offers for many an alternative vision to the 'eco-efficiency' approach that has been dominant for years.

The basis for the Cradle-to-Cradle approach involves three guiding principles:

1 Use current solar income.
2 Waste equals Food.
3 Celebrate diversity.

The Cradle-to-Cradle framework, like many others, acknowledges the need to address the entire life cycle of production, transportation, use, and disposal, as well as the need to foster diversity in the environment.

When Can You Use Cradle to Cradle?

Cradle to Cradle can be applied in the strategic phase of the design process, to give direction to the product development process, possibly with a general product idea in mind.

How to Use the Cradle-to-Cradle Framework

McDonough and Braungart give a five-step approach to eco-effectiveness. Following these steps will lead to a product that is optimised according to the second principle: 'Waste equals Food'. The steps are presented here with quotes from the book *Cradle to Cradle:*

Possible Procedure

1 Get free of known culprits (X-substances, for instance PVC, cadmium, lead, mercury).
2 Follow informed personal preferences. We must begin somewhere. Many real-life decisions come down to comparing two things that are both less than ideal. Prefer ecological intelligence. Be as sure as you can that a product or substance does not contain or support substances and practices that are blatantly harmful to human and environmental health.
In general: opt for products that can be taken back to the manufacturer and disassembled for reuse (or at the very least, for downcycling). Opt for chemical products with fewer additives, especially stabilisers, antioxidants, antibacterial substances. Prefer respect, delight, celebration and fun.

3 Create a 'passive positive' list, going beyond existing, readily available information as to the contents of a product. Conduct a detailed inventory of the entire palette of materials used and substances it may give off in the course of its manufacture and use. Are there problematic or potentially problematic characteristics? Are they toxic? Carcinogenic? How is the product used and what is its end state? What are the effects and possible effects on the local and global communities? Make lists:
   - X list: highest priority for a complete phase-out
   - Grey list: problematic substances, not quite so urgently in need of phase-out (this includes problematic substances essential for manufacture, and for which we currently have no viable alternatives)
   - P list: positive list. Substances actively defined as healthy and safe for use.
4 Activate the P list. Here is where the redesign begins in earnest, where we stop trying to be less bad and start figuring out how to be good. Now you set out with eco-effective principles, so that the product is designed from beginning to end to become food for either biological or technical metabolisms.
5 Reinvent. Recast the design assignment. Not 'design a car', but 'design a nutrivehicle' (cars designed to release positive emissions and generate other nutritious effects on the environment). Push the assignment further: 'design a new transportation infrastructure'. 'Design transportation'.

Tips and Concerns

- Cradle to Cradle is often criticised for its lack of attention to energy (energy consumption of products in the use phase).

References and Further Reading

Braungart, M. and McDonough, W. (2002)*Cradle to Cradle, Remaking the Way We Make Things*, New York: North Point Press.

EcoDesign Checklist

Keywords
Sustainability
Environmental profile
Product life cycle

What Is the EcoDesign Checklist?

The EcoDesign Checklist (see figure 2.6) is a checklist of questions that provides support for the analysis of a product's impact on the environment. The EcoDesign Checklist provides relevant questions that need to be asked when establishing environmental bottlenecks during the product life cycle. Thus, you can use the checklist to complement the MET matrix. The checklist also suggests improvement options for areas where environmental problems are identified.

The checklist starts with a needs analysis, which consists of a series of questions concerning the functioning of a product as a whole. The main question asked in a needs analysis is to what extent the product fulfils its main and auxiliary functions. You should answer this question before focusing on the environmental bottlenecks in the various stages of the product's life cycle. The needs analysis is followed by a set of questions, categorised per stage of the product life cycle (production, distribution, utilisation, recovery and disposal).

The EcoDesign Checklist consists of two columns: the questions to be asked are given in the left-hand columns of the tables. Some improvement options are suggested in the right-hand columns. These improvement options are derived from the EcoDesign Strategy Wheel (see 'EcoDesign Strategy Wheel' in this section).

When Can You Use the EcoDesign Checklist?

The EcoDesign Checklist is best applied in the concept generation phase, when a clear idea of a product has been developed. You can also use it to analyse existing products.
The EcoDesign Checklist is often used as a tool to avoid missing any environmental impact of the product, and in combination with the MET matrix and the EcoDesign Strategy Wheel (see 'EcoDesign Strategy Wheel' in this section)

How to Use the EcoDesign Checklist

Starting Point

The starting point of the EcoDesign Checklist is a product idea, a product concept, or an existing product.

Expected Outcome

The expected outcome of using the EcoDesign Checklist is a thorough and systematic understanding of the product's impact on the environment. This can be used to fill out the MET Matrix, and to fill out the EcoDesign Strategy Wheel.

Possible Procedure

1. Define the product idea, product concept or existing product that will be analysed.
2. Perform a needs analysis. Answer the questions from the EcoDesign Checklist.
3. Systematically answer all the questions from the EcoDesign Checklist, per stage of the product's life cycle.
4. Provide options for improvement following the right-hand side of the EcoDesign Checklist. Describe the options for improvement as clearly and precisely as possible.
5. Use the answers to the EcoDesign Checklist to fill out the MET Matrix.

Tips and Concerns

- Make sure you answer all the questions in the EcoDesign Checklist.
- Think about questions you might want to ask yourself that are not in the EcoDesign Checklist.
- Use the EcoDesign Checklist together with the MET Matrix and the EcoDesign Strategy Wheel (see 'EcoDesign Strategy Wheel' in this section).

References and Further Reading

Brezet, H. and Hemel, van, C. (1997) *EcoDesign: A Promising Approach to Sustainable Production and Consumption*, France: UNEP.

Remmerswaal, H. (2002) *Milieugerichte Productontwikkeling*, Schoonhoven: Academic Service.

The EcoDesign Checklist

Needs Aanalysis

How does the product system actually fulfill social needs?
- What are the product's main and auxiliary functions?
- Does the product fulfil these functions effectively and efficiently?
- What user needs does the product currently meet?
- Can the product functions be expanded or improved to fulfil user's needs better?
- Will this need change over a period of time?
- Can we anticipate this through (radical) product innovation?

EcoDesign Strategy @ New Concept Development
- Dematerialisation
- Shared use of the product
- Integration of functions
- Functional optimisation of product (components)

Life cycle stage 1: Production and supply of materials and components

What problems arise in the production and supply of materials and components?
- How much, and what types of plastic and rubber are used?
- How much, and what types of additives are used?
- How much, and what types of metals are used?
- How much, and what other types of materials (glass, ceramics, etc.) are used?
- How much, and which type of surface treatment is used?
- What is the environmental profile of the components?
- How much energy is required to transport the components and materials?

EcoDesign Strategy 1: Selection of low-impact materials
- Clean materials
- Renewable materials
- Low energy content materials
- Recycled materials
- Recyclable materials

EcoDesign Strategy 2: Reduction of material usage
- Reduction in weight
- Reduction in (transport) volume

Life cycle stage 2: In-house production

What problems can arise in the production process in your own company?
- How many, and what types of production processes are used? (including connections, surface treatments, printing and labeling)
- How much, and what types of auxiliary materials are needed?
- How high is the energy consumption?
- How much waste is generated?
- How many products don't meet the required quality norms?

EcoDesign Strategy 3: Optimisation of production techniques
- Alternative production techniques
- Fewer production steps
- Low/clean energy consumption
- Less production waste
- Few/clean production consumables

Life cycle stage 3: Distribution

What problems can arise in the distribution of the product to the customer?
- What kind of transport packaging, bulk packaging, and retail packaging are used (volume, weights, materials, reusability)?
- Which means of transport are used?
- Is transport efficiently organised?

EcoDesign Strategy 2: Reduction of material usage
- Reduction in weight
- Reduction in (transport) volume

EcoDesign Strategy 4: Optimisation of the distribution system
- Less/clean/reusable packaging
- Energy-efficient transport mode
- Energy-efficient logistics

Life cycle stage 4: Utilisation

What problems arise when using, operating, servicing and repairing the product?
- How much, and what type of energy is required, direct or indirect?
- How much, and what kind of consumables are needed?
- What is the technical lifetime?
- How much maintenance and repairs are needed?
- What and how much auxiliary materials and energy are required for operating, servicing and repair?
- Can the product be disassembled by a layman?
- Are those parts often requiring replacement detachable?
- What is the aesthetic lifetime of the product?

EcoDesign Strategy 5: Reduction of impact in the used stage
- Low energy consumption
- Clean energy source
- Few consumables
- Clean consumables
- No wastage of energy or consumables

EcoDesign Strategy 6: Optimisation of initial lifetime
- Reliability and durability
- Easy maintenance and repair
- Modular product structure
- Classic Design
- Strong product-user relation

Life cycle stage 5: Recovery and disposal

What problems arise in the recovery and disposal of the product?
- How is the product currently disposed of?
- Are components or materials being reused?
- What components could be reused?
- Can the components be reassembled without damage?
- What materials are recyclable?
- Are the materials identifiable
- Can they be detached quickly?
- Are any incompatible inks, surface treatments or stickers used?
- Are any hazardous components easily detachable?
- Do problems occur while incinerating non-reusable product parts?

EcoDesign Strategy 7: Optimisation of the end-of-life system
- Reuse of product (components)
- Remanufacturing/refurbishing
- Recycling of materials
- Safe incineration

fig. 2.4 The EcoDesign Checklist (Brezet, 1997)

Keywords
Sustainability
Environmental profile
Product life cycle

EcoDesign Strategy Wheel

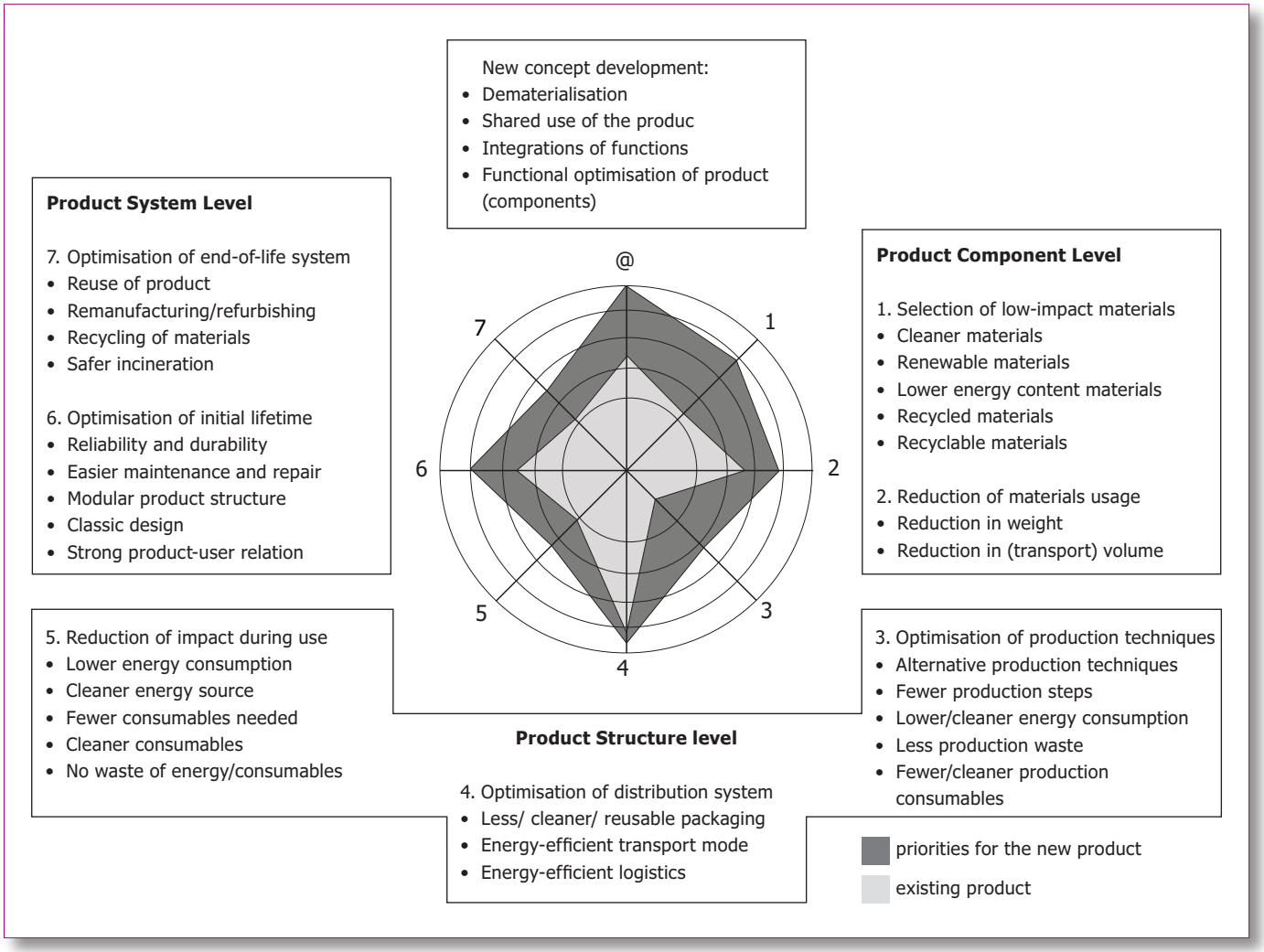


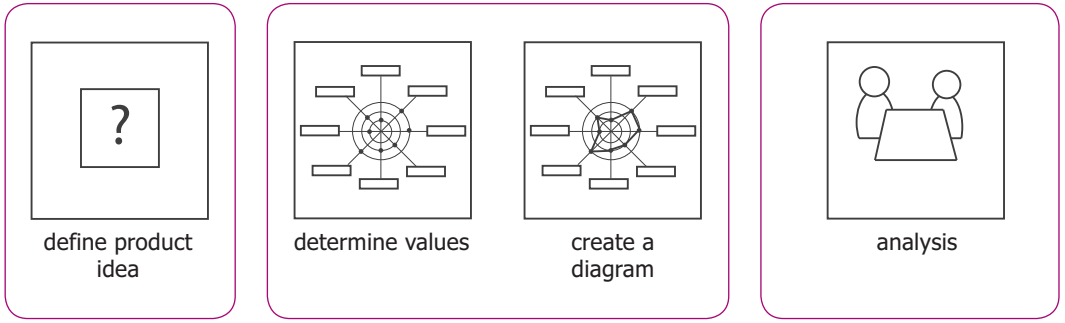
fig. 2.5 The EcoDesign Strategy Wheel (Brezet and van Hemel, 1995)

What Is the EcoDesign Strategy Wheel?

The EcoDesign Strategy Wheel (also called Life cycle Design Strategies - LiDs, see fig. 2.5) visualises the strategies that can be followed for EcoDesign.
The development of new products will inevitably have an impact on the environment. To minimise the impact on the environment, you can follow an EcoDesign strategy. The EcoDesign Strategy Wheel is a tool to select and communicate the EcoDesign strategies.
The EcoDesign Strategy Wheel presents 8 EcoDesign strategies: new concept development, selection of low-impact materials, reduction of materials usage, optimisation of production techniques, optimisation of distribution system, reduction of impact during use, optimisation of initial lifetime, and optimisation of end-of-life system. Most of the EcoDesign strategies relate to the product life cycle. The first strategy is different, since it relates to a much more innovative strategy than the others. Some strategies relate to the product component level, some to product structure level and others to the product system level.

During the analysis of the environmental product profile, many improvement options will have come up spontaneously. These improvement options can be grouped according to the classification of eight EcoDesign strategies and visualised in the EcoDesign Strategy Wheel as EcoDesign strategies in the product design project. To generate even more

How to
EcoDesign
Strategy Wheel



improvement options, the project can also go the other way around by using the EcoDesign Strategy Wheel as an option-generation tool.
You can visualise the results of establishing the most promising EcoDesign strategy for the project by using the EcoDesign Strategy Wheel. Next, once you have established EcoDesign priorities, you can draw them up and visualise them by adding two activity lines to the EcoDesign Strategy Wheel: short-term activities versus long-term activities. This makes it easy to communicate the EcoDesign strategy both internally and externally.
Finally, the EcoDesign strategy which is established for the short term is included in the list of requirements for the product to be redesigned. You should describe the environmental requirements quantitatively as far as possible. At a later stage this will facilitate the mutual comparison of various product concepts or detailed solutions.

When Can You Use the EcoDesign Strategy Wheel?

The EcoDesign Checklist is best applied in the first stage of a product design process, the problem analysis stage. The EcoDesign Strategy Wheel is best applied to present and select new strategies for product design, possibly with a general product idea in mind. The EcoDesign Strategy Wheel is often used in combination with the MET Matrix (Brezet and van Hemel, 1997. see fig. 2.6) as a tool to avoid missing any environmental impacts of the product and also in combination with the EcoDesign Checklist.
In practice, it is preferable to do the analysis of environmental problems and the creative thinking about options for improvement in groups. Such a group consists of the project team and possibly other stakeholders.

How to Use the EcoDesign Strategy Wheel?

Starting Point

The starting point of the EcoDesign Strategy Wheel is formed by the information from the EcoDesign Checklist and the MET Matrix. Another starting point for the Strategy Wheel is a first view on the direction for product design (first product ideas included).

Expected Outcome

The expected outcome of using the EcoDesign Strategy Wheel is a clear understanding of possible strategies for new product design. Based on this understanding, you can make a selection of the strategy you will apply in the next phase: product design.

Possible Procedure

1. Define the product idea, product concept or existing product that will be analysed.
2. Systematically score the product on each dimension of the Strategy Wheel. You can use the answers from the EcoDesign Checklist and/or the data from the MET matrix.
3. Consider the optimisation options for each of the dimensions, paying special attention to those on which the current design scores badly and those that have the most relevant environmental impact for that product (based on the MET matrix).

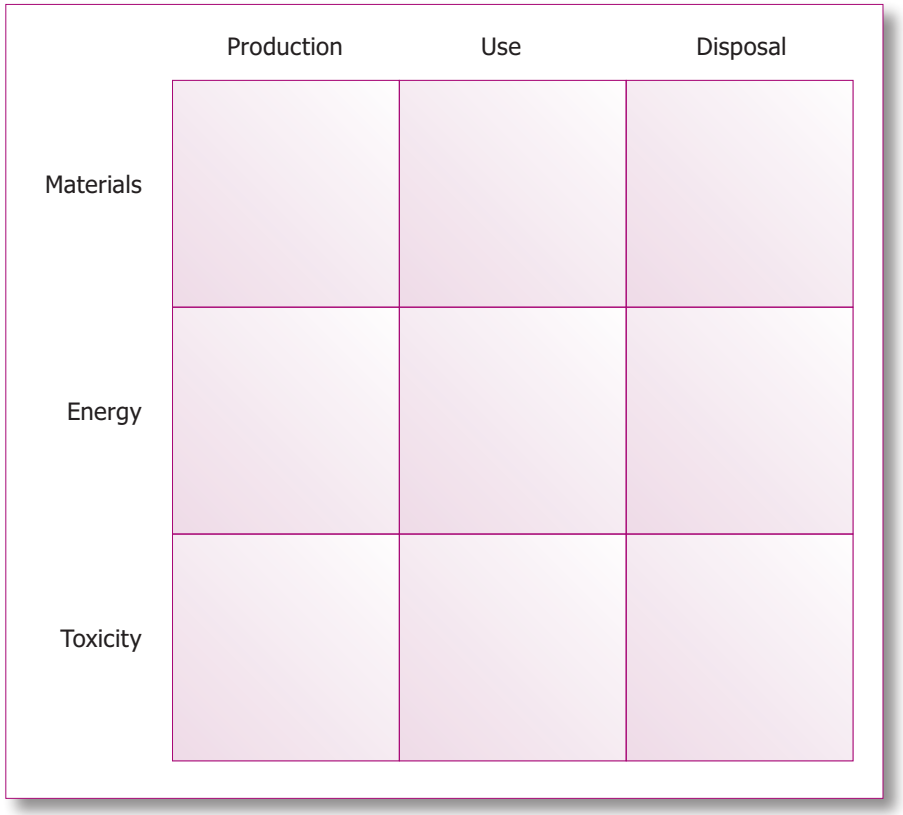


fig. 2.6 The MET Matrix (Brezet and van Hemel, 1997)

Tips and Concerns

- Use the EcoDesign Strategy Wheel together with the MET Matrix and the EcoDesign Checklist (see 'EcoDesign Checklist', in this section).
- Do not only consider technical solutions but also psychological ones. How does the design influence the user regarding energy efficiency, length of the life cycle, and end-of-life.
- Be aware that some EcoDesign strategies may strengthen each other, but some can also conflict with each other. The same goes for EcoDesign strategies and normal design and business considerations.
- Recheck your final redesign to see whether it offers the same functionality as the 'old' product, both physically and immaterially.

References and Further Reading

Brezet, H. and Hemel, van, C. (1997) *EcoDesign: A Promising Approach to Sustainable Production and Consumption*, France: UNEP.

Remmerswaal, H. (2002) *Milieugerichte Productontwikkeling*, Schoonhoven: Academic Service

Collage Techniques

Keywords
Visualisation
Mood board
Image board
Form characteristics
Context analysis

fig. 2.7 Example of a collage used in the design process (from student report)

What Is a Collage?

A collage is a visual representation made from an assembly of different forms, materials and sources creating a new whole. A collage may include newspaper clippings, ribbons, bits of coloured or hand-made papers, portions of other artwork, photographs, and such, glued (photoshopped) to a solid support or canvas. Making collages is an important visualisation technique in the design process, next to design drawing and three-dimensional modelling (see 'Design Drawing' and 'Three-dimensional Models' in section 2.2).
By means of collages, you make visual representations of the context, user group or product category with the objective of deriving (visual) criteria.

When Can You Use a Collage?

The use of collages serves different purposes in the design process. A collage can aid in determining the colour palette of the product ideas and concepts. Collages are very suitable to present a particular atmosphere or context that you want to capture in the form of the new product ideas and concepts.
In addition, collages help to determine and analyse the context in which the product will be used. As a designer you must take into account the context of which the product will be a part, i.e. the users, usage and usage environment. Making a collage helps to identify an existing or a new context.

Visual thinking and visualisation of ideas is inherent in thinking up ideas and solutions in design. Some issues cannot simply be captured in words, and this is where collages come into play. Collages help in structuring, developing, analysing and presenting visual issues that are difficult to express in words. You could think of shape characteristics, colour palette, compositional issues and so on. The overall purpose of using collages in the design process is to bring together visual elements to explore their commonalities.

Deriving Criteria from Collages?

Analysing collages helps determine criteria (design requirements) to which the solution must apply. Criteria of this kind also set a general direction for idea generation. With a collage we can find criteria for such matters as the lifestyle of a target group, the visual appearance of a product, the context of use and the interaction with a product (actions and handling). Other criteria may be how the product functions in its environment, and criteria that concern the category of products with which the new product is comparable. Collages in that way help to generate criteria by which the aesthetic qualities of ideas and solution can be assessed. Therefore, the creation of a collage is a process that is both creative (designing the collage) and analytical (deriving criteria).

fig. 2.8 Examples of abstact collages for establishing a colour palette (note the technique used in the botom collage - tearing up paper) (from student report)

Choosing Colour, Texture and Materials

After making collages for the context, target group, usage and environment, you can use these images to define a number of characteristic types of colour/ texture and materials. By means of analyses of collages you can determine the colours that will play a role. You can determine environment colours, preferred colours, target group and the colours used for existing products. Produce a palette for this by using for example cuttings from magazines/ colour guides and/or the computer. The advantage of cuttings from magazines is that you can also obtain an impression of a gloss, material and possible transparency and texture. After gathering these provisional palettes, try to determine which colours will be the main colour for each palette and what the accent colours will be. Determine the relationships of these colours to each other.

Types of Collages?

We distinguish between an abstract collage (see figure 2.8) and a figurative collage. An abstract collage is built from pictures and images that are distorted in such a way that their origins are not visible anymore. Simple techniques are tearing up images, pasting images over one another, applying coloured surfaces with either straight edges or organically ripped edges (see figure 2.8). Usually, abstract collages also contain sections where drawing or painting is applied. Abstract collages miss any pictorial meaning, but only contain meaning on an abstract level in their use of colours and composition. Figurative collages are collages that make use of the pictorial meaning of the original pictures and images used in the collages. Various types of images are used to create a new image, which itself has a new pictorial meaning.

Image Board and Mood Board

Image Boards and Mood Boards are types of collages that originated from disciplines such as marketing and consumer research. An Image Board and a Mood Board are collages that display the intended user and his/her lifestyle. An Image Board or a Mood Board displays typical lifestyle elements (such as brand preferences, leisure activities and product type preferences) of the users, but also their dreams and aspirations.

How to Make a Collage?

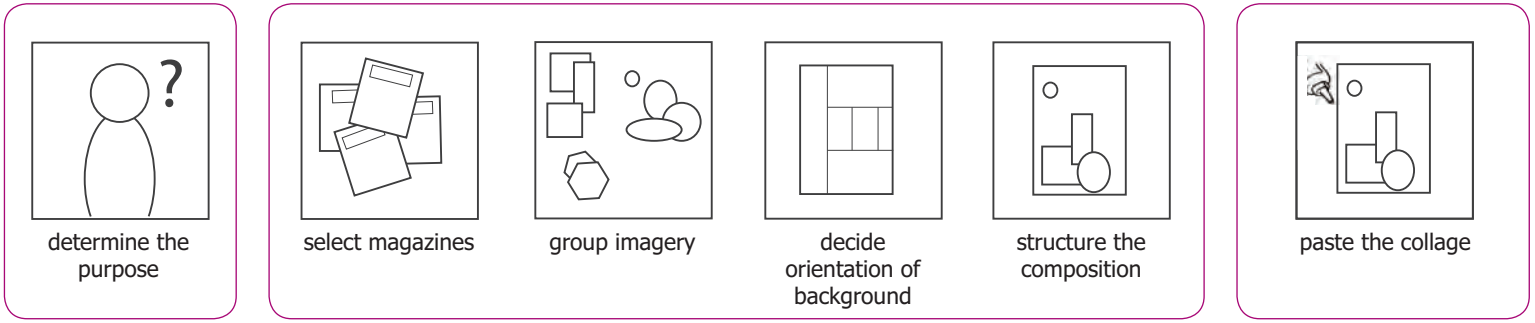
Starting Point

The starting point of making a collage is to determine what the collage is used for. What will be displayed in the collage: the user's lifestyle, the context of interaction, or similar products? Second, it is important to determine how the collage will be used: is the collage instrumental in the design project as a means to generate for example criteria, or will the collage be used to communicate a design vision? (see 'Desgin Vision' in this section)

Expected Outcome

The outcome of making a collage is a visualisation of an aspect of the problem context, e.g. the lifestyle of users, the context of interaction or the product category. The collage could also be the visualisation

How to
Collage Techniques



of a design vision (see 'Design Vision' in this section). Also, criteria can be derived from the collage that serve the design process.

Possible Procedure

1 Determine which magazines and/or imagery will produce the most suitable material. Certain magazines are already focused on a certain target group/lifestyle. Take advantage of them. Intuitively gather as much raw imagery as possible (an entire page!).
2 Group together the imagery that concerns the target group, environment, handling, actions, products, colour, material and so on. At the same time, make a selection according to usable and less usable images, but do not throw anything away.
3 For each collage decide the orientation of the background. Ask yourself what influence it will have on the picture that you want to convey (formal and businesslike or informal and fun - vertical versus horizontal).
4 Try by means of small sketches to set down the structure of the composition, paying attention to the creation of lines and axes. Describe the consequences and state whether they are desirable in relation to your vision/picture.
5 Think which consequences the treatment of the imagery (clipping, cutting, tearing) will have for the overall picture. Does the background have its own colour or will the collage be filled entirely with imagery? A decision to create a framework/ background will be of significance to the overall picture.
6 Examine which imagery will be placed in the foreground or in the background. Consider the size of the imagery (copy) and the relationship with the underground.
7 Identify which consequences play a role in merging (integrating) or separating the available pictures.
8 Make a provisional composition of the collage with the means at your disposal.
9 Assess the overall picture - are most of the characteristics represented?

fig.2.9 Examples of collages 'existing product' and 'usage environment' (from student report)

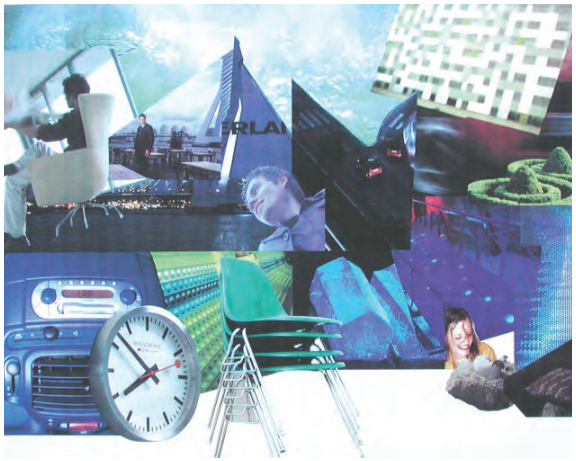
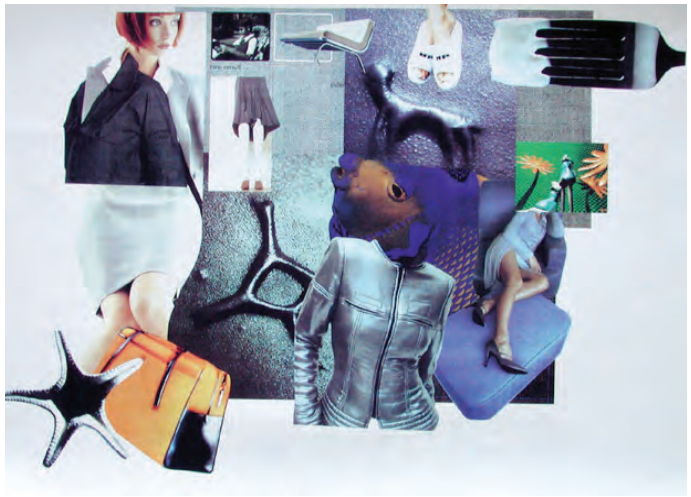


fig. 2.10 Examples of collages used in the design process (from student report)



10 Paste the collages once the picture meets your expectations and contains most of the characteristics and they are identifiable.

11 If this is not the case, try to identify which part or parts evoke the conflicting picture: imagery (target group, products, etc.), quantity of material, orientation, relationship, structure of the composition, foreground/background, treatment of material, separation/integration of material or types of colours/ shapes.

Colour

1 For each colour palette, determine the main colour and accent colour: hue (sometimes referred to as the type tone of colour, yellows, reds, greens, etc.), value (or grey tone or light or dark colours), saturation (also referred to as the degree of colour), pastel colours.

2. Address the following questions when looking at your collages: must the product be conspicuous or inconspicuous in its environment? Must the product correspond or contrast with the existing products? Must the product fit in with the colours preferred by the target group?

3. Decide the definitive palette on the basis of the answers to these questions.

References and Further Reading

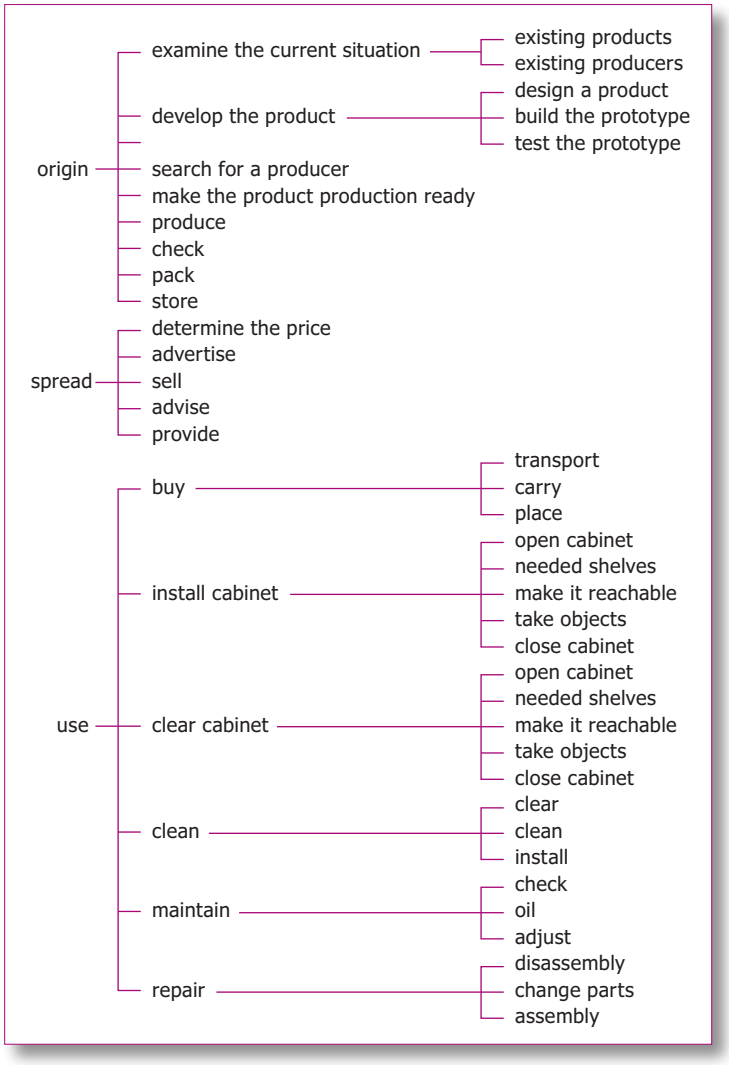
Muller, W. (2001) *Order and Meaning in Design*, Utrecht: Lemma

Bruens, G. (2007) *Form/Color Anatomy*, Utrecht: Lemma.

Keywords
Requirements
Product life cycle

Process Tree

fig. 2.11 Examples of a Process Tree (Roozenburg and Eekels)



What Is a Process Tree?

A Process Tree (see figure 2.11) is a schematic diagram of the processes that a product goes through during its life. Between its origination and disposal, a product goes through processes such as manufacturing, assembly, distribution, installation, operation, maintenance, use, reuse and disposal. Each of these processes comes with certain requirements and wishes for the new product. Making a process tree forces you to think ahead: in which situations, places, activities will the new product turn up? Who is doing what with the product then? What problems are to be expected? What requirements do these situations necessitate? A process tree forces the designer to systematically think through all the subprocesses that a product goes through: production (including development), distribution, use and disposal. Starting with these four main processes, a tree of (sub) processes comes into being (see figure 2.11).

When Can You Use a Process Tree?

A process tree is preferably made in the beginning of the problem analysis.

How to Make a Process Tree?

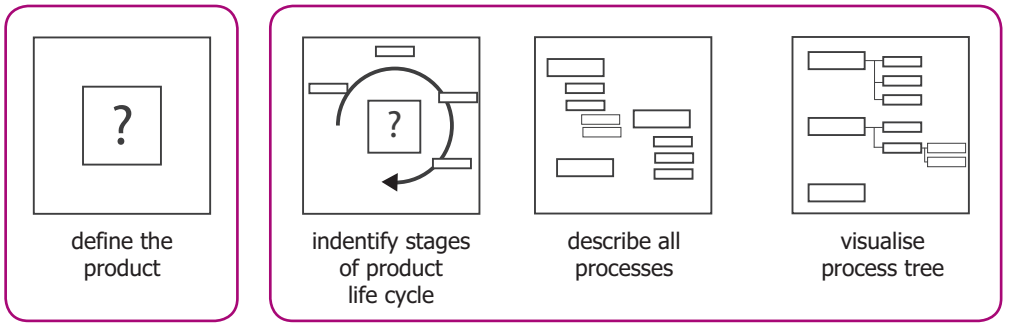
Starting Point

The starting point of a process tree is a product, or a product group.

Expected Outcome

The outcome of a process tree is a structured overview of the important processes that a product goes through. This overview helps in setting up requirements and defining functions.

How to
Process Tree



Possible procedure

1. Define the product, or product group.
2. Identify the relevant stages in the life cycle of the product. Use the following stages as a start: production, distribution, use, maintenance and disposal.
3. Describe all the processes that a product goes through in the determined stages.
4. Visualise the process tree (for example see figure 2.11).

Tips and Concerns

- By taking on the role of the product, you can ask yourself in respect of each process *in which processes am I involved during this stage...?*
- When identifying requirements from the process tree, ask yourself the following question: *which criteria must the product satisfy during the process of...?*
- You will sometimes identify processes that are preceded by a more important process. It is important to break down this hierarchy into processes until you have reached a level where further breakdown is not possible.
- When describing the processes, use verb-noun combinations, for example: *transport product to store - place product in the store.*
- *Use* is typically the stage in which the product fulfils its *function*. In the stage of use, you can distinguish between processes performed by the user and processes performed by the product. Ideally, processes performed by the user are *user tasks* and processes performed by the product are functions of the product. However, they can also be forms of *misuse* (or *unintended use*) and *malfunction*, respectively. It is a good idea to distinguish between these different types of processes, for instance by using different colours or fonts.
- Create a table in Microsoft Word (or any other word processor or spreadsheet) for the process tree: the column on the left shows the general stages in the product life cycle (production, distribution, use and disposal), the column on the right presents the processes.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) P*roduct Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

WWWWWH: Who, What, Where, When, Why, and How

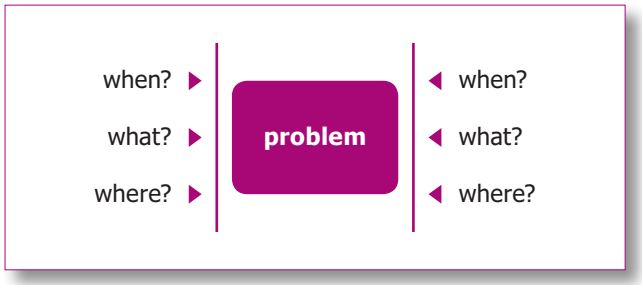


fig. 2.12 Who, What, Where, When, Why, and How

What Is 'Who, What, Where, When, Why, and How'?

Analysing a problem means obtaining a thorough understanding of the problem, its stakeholders and the facts and values involved. An important notion in problem analysis is deconstruction of the problem: by asking yourself a multitude of questions (about the stakeholders, facts, etc.), you are able to deconstruct the problem systematically. Consequently, you can review the problem and set priorities. There are several methods available for analysing a problem systematically, one of which is WWWWWH (who, what, where, when, why, and how?). Another method is breaking down the original problem into means-end relationships.

When Can You Use 'Who, What, Where, When, Why, and How'?

Problem analysis is one of the first steps in a design process, right at the beginning of a design project.

How to Use 'Who, What, Where, When, Why, and How'?

Starting Point

Define the preliminary problem or draft a design brief

Expected Outcome

The outcome you can expect is that you will get greater clarity about the problem situation (the problem context), you will gain a better understanding of the stakeholders, facts and values of the problem, and more insight into problems underlying the initial problem.

Possible Procedure

1 Write down the initial design problem in brief statements.
2 Ask yourself the following WWWWWH questions in order to analyse the initial design problem. Perhaps you can find more questions yourself: Who are the stakeholders? Who has the problem? Who have an interest in finding a solution? What is the problem? What has been done to solve the problem? Why is it a problem? Why is there no solution? When did the problem occur? How did the problem come about? How did (some of) the stakeholders try to solve the design problem?
3 Review the answers to the questions. Indicate where you need more information.
4 Prioritise the information: what is important? why?
5 Rewrite your initial design problem (see also 'Problem Definition' in this section)

Tips and Concerns

- Who: mention as many people as possible that are involved with the problem
- What: think also about the problems behind the problem. Try to find the essence of the problem.
- You can also ask "What for".

References and Further Reading

Tassoul, M. (2006) *Creative Facilitation: a Delft Approach*, Delft: VSSD.

Problem Definition

Keywords
Design goal
Fields of tension

What Is a Problem Definition?

What is a problem? What does a problem definition (see figure 2.13) consist of, and how do goals and objectives fit in? A problem always has to do with dissatisfaction about a certain situation. However, satisfaction is a relative concept, so problems are also of a relative nature. A big problem for one person may not be a problem at all for someone else.
An expected situation in the future does not have to be accepted. You can try to do something about it, by acting now. For defining a problem this implies that it is not sufficient to describe the existing state. Therefore, we speak consciously of the situation that someone is or is not satisfied with. As a result, a description of the situation is a description of a state plus the relevant causal model(s), including the assumed patterns of behaviour of the people and organisations involved. A situation is only a problem if the problem-owner wants to do something about it. This implies that a situation must be conceivable that is more desirable than the present one: the goal situation. The existing situation, however, can also be formulated in such a manner that a problem does arise.

When Can You Use a Problem Definition?

A problem definition is usually set up at the end of the problem analysis phase.

What is the problem?

The problem is that in the opinion of the company Fun-Play BV their target market is too small.
The company wants to expand their target market by developing a toy that can be used on water.
The toy must be able to be moved in and on water.
The product needs to have a driving mechanism and a transportation system that the user eventually could use to get acquainted with the technical aspect of the system. A potential problem is that the product is supposed to attract a target group from 7 - 11 years. Therefore the design should communicate to this target group.

Who has the problem?

The main problem is that the company Fun-Play BV thinks that their target market is too limited. The company wants to expand into the European market. In order to do that, bigger product sales need to be achieved. Therefore the numbers of products need to be increased by creating a new series of toys

What are the goals?

The goal is to design a product that is suitable for kids between 7 - 11 years and addresses a certain play activity of this group. Next to that the product needs to move in or through water with help of a driving mechanism or other transportation system. Furthermore the product needs to be suitable for competition or game element.

What are the avoidable side effects?

Some effects that are created by this product have to be avoided. Next to pollution that the production causes, effects of the user have to be taken into account, such as noise created by the users. Also the space that the product will occupy in public spaces, which in turn can create problems by not leaving enough space for i.e. storage.

Which ways of action are available in the beginning?

There are a number of conditions that need to be agreed on before solving the problem. For this product only the following materials can be used: metal, wood and plastics. The deadline needs to be met in 14 weeks.

fig. 2.13 Example of a Problem Definition (from student report)

Problem Definition

Watch interview with René Bubberman (Fabrique) via the OpenCourseWare version of this guide: http://ocw.tudelft.nl

How to Use a Problem Definition?

Starting Point

The starting point of a problem definition is the information gathered in the problem analysis stage. The different aspects surrounding the design problem have been analysed and should be taken into account in the problem definition.

Expected Outcome

A structured description of the design problem, with the goal of creating an explicit statement on the problem and possibly the direction of idea generation. Also, a problem definition clearly written down provides a shared understanding of the problem and its relevant aspects.

Possible Procedure

Answering the following questions will help to create a problem definition:

1. What is the problem?
2. Who has the problem?
3. What are the goals?
4. What are the side-effects to be avoided?
5. Which actions are admissible?

Tips and Concerns

- When analysing problems there is always a tension between the 'current situation' and the 'desired situation'. By explicitly mentioning these different situations you are able to discuss the relevance of it with other people involved in your project.
- Make a hierarchy of problems; start with a big one and by thinking of causes and effects, divide this problem into smaller ones. Use post-its to make a problem tree.
- A problem can also be reformulated in an opportunity or 'driver'. Doing this will help you to become active and inspired.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

Keywords Requirements, Criteria

Checklist for Generating Requirements

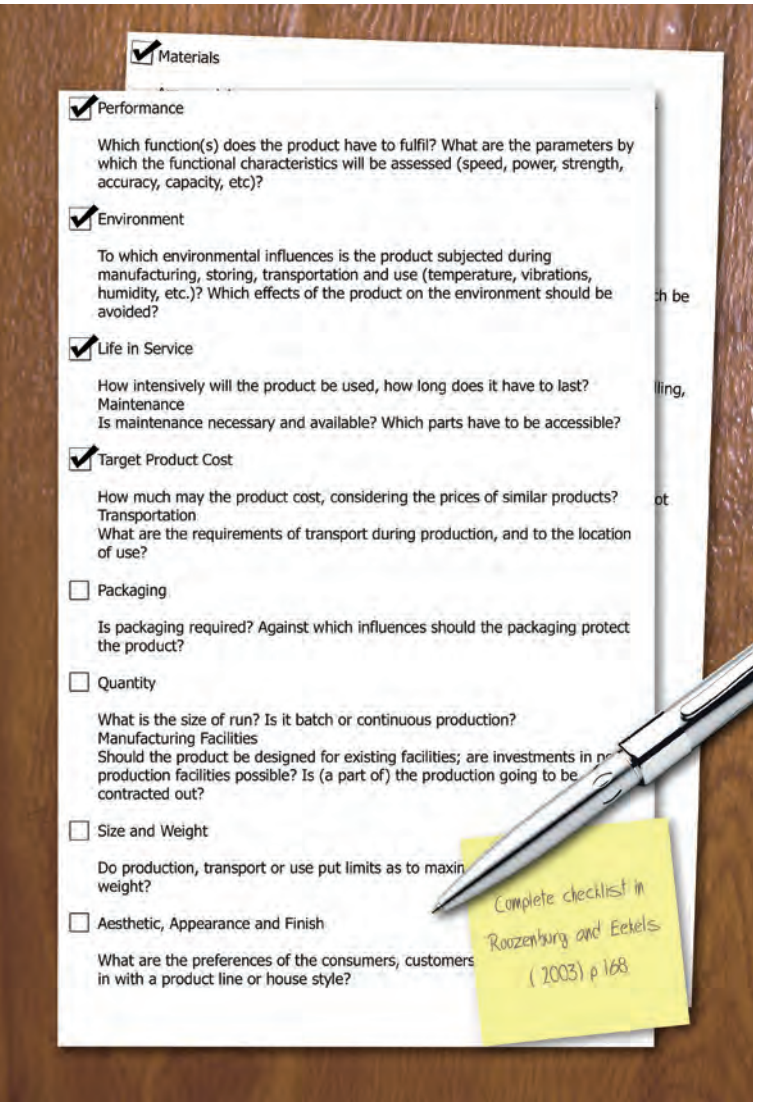


fig. 2.14 Example of a Problem Definition (from student report)

What Is a Checklist for Generating Requirements?

Checklists for Generating Requirements are lists of questions that you can ask yourself when creating a design specification (list of requirements) (see also 'Design Specificaction (Criteria)' in this section). Checklists ensure that you adopt a systematic approach to the creation of the programme of requirements. The most important thing is not to forget a particular requirement, meaning that we have to arrive at a complete collection of requirements. You can create a programme of requirements by taking into account three points of view (see also 'Design Specificaction (Criteria)' in this section): (1) the stakeholders, (2) the aspects involved, and (3) the product life cycle. You can take these different points of view into account when generating requirements, and some provide explicit, clear-cut checklists (for example Pugh). Other points of view, for example the process tree, are not checklists by definition. However, they help the generation of requirements in the same way.

The Stakeholders

The aims and preferences of people set the requirements for a new product. Who are the people affected by the new product, what interests do they have, what do they decide on, and what information can they provide? Important stakeholders are the company, its (future) customers, suppliers, transport companies, wholesale and retail trade, consumer organisations, and legislators. An example of a checklist to distinguish relevant stakeholders can be found in Jones (1982).

Aspects Involved in Product Design

There are checklists of aspects which usually play a role in the assessment of a product. By aspects we mean such general issues as performance, environment, maintenance, aesthetics and appearance, materials, and packaging among others. Such checklists have been drafted by Hubka and Eder (1988), Pahl and Beitz (1984), and Pugh (1990) - see the example in figure 2.14.

Product Process Tree

The process tree of a product (see 'Process Tree' in this section) provides a third viewpoint to arrive at a complete specification. Between its origination and disposal, a product goes through several processes, such as manufacturing, assembly, distribution, installation, operation, maintenance, use, reuse and disposal. Each of these processes comes with certain requirements and wishes for the new product. You become aware of these requirements by making a process tree.

When Can You Use a Checklist for Generating Requirements?

Checklists are useful when devising a first list of requirements (see 'Design Specificaction (Criteria)' in this section), at the end of the analysis stage in the design process.

How to Use a Checklist for Generating Requirements?

Starting Point

The starting point of using checklists is formed by the information found in the analysis of the design problem, the context of the design problem etc.

Expected Outcome

The outcome of using checklists for generating requirements is a first list of requirements, which contains redundant requirements.

Possible Procedure

1. Search for the appropriate checklist.
2. Use the checklist to generate as many requirements as possible.
3. Work systematically through the checklist. Do not skip any of the points on the checklist.
4. Follow the procedure indicated in section 2.1.11.

Tips and Concerns

- Use more than one checklist; checklists complement each other.
- More practical guidelines for developing design requirements can be found in: Cross, N. (1989) *Engineering Design Methods*, Chichester: Wiley.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

Jones, J.C. (1982) *Design Methods: Seeds of Human Futures*, Chichester: Wiley.

Hubka, V. and Eder, W.E. (1988) *Theory of Technical Systems: A Total Concept Theory for Engineering Design*, Berlin: Springer.

Pahl, G. and Beitz W. (1984) *Engineering Design: A Systematic Approach*, London: Design Council.

Pugh, S. (1990) *Total Design: Integrated Methods for Successful Product Engineering*, Wokingham: Addison Wesley.

Keywords Requirement

Design Specification (Criteria)

2. Distribution:

2.01 The electrical home scissors should be efficiently transported from producer to wholesale and/or small shops
2.02 The electrical home scissors be efficiently transported from wholesale or small shops to the consumer
2.03 The product may not be damaged during transportation and storage
2.04 The packaged product needs to be stackable
2.05 The displayed product should clearly communicate its function and possibilities

3. Use:

3.01 The product can be carried and hand-held
3.02 The electrical home scissors have to be ready for use in 1minute, preferably without use of any extra tool
3.03 The method of assembly of parts needs to be clear
3.04 The use of the electrical home scissors needs to be clear
3.05 Possible use restrictions of the electrical home scissors need to be clear
3.06 The operation of the product needs to be clear
3.07 The product needs to be operated standing and seated.
3.08 The product needs to be able to be used with one hand left and right handed
3.09 The product needs to resist a fall of 0.8m
3.10 The product may not damage the environment in which the product will be used
3.11 The product has to be designed in such a way that it will not harm users
3.12 The electrical home scissors need to be able to be cleaned with a wet tissue
3.13 Adjustments should be done by the user
3.14 The electrical home scissors need to be able to be repaired at a repair service

fig. 2.15 Example of a Design Specification (Criteria) (from student report)

What Is a Design Specification?

The Design Specification consists of a number of requirements (see figure 2.15). The design of a product is 'good' in so far as it complies with the stated requirements. A requirement is an objective that any design alternative must meet. The programme of requirements is thus a list of objectives, or goals. Goals are images of intended situations, and consequently requirements are statements about the intended situations of the design alternative. Design alternatives should comply optimally with the requirements; an alternative which does not comply with one or more of the requirements is a bad alternative and cannot be chosen. Many requirements are specific; they apply to a particular product, a specific use, and a specific group of users. There are also requirements with a wider scope, as they are the result of an agreement within a certain branch of industry or an area of activity. Such a requirement is called a standard. To some extent, a designer is free to choose requirements; standards, however, are imposed by an external authority.

When Can You Make a Design Specification?

Normally, a design specification is constructed during the problem analysis, the result being some finished list of requirements. However, a design specification is never really complete. During a design project, even during the conceptual designing stages, new requirements are frequently found because of some new perspective on the design problem. Therefore, a design specification should be constantly updated and changed.

How to Make a Design Specification?

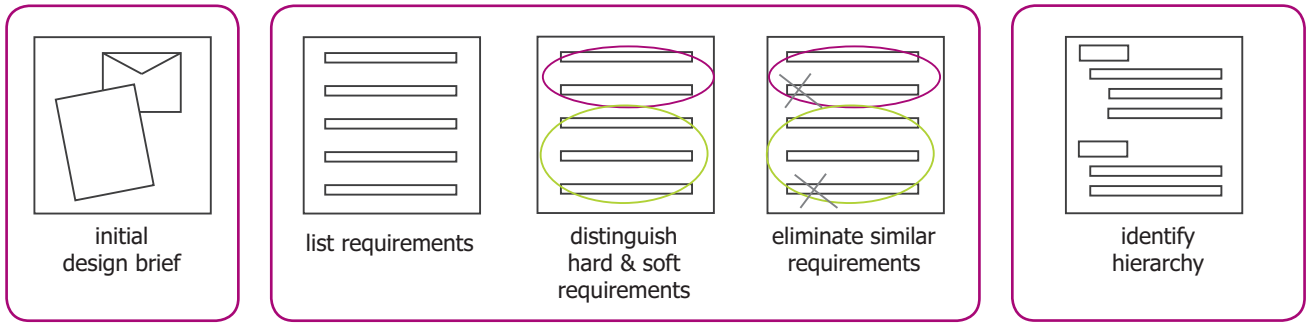
Starting Point

The starting point for making a design specification is formed by the analyses that take place during the stage of problem analysis.

Expected Outcome

The outcome is a structured list of requirements and standards. Programmes consisting of 40 or 50 requirements are not uncommon.

How to
Design Specification (Criteria)



Possible Procedure

1 List as many requirements as possible. Roozenburg and Eekels state that in order to arrive at a complete design specification, different points of view can be taken into account (see 'Checklists for Generating Requirements' in this section). Choose one, or several, of these points of views (stakeholders, aspects, or process tree) to help generate requirements. You can also use checklists, for example Pugh's checklist (see figure 2.14).

2 Make a distinction between hard and soft requirements (i.e. between quantifiable requirements and wishes).

3 Eliminate requirements which are in fact similar or which do not discriminate between design alternatives.

4 Identify whether there is a hierarchy in requirements. Distinguish between lower-level requirements and higher-level requirements.

5 Put requirements into practice: determine the variables of requirements in terms of observable or quantifiable characteristics.

6 Make sure that the programme of requirements fulfils the following conditions:
   a. each requirement must be valid
   b. the set of requirements must be as complete as possible
   c. the requirements must be operational
   d. the set of requirements must be non-redundant
   e. the set of requirements must be concise
   f. The requirements must be practicable.

Tips and Concerns

- Be careful: do not make the possibilities for your design too limited by defining too many requirements.
- Distinguish between measurable requirements and non-measurable requirements.
- Give your requirements numbers in order to be able to refer to them.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

Cross, N. (1989) *Engineering Design Methods*, Chichester: Wiley.

Watch interview with Oscar Toetenel (MMID) via the OpenCourseWare version of this guide: http://ocw.tudelft.nl

Keywords Subjective

Design Vision

fig. 2.16 Example of a Design Vision (from student report)

What Is a Design Vision?

According to the description in the Dutch dictionary 'van Dale' vision means 'The way in which someone judges, considers matters (or things), consideration, view, opinion'. A vision in the context of product design provides us with a personal, inspiring image of a new future situation created by a designer or a group of designers and/or other professionals. This new future situation may directly concern the new product itself (features, functions etc.), but also the domain and context within which the product will be used, the user(s), the usage (or interaction) of the user(s) with the product, the business or other aspects related to the product design. A design vision includes: (1) an insight into or understanding of the product-user-interaction-context system; (2) a view on the essence of the problem: "which values are to be fulfilled?"; and (3) a general idea or direction about the kind of solutions to be expected.
A strong, convincing vision is often well-founded by arguments based on theories and facts, and is often communicated effectively by using images, text and other presentation techniques. A design vision should be sharable and inspiring. As it is the result of the use of theories, facts and arguments, it should be an 'objective' interpretation.

When Can You Make a Design Vision?

An explicit vision on the product (to be designed) supports you, the designer, during your search for ideas and the final design. It provides a design direction and thus helps you steer the product design process. This process is supported by many aspects that are influenced by factors such as the opinions of clients, users, team members, producers etc. Therefore a vision (on something - to be specified) should be created in an early stage of the design process.

How to Make a Design Vision?

Starting Point

The starting point of a design vision is a personal vision on the design problem.

Expected Outcome

The expected outcome is a written statement of a design vision or design philosophy.

Possible Procedure

A design vision usually does not 'come out of thin air' but is a result of thorough analyses, creative thoughts and personal experiences in design, as well as experience of life in general. The elective course ViP of the master courses provides a specific approach for it (see also section 1.6). A vision development approach is also incorporated in the 2nd year of the Bachelor course 'Fuzzy Front End' and Strategic Product Innovation.

Design Vision

Function

The most important functions for the design are:

- Transport children on water, the toy needs to float on water, the transportation function enables that children can take part in competitions and water cycle
- Transform muscle strength into driving force; the children have to use of the driving mechanism to move the water cycle
- Teach children something about mechanics; one of the goals of the company is to introduce children to mechanics and how the product works
- Children should enjoy themselves; of course this has to be a result of the points listed above

Target Group

The most important target group are children from 7 – 11 years. Nevertheless the product also needs to be used by youngsters and elder people. A distinctive characteristics of this group is the ability to swim thus need less guarding. Children have a lot of fantasy and have a keen interest in mechanics. The other relevant group is camping users or café users next to lakes. The intention is that these people buy the product to provide children with maximum fun. These people do not care about the product. They only want that it is stored very well during winter at minimum maintenance.

Interested Party

The remaining interested party are the parents. They want their child to have fun and at the same time be safe without their constant guard. Others concerned are other water users who should experience minimum inconvenience from the product, the water cycle.

Environment for use

The product is going to be used on lakes next to campings and other recreational areas. Lakes have no current, often little beaches with gras on them. Lakes often have little cafes or toilet spots which could serve as storage space for the product.

Relation with other products

The product will have to compete with other water game activities. Other products can be water cycles, beach balls but also bigger beach balls or rubber boats. The unique quality of this product is that it embodies all of these functions including the fantasy aspect of the target group.

Distinguishing aspects

The product needs to command attention in between all other activities in such a lake. It has to come across as very safe. The product needs to be produced as environmentally friendly as possible and should resist long term influences of sand, water and sunlight.

fig. 2.17 Example of a Design Vision (from student report)

Tips and Concerns

- Since beginning Bachelor students do not have much experience in design, some design researchers and tutors have stated that we cannot expect strong design visions from beginners and therefore not ask them to create a vision in the early Bachelor years. This can be contradicted by the argument that young people do have opinions and by not supporting them in their development we miss a chance to link general design knowledge and skills to the personal motivation of people. Besides, people learn more effectively if there is a link between their external and their internal world (the person's own ideas and thoughts).
- Since there are so many aspects involved in the creation of a vision, it should be clear in advance on what the designer gives his or her vision.
- A design vision can have the form of a written story, but visualisations are used as well to express a design vision.

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2.2 Creating Product Ideas and Concepts

After the phase of problem analysis, the conceptual design phase begins. Conceptual designing means the creative act of thinking up product ideas and concepts. Once a design problem, requirements and a product vision have been formulated, product ideas and concepts have to be generated. An idea is a first thought that comes to mind, usually in the form of a simple drawing, without dimensions, proportions, shape and materials. Concepts are more developed, have materials, dimensions, shape, details and technical solution principles.

Conceptual design is a process of creative thinking, of developing initial ideas into concepts and offering realistic solutions to the design problem. It is a divergent and convergent process in which ideas are generated, tested and evaluated and developed into concepts.

Ideas are generated by means of creativity techniques, such as brainstorming or Synectics. In your evaluation of ideas, you bear in mind the design goal and the design specification. Visualising is an important aspect in the creative phase of designing: often you explore early ideas by means of sketches. Three-dimensional models such as sketch models, mock-ups and prototypes are also used. Such representations of ideas can be used for simulation and for testing the ideas and concepts (see also 'Product Simulation and Testing' in section 2.4).

Creativity Techniques

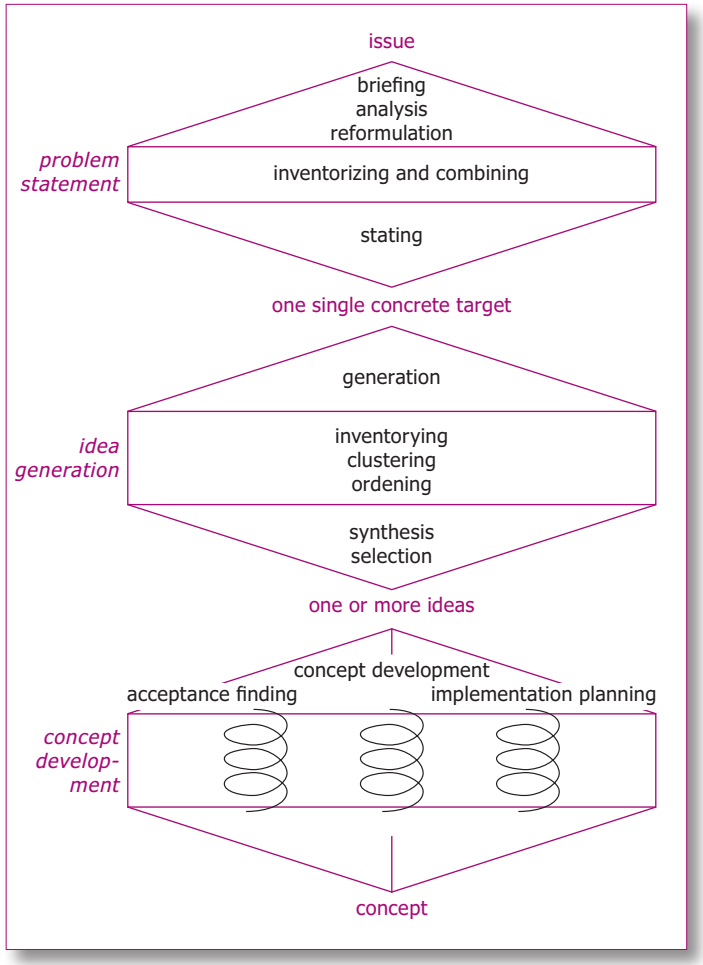

fig. 2.18 CPS model revisited of the Creative Problem Solving Process (Tassoul and Buijs, 2005)

What Are Creativity Techniques?

The techniques for thinking up solutions to problems are called 'creativity techniques' or 'creativity methods'. Most of these methods are general - they are applicable to a wide variety of problems. Creativity techniques are very useful in the design process, generating large amounts of ideas in a short time. There are many different creativity techniques, often classified according to structures like the following one (see Marc Tassoul, 2007):

1 **Inventorying techniques**
Techniques used to collect and recall all kinds of information around an issue. This helps in making an inventory of what we have in terms of ideas, or data, or whatever. Examples are Mind Maps (see 'Mind Map' in this section).

2 **Associative Techniques**
With associative techniques, great numbers of ideas and options are generated through association within a relatively short time. Association techniques encourage spontaneous reactions to ideas expressed earlier. An example of an associative technique is the brainstorming method (see 'The Brainstorming Method'in this section)

3 **Confrontational Techniques**
With confrontational techniques, ideas are generated by thinking outside one's familiar frame of reference. By identifying and breaking assumptions you are able to open up a wider solution space. New connections are made between the original issues in hand and a new idea through bisociation or force-fit. Completely new, unexpected combinations of viewpoints can arise, which bring the solution of the problem one step closer. An example is the Synectics method (see 'Synectics' in this section).

4 **Provocative Techniques**
With provocative techniques, assumptions and preconceptions are identified and broken from inside the familiar frame of reference (e.g. by asking questions like: "What if not?" and "What else?"). Provocative techniques make use of analogies, metaphors and random stimuli. Ideas will seem strange at first, but when force-fitted on the original issues they provoke new insights. Both confrontational and provocative techniques contain the principle of (1) making the strange familiar and (2) the familiar strange.

5 **Intuitive Techniques**
With intuitive techniques you develop a vision, or a new perspective on the original issue in hand. Intuitive techniques are useful for letting go: to guide the idea generation techniques by whatever comes to mind. It is a technique that allows for spontaneous and intuitive idea generation and reflecting upon the generated ideas. These techniques have a great influence on enthusiasm, motivation and courage of the team members.

6 **Analytic-Systematic Techniques**

Analytic-systematic methods are based on the analysis and systematic description of a problem, the drawing up of an inventory of solutions, variants to subproblems, and the systematic varying and combining of these solution variants. The morphological method and function analysis are the most typical examples (see 'Function Analysis' and 'Morphological Chart' in this section).

Creative Problem Solving

In order to apply the various creativity techniques effectively, a creative process needs to be followed. A very simple model of the creative process is provided by Wallas (1926): (1) preparation, (2) incubation, (3) illumination, and (4) verification. In the preparation phase the problem is defined. During the incubation phase, the issue is let go and attention is focused on other (inspirational) aspects. In the illumination phase an opening is (suddenly) found, from which an approach is developed to deal with the issue in hand. During the verification phase the idea is tested and evaluated. Tassoul and Buijs (2005) have modelled the creative problem-solving process in a more elaborate model, called the CPS model revisited (see figure 2.18). This model consists of three phases: (1) problem statement, (2) idea generation, and (3) concept development.

fig. 2.19
Creative Diamond Marc Tassoul/Jan Buijs (2005)

When Can You Use Creativity Techniques?

Creativity techniques are mostly used in a creative workshop, or in a brainstorm setting typically taking place at the beginning of the conceptual design phase, starting the phase of creating product ideas and concepts.

How to Use Creativity Techniques?

Starting Point
Expected Outcome
Possible Procedure
Tips and Concerns

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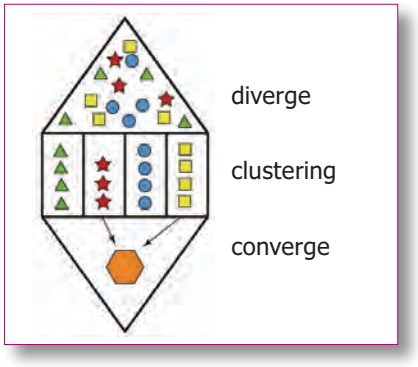


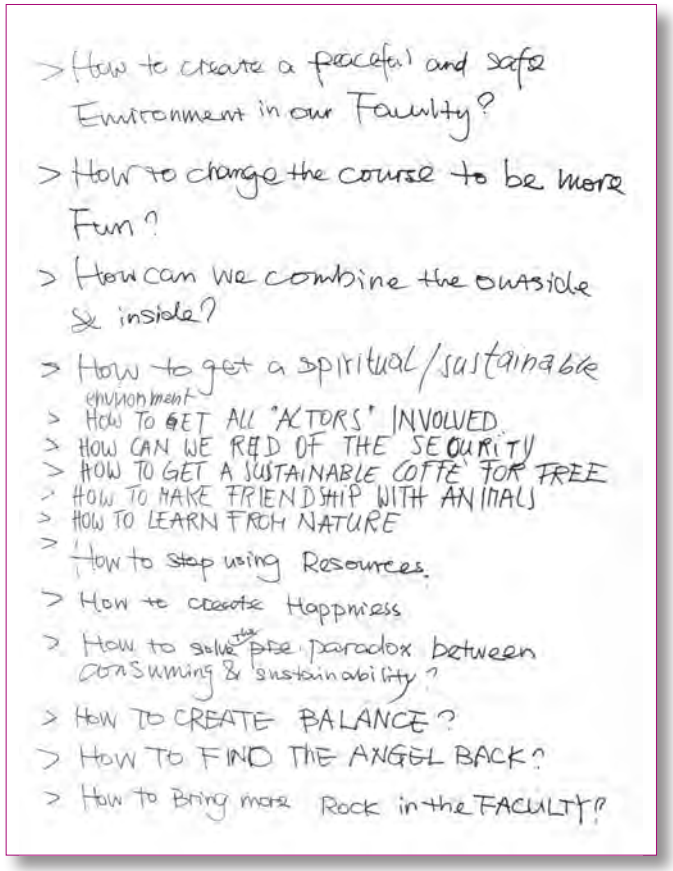


fig. 2.20 Example of H2's

How To's

What Are How To's?

'How to's' (see figure 2.20) are problem statements written in the form of "How to..." (How to's are often written as H2 for short). Examples are: How to carry luggage in the airport? How to transport deep-frozen food in a shop? How to supply people with beverages at a festival?

The "How to.." way of phrasing is dynamic and inviting. The idea is to create a wide variety of problem descriptions. In this way different perspectives are briefly shown, and the problem is described from these different points of view. There are rules in force such as 'postpone judgment', 'associate on the ideas of others' and'strive for quantity rather than quality'. The How to's are open questions that stimulate your creativity almost immediately. The various "how to" questions give a comprehensive overview of the problem that you are working on.

When Can You Use How To's (H2's)?

'How to's' are most helpful at the start of idea generation. With 'How to's' the problem is reformulated in many different ways and ideas come up easily.

How to Generate How To's (H2's)?

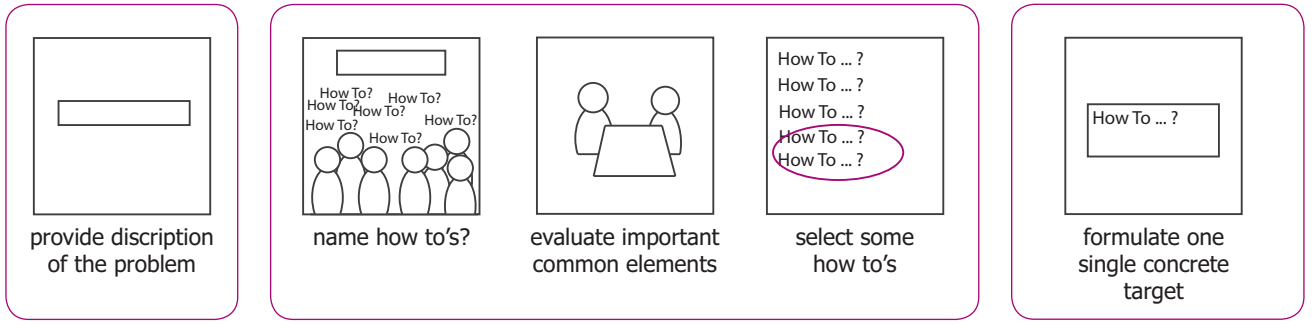
Starting Point

The starting point is the result of the problem analysis stage. Often it is a short description of the problem or a problem statement.

Expected Outcome

The outcome of the 'How to's' are various problem reformulations in the form of How to's. A benefit of this method is that the problem reformulations reflect different points of view towards the problem.

How to
How To's



Keywords
Problem formulation
Creative
Solution finding

Possible Procedure

1 Provide a short description of the problem and invite the group to name all important stakeholders and aspects of the problem (you could use a Mind Map for this – see section 2.2.3).
2 Invite the group to name as many 'How to's...' as possible, seen from the different points of view (stakeholders) and seen from the different aspects. You can use a flip chart to write down the 'How to's...' or post-its.
3 Evaluate the most important common elements of the 'How to's..'.
4 Select a number of 'How to's...' that cover the different points of view.
5 Formulate "one single concrete target" (e.g. one final 'How to' to continue with).

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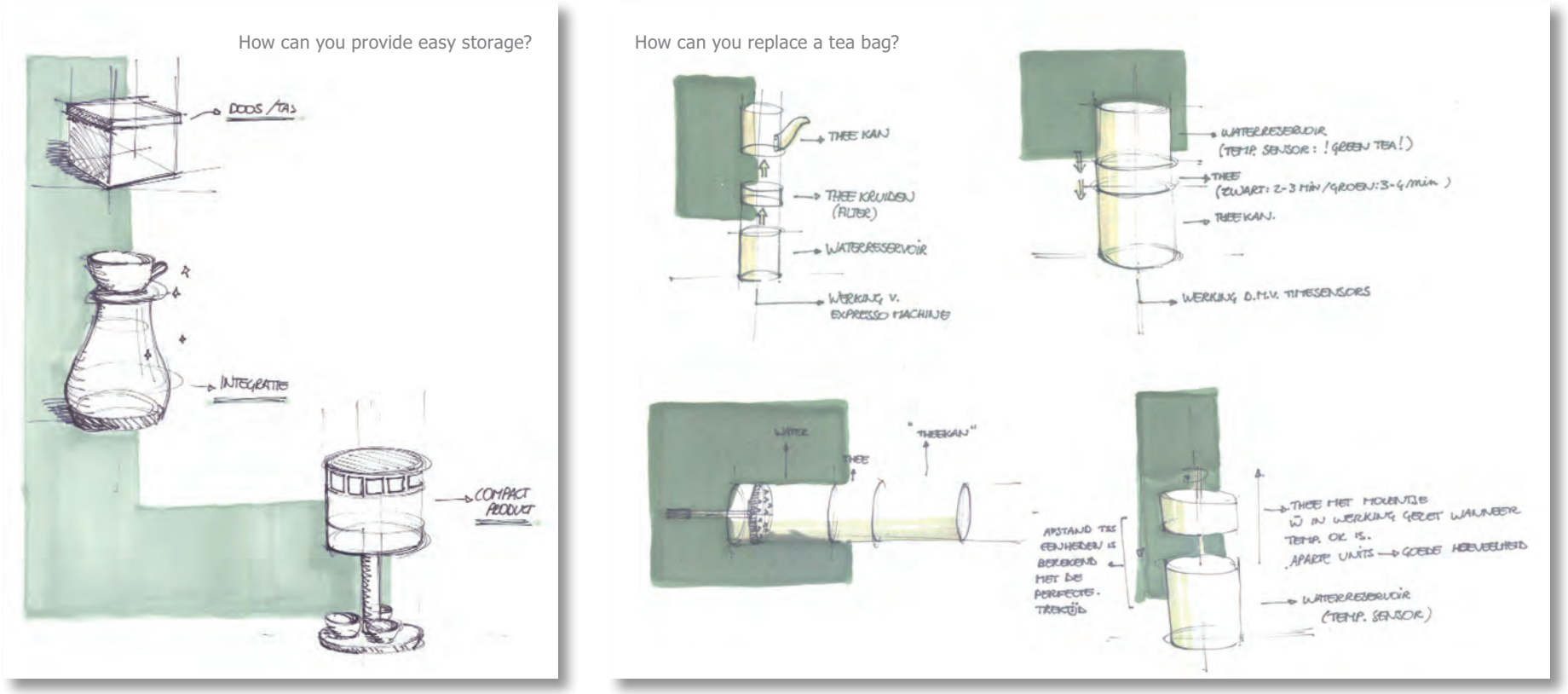

fig. 2.21 Examples of H2's (from student report)

Mind Map

Keywords
Creative
Association
Inventorying

What Is a Mind Map?

A Mind Map is a graphical representation of ideas and aspects around a central theme, showing how these aspects are related to each other. With a Mind Map you can map all the relevant aspects and ideas around a theme, bringing structure, overview and clarity to a problem. A Mind Map helps in systematically unpacking abstract thoughts and notions. It is like a tree, with branches leading to the thoughts and aspect of the theme. Graphically, one can use the analogy of the tree by making branches that are important thicker than others.

Mind Mapping is an excellent technique for developing your intuitive capacity. It is especially useful for identifying all the issues and subissues related to a problem. Mind Maps can also be used for generating solutions to a problem and mapping their advantages and disadvantages. The latter is accomplished by making the main branches the solutions and the subbranches from each of these the pros and the cons. Analysing the Mind Map helps you find priorities and courses of action.

When Can You Use a Mind Map?

A Mind Map can be used in different stages of the design process, but is often used in the beginning of idea generation. Setting up a Mind Map helps you to structure thoughts and ideas about the problem, and connect these to each other. However, a Mind Map can also be used in the problem analysis phase of a design project. Mind Maps also work well for outlining presentations and reports. In fact, Mind Mapping can be used in a wide variety of situations.

How to Use a Mind Map?

Starting Point

The starting point of a Mind Map is a central theme, for example a problem or an idea.

Expected Outcome

The outcome of a Mind Map is a structured overview of ideas and thoughts around a concept or a problem, represented graphically.

Possible Procedure

1. Write the name or description of the theme in the centre of a piece of paper and draw a circle around it.
2. Brainstorm each major facet of that theme, placing your thoughts on lines drawn outward from the central thought like roads leaving a city.
3. Add branches to the lines as necessary.
4. Use additional visual techniques – for example, different colours for major lines of thought, circles around words or thoughts that appear more than once, connecting lines between similar thoughts.
5. Study the Mind Map to see what relationships exist and what solutions are suggested.
6. Reshape or restructure the Mind Map if necessary.

Tips and Concerns

- You can find software for Mind Mapping on the Internet. The disadvantages of using computer software are that there is some limitation in freedom of using hand drawings and colours, it is less personal, and it might be less suitable when sharing it with others (you and your computer alone).
- Make digital pictures of your handmade Mind Maps.

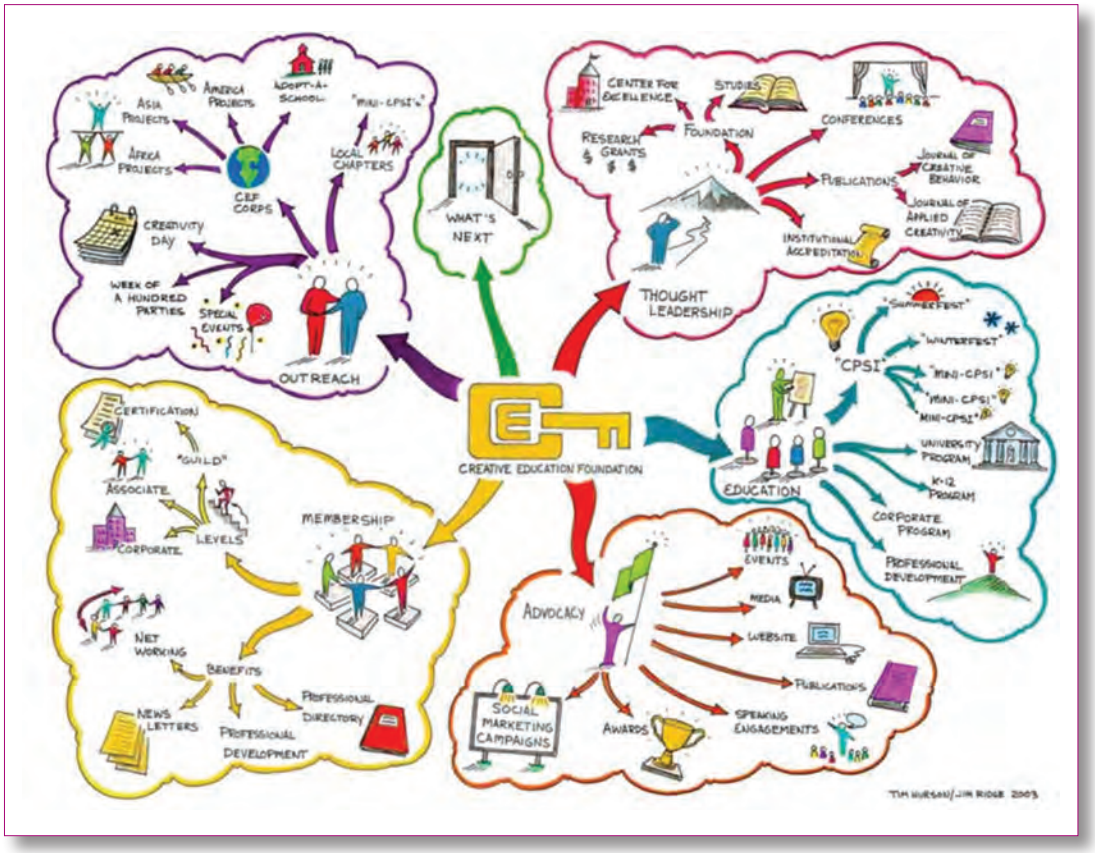

fig. 2.22 Example of a Mind Map (Tassoul, 2006)

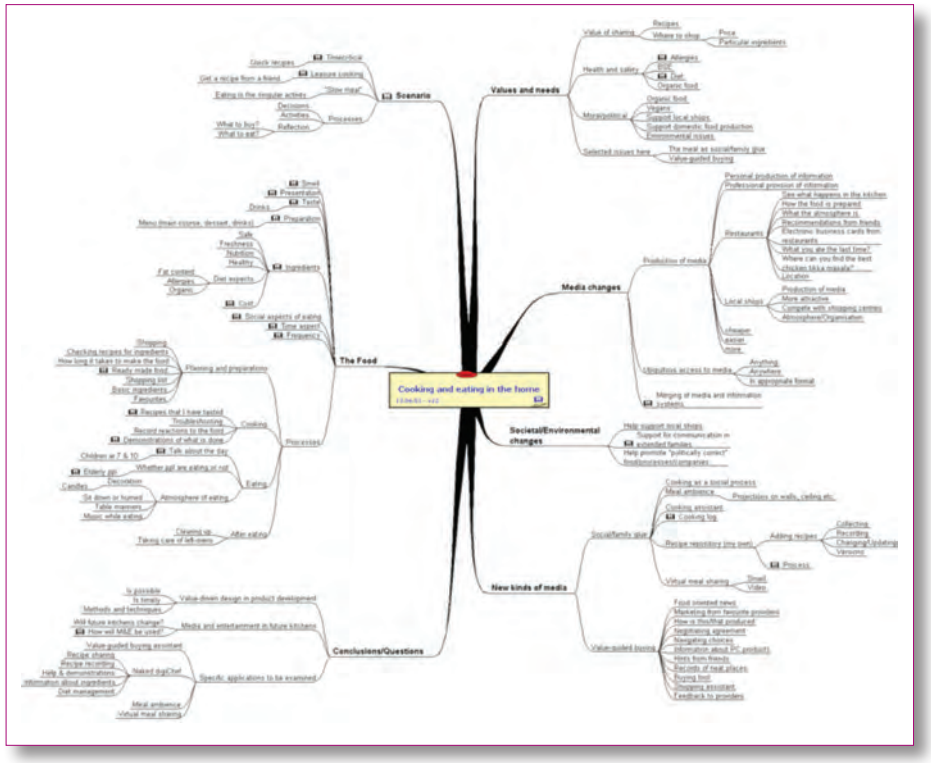

fig. 2.23 Example of Mind Map created with a Mind Map Software Tool. (from student report)

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Keywords
Creative
Problem solving
Brainwriting
Braindrawing
Association

The Brainstorming Method

What Is the Brainstorming Method?

When people hear the word brainstorming they often think of people sitting together and thinking up ideas wildly and at random. This is partly true! Brainstorming as a method prescribes a specific approach with rules and procedures for generating ideas. It is one of many methods used in creative thinking to come up with lots of ideas to solve a problem. Various methods or approaches to creativity exist, such as: brainstorming, synectics, lateral thinking/random stimulus and biomimetics. Brainstorming was invented by Osborn as early as the 1930s. Apart from producing large numbers of ideas, brainstorming is based on another very important principle: the avoidance of premature criticism. Of course ideas must be assessed critically, but an all too critical attitude often holds back the process of generating ideas.

We follow the brainstorm method of Osborn (1953) and Parnes (1992). This method consists roughly of the following steps:

1 Diverging from the problem
Beginning with a problem statement, this first stage is about a "creative démarche": a creative path where lots of ideas are generated using different techniques. Wild and unexpected ideas are welcomed.

2 Inventorying, evaluating and grouping ideas
The second step is about evaluating, reviewing and grouping ideas. Now an overview is created of the solution space (e.g. all possible solutions) and whether more ideas are needed.

3 Converging: choosing a solution
The third step is about choosing ideas and selecting ideas for the next phase in the design process.

The process underlying this method is built upon the following assumptions:

1 Criticism is postponed.
The participants in a brainstorming session should try not to think of utility, importance, feasibility and the like, and certainly not make any critical remarks thereon. This rule should not only lead to many, but also to unexpected associations. Also, it is important to avoid participants feeling attacked.

2 'Freewheeling' is welcomed.
The purpose is to have participants express any idea they think of; 'the wilder the idea, the better', it is said. In a brainstorming session an atmosphere must be created which gives the participants a feeling of safety and security.

3 Combination and improvement of ideas are sought
You should endeavour to achieve better ideas by adding to, and building upon, the ideas of others.

4 Quantity is wanted.
Try to think of as many associations as possible. The objective of this rule is to attain a high rate of association. The underlying idea is not only that 'quantity breeds quality' but also that through a rapid succession of associations the participants have little chance of being critical.

Brainstorm Session

Brainstorming (see figure 2.24) is done with a group consisting of 4-8 people. A facilitator leads the brainstorm session, and asks the group provocative questions. The group's responses (the ideas) are written down on a flip-chart. The stages that the group goes through in a brainstorm session are methods on their own, and different alternative methods are possible within a brainstorm session (for example: how to's, who-what-where-when-why-how, forward and backward planning, and wishful thinking).

fig. 2.24 Brainstorm session (Tassoul, 2007)

fig. 2.25 Braindrawing session

Brainwriting Session

Brainwriting is done with a group consisting of 4-8 people. A facilitator leads the Brainwriting session, and asks the group provocative questions. Each participant writes down his/ her idea on a piece of paper, and the papers are passed on to each other. In this way, an idea is elaborated when it passes through numerous participants, or an idea could serve as an inspiration for new ideas. Different versions of this method are possible. A well-known method is the 6-5-3 method.

Braindrawing Session

In a Braindrawing session (see figure 2.25) ideas are not written down, but are drawn or sketched. This distinguishes Braindrawing from brainstorming, which only uses words. In a Braindrawing session each participant draws his/her ideas on paper. Also, it is possible to build on each other's ideas by passing through the drawings similar to a Brainwriting session.

When Can You Use the Brainstorming Method?

A brainstorm is usually carried out in the beginning of the idea generation, with the goal of producing a large number of ideas with a group of participants.

How to Use the Brainstorming Method?

Starting Point

The starting point of a brainstorm session is a problem statement (one single concrete target).

Expected Outcome

The outcome of a brainstorm session is a large number of ideas.

Possible Procedure

1 Develop a statement of the problem (e.g. with H2's, one single concrete target) and select a group of 4-8 participants. Draw up a plan for the brainstorm session, including a detailed time line, the steps written down, and the methods used in the brainstorm session (example of a session plan).

fig. 2.26 A typical brainstorm session: facilitator and participants

2 You could send a note containing the statement of the problem, background information, examples of solutions and the four brainstorming rules, to the participants some time before the session.
3 Have a preparatory meeting together with the participants, right before the actual brainstorm session, whereby the method and rules are explained, the problem, if necessary, is redefined, and a so-called warm-up is held. A warm-up is a short stimulating brainstorming exercise unrelated to the problem.
4 At the beginning of the actual brainstorm session, write the statement of the problem on a blackboard or flip chart clearly visible to everyone, as well as the four rules.
5 The facilitator should ask provocative questions to the group, and write down the responses on a flip chart.
6 Once a large number of ideas has been generated, the group should make a selection of the most promising and interesting ideas. Usually, some criteria are used in the selection process, which should be established with the group.

Tips and Concerns

- Brainstorming is suited for solving relatively simple problems with an 'open' formulation. For more complex problems, it would be possible to brainstorm about subproblems, but then the overall view might be lost. Furthermore, brainstorming is not suited very well for problems whose solution requires highly specialised knowledge.

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Keywords
Creative
Problem solving
Confrontational
Analogies

Synectics

What Is Synectics?

The synectics procedure (see figure 2.27) was set up by Gordon and Prince (1976). It is a comprehensive creative procedure, containing techniques for problem analysis, idea generation and the selection stage. Synectics concentrates on the idea generation steps with the use of analogies. Analogies allow for moving away from the original problem statement and making a forced fit to develop solutions on the basis of these analogies. The synectics procedure is also based on the process of (1) preparation, (2) incubation, (3) illumination and (4) verification (Wallas, 1926). The incubation and illumination stages are now brought about through the use of analogies: 'To make the strange familiar and the familiar strange'.

In the preparatory stages, there is a problem briefing by the problem owner, an extensive problem analysis phase through questioning by the participants, and definition of a problem statement into 'one single concrete target'. After this, a purging phase takes place in which known and immediate ideas are collected and recorded. This phase is also called 'Shredding the Known'. From this point on, analogies are used to estrange yourself from the original problem statement and come up with inspirations for new solutions and approaches. These analogies take a number of forms that are presented in figure 2.27.

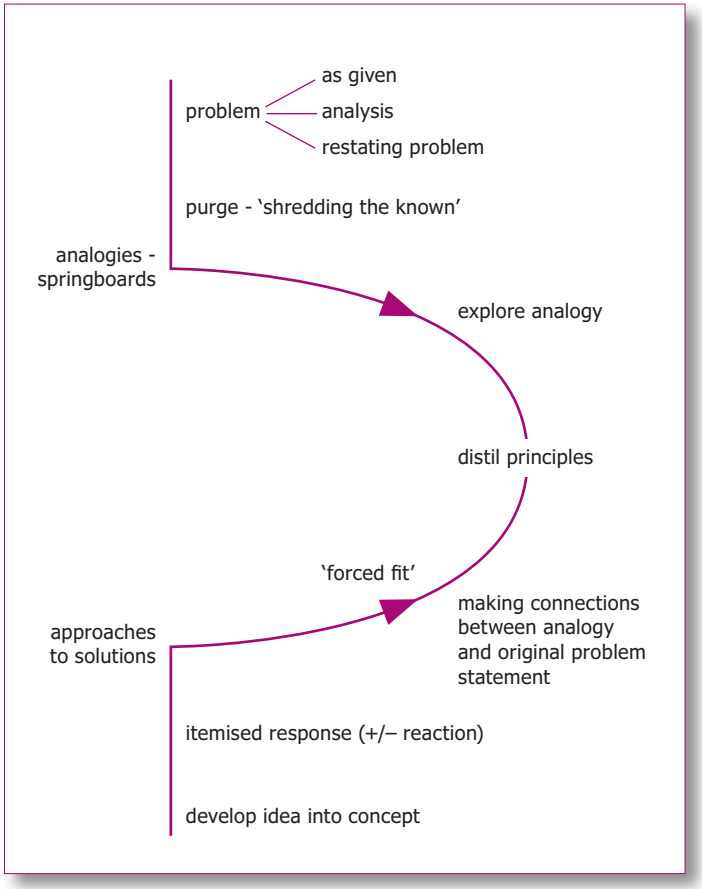


fig. 2.27 The Synectics Process (Tassoul, 2006)

For the assessment of the new solution possibilities, the synectics approach introduces yet another special technique: 'itemised response' (see 'Itemised Response and PMI' in section 2.3). To every idea there are both good sides (the pluses) and poor or bad sides (the minuses). By breaking down the idea into pluses and minuses and then trying to turn the minuses into pluses (for example, through a creativity method), the original idea may be - systematically - transformed into a better one.

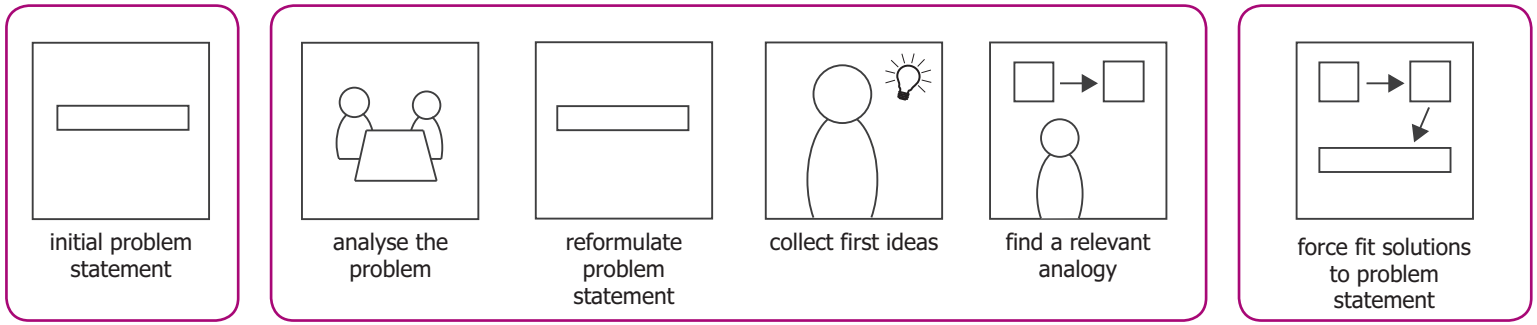
Visual Synectics

A variation is that of visual synectics: quiet images and music are introduced to induce an incubation phase. Music and images let people quietly simmer away, daydream on the images and on the music. This is done for some length of time after which there comes a switch to much more active music and images on the basis of which the participants now have to generate ideas, similar to the brainstorming or brainwriting presented earlier .

When Can You Use Synectics?

Synectics is best applied for more complex and intricate problems. Synectics can be used in groups as well as individually. With an untrained group, the facilitator will have to work in small steps at a time; he or she must have enough experience to inspire the group through such a process.

How to
Synectics



Direct Analogy	Starting from some aspect in the problem, one looks for comparable or analogous situations	For a time pressure problem, take for example 'ships in a busy harbour'. How do they manouvre without incidents?
Personal Analogy	What if you were an element in the problem, e.g. a planning problem?	Imagine you are the time. How would you feel? Maybe pressed. How would you influence the situation from such a perspective?
Nature Analogy	What kind of situations in nature does this remind me of?	E.g. an anthill, or the jungle with all the animals closely together, lungs and blood stream and all the gaseous matter that needs to be transported through the body.
Fantastic Analogy	Can you place the problem in a fairytale or other mythical situation and develop it from there?	How does the Nautilus withstand the pressure at 2000 miles under the sea, and what did the people aboard the Nautilus do? (thinking of Jules Verne's '20.000 miles under the seas')
Paradoxical Analogy	Characterise the issue in two words which are each other's opposites.	For example: blind open-mindedness, or overwhelming silence.

fig. 2.28
Type of analogies that can be used in Synectics (Tassoul, 2006)

How to Use Synectics?

Starting Point

The starting point of synectics is an initial problem statement. In the design process it continues with the design goal, problem definition and design specification generated in the problem analysis phase.

Expected Outcome

The outcome of synectics is a limited number of preliminary yet surprising ideas.

Possible Procedure

1. Start with the original problem statement. Invite the problem owner to present and discuss the problem briefly.
2. Analyse the problem. Restate the problem. Formulate the problem as one single concrete target.
3. Generate, collect and record the first ideas that come to mind (shredding the known).
4. Find a relevant analogy in one of the listed categories of analogies (personal, nature, fantastic, etc.).

fig. 2.29
Example of an analogy; King Fisher and Shinkansen Bullit Train

- Ask yourself questions in order to explore the analogy. What type of problems occur in the analogous situation? What type of solutions are there to be found?
- Force-fit various solutions to the reformulated problem statement.
- Generate, collect and record the ideas.
- Test, and evaluate the ideas. Use the itemised response method to select from among the ideas.
- Develop the selected ideas into concepts.
- Present your concepts in a manner that is to the point.

Tips and Concerns

References and Further Reading

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Keywords
Function
Structure
Morphological method

Function Analysis

What Is a Function Analysis?

Function analysis is a method for analysing and developing a function structure. A function structure is an abstract model of the new product, without material features such as shape, dimensions and materials of the parts. It describes the functions of the product and its parts and indicates the mutual relations. The underlying idea is that a function structure may be built up from a limited number of elementary (or general) functions on a high level of abstraction. Functions are abstractions of what a product should do. Being forced to think about the product in an abstract way stimulates creativity, and prevents you from 'jumping to solutions', i.e. immediately elaborating on the first idea that comes to mind, which may not be the best.

In function analysis, the product is considered as a technical-physical system. The product functions, because it consists of a number of parts and components which fulfil subfunctions and the overall function. By choosing the appropriate form and materials, a designer can influence the subfunctions and the overall function. The principle of function analysis is first to specify what the product should do, and then to infer from there what the parts - which are yet to be developed - should do. Function analysis forces designers to distance themselves from known products and components in considering the question: what is the new product intended to do and

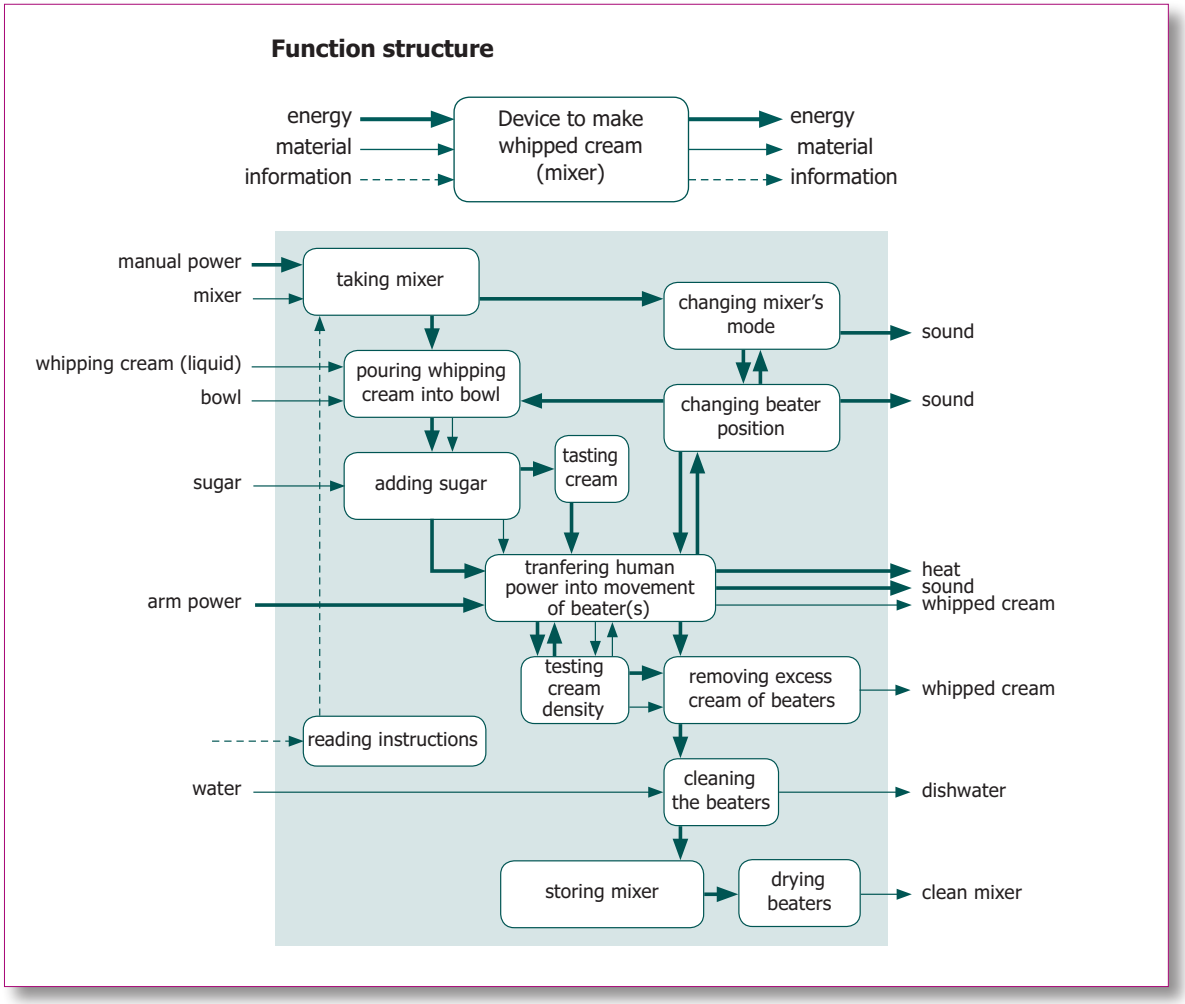


fig. 2.30 Example of the function structure of a 'device to make whipped cream' (mixer) (from student report)

how could it do that? The method is useful to accomplish a breakthrough in thinking in conventional solutions.

A function analysis often precedes the morphological method (see 'Morphological Chart' in this section). The functions and subfunctions that are identified in the function analysis serve as the parameters in the morphological chart.

When Can You Use a Function Analysis?

A function analysis is typically carried out at the beginning of idea generation.

How to Use a Function Analysis?

Starting Points

There are two possible starting points, which may be used in a combined form:

- A process tree, which can be drafted from scratch or based on an existing solution of the design problem (or a comparable problem)
- A collection of elementary (general) functions, for instance the *functional basis* developed by the American National Institute of Standards and Technology (NIST).

Expected Outcome

The outcome of the function analysis is a thorough understanding of the functions and subfunctions that the new product has. From functions and subfunctions the parts and components for the new product can be developed, for instance by using them as input for the creation of a morphological chart.

Possible Procedure

1 Describe the main function of the product in the form of a black box. If you cannot define one main function, go to the next step.

2 Make a list of subfunctions. The use stage of a process tree is a good starting point. By adding extra columns to the process tree in which you distinguish between product functions and user tasks, you can make a first list of functions.

3 Just like the processes in a process tree, functions are based on verb-noun combinations. Only those processes that are carried out by the product are functions; processes performed by the user are user tasks. For user tasks, you can often define functions that support the user in performing the task. For instance, for a user task *lift product* a supporting function would be *provide grip for lifting*

4 For a complex product, you may want to develop a function structure. There are three principles of structuring: putting functions in a chronological order, connecting inputs and outputs of flows between functions (matter, energy and information flows) and hierarchy (main functions, subfunctions, sub-subfunctions, etc.). These principles cannot always be applied - see the last item of Tips and Concerns.

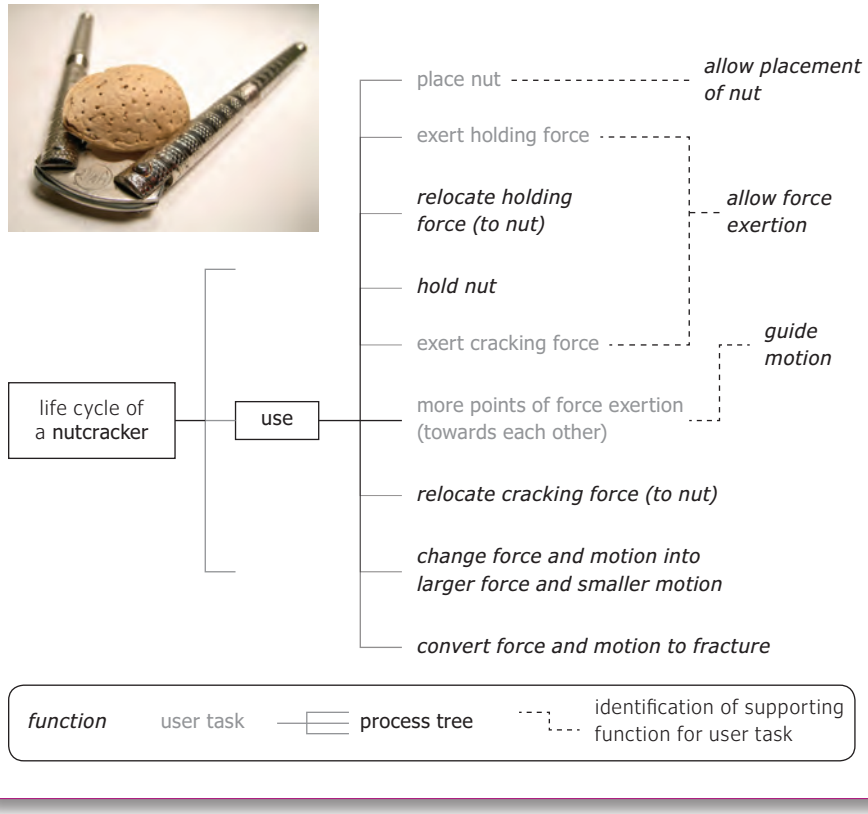


fig. 2.31 Process Tree and elaboration of functions of a nutcracker (from student report)

To visualise the chronological order, you can simply list the functions. To visualise the flows, you can connect boxes by arrows. To visualise hierarchy, you can draw a tree structure (just like the process tree) so that you can combine hierarchy with chronological order, or you can draw boxes-in-boxes, so that you can combine hierarchy and flows in one diagram.

5. Elaborate the function structure. Fit in a number of `auxiliary' functions which were left out and find variations of the function structure so as to find the best function structure. Variation possibilities include moving the system boundary, changing the sequence of subfunctions and splitting or combining functions. Exploring various possibilities is the essence of function analysis: it allows for an exploration and generation of possible solutions to the design problem.

Tips and Concerns

- If you have a function structure, it is recommended you develop variants of it. A statement of a problem never leads imperatively to one particular function structure. The strength of function analysis lies in the possibility of creating and comparing, at an abstract level, alternatives for functions and their structuring.
- Certain subfunctions appear in almost all design problems. Knowledge of the elementary or general functions helps in seeking product-specific functions.
- The development of a function structure is an iterative process. There is nothing against starting by analysing an existing design or with a first outline of an idea for a new solution. However, in the course of the analysis you should abstract from it.
- Function structures should be kept as simple as possible. The integration of various functions into one component (function carrier) is often a useful means in this respect.
- Block diagrams of functions should remain conveniently arranged; use simple and informative symbols. Be aware of different types of functions.
- In industrial design engineering and product design, it is not always possible to apply structuring principles. The principles have their background in mechanical engineering, where functions describe machines processing raw materials in steps to produce products. Don't worry: an unstructured list of (sub)functions is better than no function descriptions at all.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

Cross, N. (1989) *Engineering Design Methods*, Chichester: Wiley.

Morphological Chart

Keywords
Function
Analytica
Morphological method
Combination
Principal solution

What Is a Morphological Chart?

The morphological chart (see figure 2.32) is a method to generate ideas in an analytical and systematic manner.

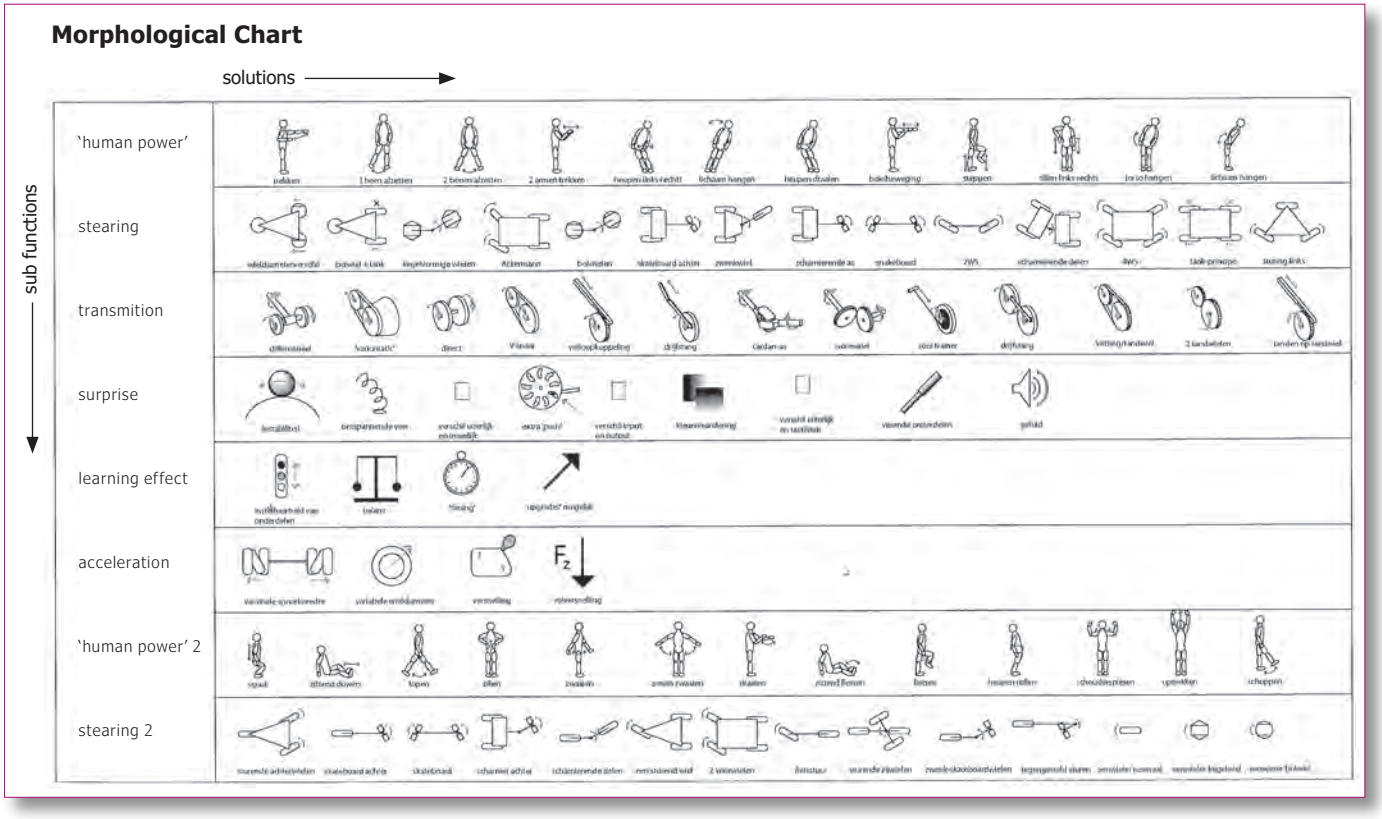
Usually, functions of the product are taken as a starting point. The various functions and subfunctions of a product can be established through a function analysis (see 'Function Analysis' in this section).

However, function analysis does not guarantee that all the relevant (sub) functions are identified. Often a number of solutions to these (sub) functions are already known, while others are thought up by yourself. These solutions will form the components in the morphological chart. The morphological method thus yields a matrix of functions and components. Possible components are listed on the basis of their functions. The components are concrete and specific, specifying the elements that belong to a category (i.e. parameter). These components are already known partially from existing solutions: analogous products. Functions are listed in columns, and components are the means that realise the functions and are listed in rows.

The parameters are identified by focusing on the commonalities of components, and describing them as the characteristics which a product should have, thus indicating what the product should be; they are essential to the solution. The parameters are independent and abstract, and indicate a category (with no reference to material features).

By means of the morphological chart, the product's purpose is split into a set of (sub)functions. For each of the (sub)functions ideas are generated and combined into an overall solution. Through careful selection and combination of a set of components, an idea comes about. This idea should be seen as a principal solution: a carefully chosen combination of components that together form a conceptual solution.

fig. 2.32 Example of a Morphological Chart (from student report)



New components are found by making the abstract parameters concrete through the establishment of technical principles. In this way, the morphological method is an evolutionary method: parameters and components are evolved in parallel until the final morphological chart is made.

In the end, solution principles are found by choosing one component from each parameter. In other words, each combination of components (one component being selected from each parameter) suggests a solution to the problem. The generation of solutions is thus a process of systematically combining components.
However, the larger the morphological matrix, the larger the amount of possible solutions (theoretically, a 10 x 10 matrix yields 10,000,000,000 solutions), which takes much time to evaluate and choose from. In order to limit the number of options, two evaluation strategies are helpful: (a) analysis of the rows and (b) grouping of parameters.

a Analysis of the rows is based on rank ordering the components per parameter in a first and second preference. The rank ordering is done against (a part of) the criteria or design requirements. Using only the first and second preferences brings down the number of components and thus reduces the number of solutions.
b The second evaluation strategy is grouping the parameters in groups of decreasing importance. As a first step, only the most important group of parameters is evaluated. After one or more combinations of components have been chosen, only these are involved in the evaluation.

When Can You Use a Morphological Chart?

The morphological chart is usually applied in the beginning of idea generation. Function analysis is used as a starting point. Not all design problems are suitable for using the morphological method. The morphological chart has been successful in particular for design problems in the field of engineering design.

How to Use a Morphological Chart?

Starting Point

The starting point of a morphological chart is a well-defined design problem. A function analysis of the product that needs to be designed forms another starting point: the product should be described in terms of function and subfunctions.

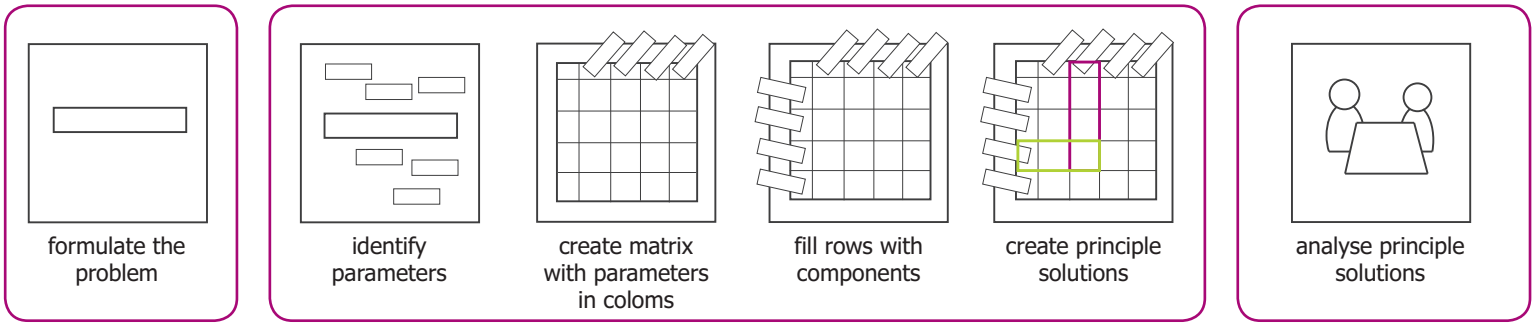
Expected Outcome

The expected outcome of the morphological method is a number of principal solutions (consisting of components) for the initial design problem.

Possible Procedure

1 The problem to be solved must be formulated as accurately as possible.
2 Identify all the parameters which might occur in the solution (i.e. functions and subfunctions).
3 Construct a morphological chart (a matrix), with parameters as the columns.

How to
Morphological Chart



4 Fill the rows with the components that belong to that particular parameter. Components can be found by analysing similar products or thinking up new principles for the parameters (functions).
5 Use the evaluation strategies (analysis of rows and grouping of parameters) to limit the number of principal solutions.
6 Create principal solutions by combining at least one component from each parameter.
7 Carefully analyse and evaluate all solutions with regard to (a part of) the criteria (design requirements), and choose a limited number of principal solutions (at least 3).
8 The principal solutions selected can be developed in detail in the remaining part of the design process.

Tips and Concerns

- When a combination of components has yielded a principal solution, be sure to draw all the components when developing the solution principle in sketches.
- You may be tempted to choose the 'safe' combinations of components. Challenge yourself by making counter-intuitive combinations of components.
- Do not describe the components in words, but use pictograms or symbols to indicate them.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

Cross, N. (1989) *Engineering Design Methods*, Chichester: Wiley.

Role-Playing Techniques

What Are Role-Playing Techniques?

Role-playing techniques (see figure 2.33) can help in developing and determining the interaction between user and product. In a role-playing technique, designers perform the tasks of the interaction by means of re-enactment. Role-playing is just like theatre acting: by acting out the tasks the user has to perform, you reach a better understanding of the complexity is reached, and different ideas for the interaction can be developed. One of the major advantages of using role-playing is that the entire body is used; this is more like real interaction as compared to using storyboards or scenarios. With role-playing techniques the tangibility of the interaction can be explored, as well as the appearance and attractiveness of elegant movements. Also, by role-playing you can simulate an interaction walk-through. Role-playing is usually captured using photography or video.

When Can You Use Role-playing Techniques?

Role-playing can be used throughout the design process, for developing ideas about the interaction with a product idea.

How to use Role-Playing Techniques?

Starting Point

Role-playing starts with a first idea about the interaction between product and user.

Expected Outcome

The outcome of using role-playing techniques is a good conceptual idea about the interaction, as well as visualisations or written descriptions of the interaction. Both visualisations and written descriptions can be used for communication and evaluation purposes.

fig. 2.33 Examples of Role-playing techniques using props (from student report)

Possible Procedure

1. Determine the actors and the goal of the actor or the interaction.
2. Determine what you want to portray in the role-playing technique. Determine the sequence of steps (this is not the final sequence).
3. Make sure that you record the role-playing.
4. Divide the roles amongst the team members.
5. Play the interaction, improvise. Be expressive in your movements. Think aloud when enacting motivations.
6. Repeat the role-playing several times until different sequences have been enacted.
7. Analyse the recordings: pay attention to the sequences of tasks, motivations and factors that could influence the interaction.

Tips and Concerns

- Comics and movies can be a great source of expressive techniques. Some of these can be applied to product design scenarios and storyboards, whereas others are less suitable. Think about camera position (close-up versus overview), sequence and the style in which you visualise the storyboards.

References and Further Reading

Jacko, J., et al. (2002) T*he Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, New York: Erlbaum and Associates.

Storyboard

What is a Storyboard?

A storyboard (see figure 2.34) is a valuable aid to the designer, because it provides a visual description of the use of a product that people from different backgrounds can 'read' and understand. A storyboard not only helps the product designer to get a grip on user groups, context, product use and timing, but also to communicate about these aspects with all the people involved. With a storyboard the powerful aspects of visualisation are exploited. At a glance the whole setting can be shown: where and when the interaction happens, the actions that take place, how the product is used, and how it behaves, and the lifestyle, motivations and goals of the users. Storyboards allow you to literally point at elements, which helps during the discussion.

However, the visualisation style of the storyboards influences the reactions, e.g. open and sketchy storyboards elicit comments, sleek and detailed presentations can be overwhelming. Storyboards used for analytical purposes, to map situations, problems and feelings, typically have a factual style of visualisation. Storyboards used to conceptualise ideas have a rough visualisation style. Storyboards used to evaluate design ideas are often open, bringing together different points of view. They have a sketchy, incomplete style of visualisation in order to invite reactions. Storyboards intended to transfer or present concepts often look polished.

When Can You Use a Storyboard?

Storyboards can be used throughout the entire design process, from ideas about the interaction with a product to ideas and concepts and also for product concept evaluations (see for example 'Product Usibility Evaluation' in section 2.4).

How to Develop a Storyboard?

Starting Point

Used as a tool for developing ideas, a storyboard starts with a first idea about the interaction between product and user.

fig. 2.34 Example of a Storyboard (from student report)

Expected Outcome

The outcome of a storyboard is a good conceptual idea about the interaction, as well as visualisations or written descriptions of the interaction. Both visualisations and written descriptions can be used for communication and evaluation purposes.

Possible Procedure

1. Start from the following ingredients: ideas, simulations, a user character.
2. Choose a story and a message: what do you want the storyboard to express? Limit your story to a clear message (e.g. 12 panels).
3. Create sketchy storylines. Don't build the story one panel at a time. Design the time line before detailing. Use variations in panel sizes, white space, frames, captions, for emphasis and expression.
4. Create a complete storyboard. Use short captions to complement (not repeat) the images. Don't make all the panels the same: use emphasis.

Tips and Concerns

- Comics and movies are a great source of expressive techniques. Some of these can be applied to product design scenarios and storyboards, whereas others are less suitable. Think about camera position (close-up versus overview), sequence and the style in which you visualise the storyboards.

References and Further Reading

Stappers, P.J. (2004) 'Storyboarding', *In*: Stappers, P.J., (August 2004) *Context and Conceptualisation*.

Jacko, J., et al. (2002) *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications,* New York: Erlbaum and Associates.

Written Scenario

What is a Written Scenario?

To write a scenario (or story), you need a basic understanding of the tasks to be performed by the user. You also need to have an understanding of the users and the context of use. Scenarios can be derived from data gathered during contextual enquiry activities.

In simple language describe the interaction that needs to take place. It is important to avoid references to technology. You should also have the scenario reviewed by users to ensure that it is representative of the real world. Use scenarios during design to ensure that all participants understand and agree to the design parameters, and to specify exactly what interactions the system must support.

When Can You Use a Written Scenario?

A written scenario can be used throughout the design process, for developing ideas about the interaction with a product idea. Scenarios can also be used for presenting ideas and concepts, and are used in product concept evaluations and product usability evaluations (see 'Product Usibility Evaluation' in section 2.4).

How to Use a Written Scenario?

Starting Point

Used as a tool for developing ideas, a written scenario starts with a first idea about the interaction between product and user.

Expected Outcome

The outcome of using a written scenario, is a good conceptual idea about the interaction. Written descriptions can be used for communication and evaluation purposes.

Possible Procedure

1. Determine the actors. The actor has an active role in the scenario. In case of several actors, more scenarios should be set up.
2. Determine the goals the actor has to complete.
3. Determine a starting point of the scenario: a trigger or an event.
4. Identify stakeholders and their interests.
5. Determine the number of scenarios that you will create, based on the number of actors and their goals.
6. Write the scenario. Work from starting point towards completing the actors' goals. Be specific about tasks, subtasks, context and the actors' motivations to complete the goals.

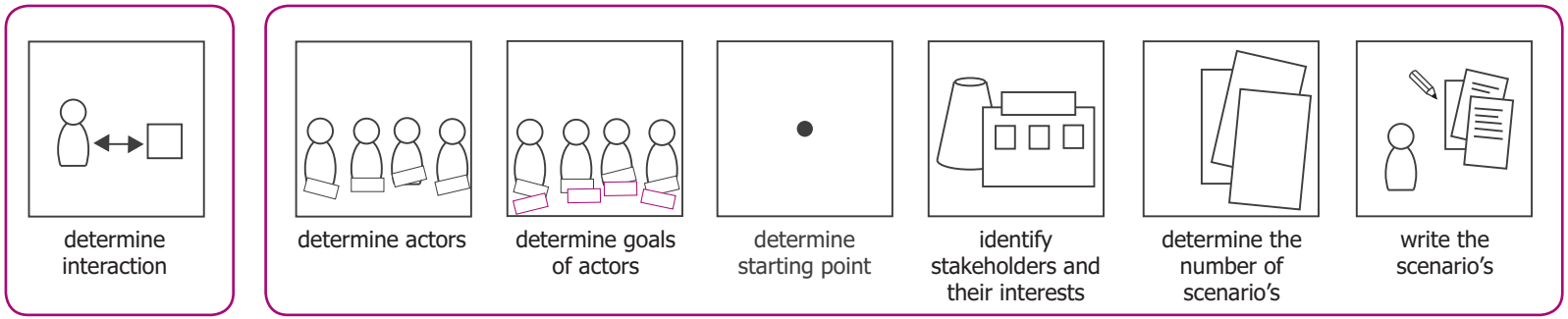
Tips and Concerns

- Comics and movies are a great source of expressive techniques. Some of these can be applied to product use scenarios.

References and Further Reading

Jacko, J., et al. (2002) *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications*, New York: Erlbaum and Associates.

How to
Written Scenario



Keyword SCAMPER

Checklist for Concept Generation

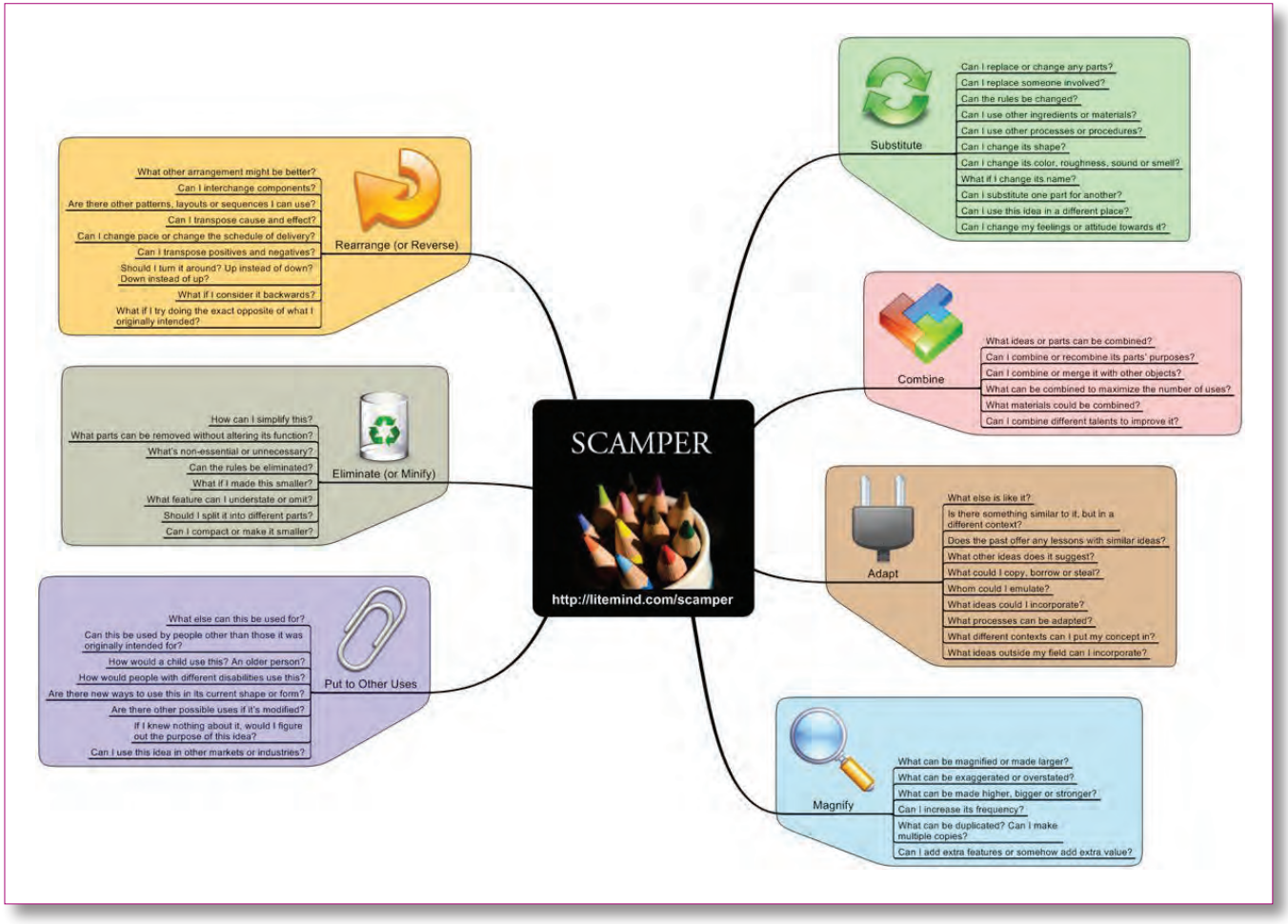
What Is a Checklist for Concept Generation?

Checklists for Concept Generation are simple tools that support concept generation. Checklists are series of simple questions, which can be used either individually or in groups (see also 'Design Specifications (Criteria)' in section 2.1). The checklist aims to encourage a systematic development of concepts. Also, the use of checklists encourages creativity and divergence in concept generation.

The questions in a checklist need a point of focus, which could either be an existing solution or proposed concepts to a design problem. The questions should be taken one at a time, to explore new ways and approaches to the problem. You can also use the checklists in a brainstorm session, where it can be useful to write each statement on a card, and randomly select a card when discussing alternative solutions.

Two widely used checklists for concept development are the SCAMPER technique and Osborn's Checklist. The SCAMPER technique was created by Bob Eberle and written about by Michael Michalko in his book Thinkertoys. SCAMPER is the acronym of: Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate and Rearrange. The SCAMPER technique is derived from Osborn's Checklist, which consists of: put to other uses?, adapt?, modify?, magnify?, minify?, substitute?, rearrange?, and reverse?

fig. 2.35 Checklist for Concept Generation
http://mappio.com/mindmap/lucianop/creative-problem-solving-with-scamper



When Can You Use a Checklist for Concept Generation?

The checklist for Concept Generation is best applied when developing an idea into a concept. As stated earlier, the technique needs a point of focus. This point of focus should be a product idea, already with material features, shape and dimensions.

How to Use a Checklist for Concept Generation?

Starting Point

The starting point of checklists for concept generation is a well-defined product idea, or an existing product.

Expected Outcome

The expected outcome is a product concept which is developed further than just its initial idea state.

Possible Procedure

- Define a product idea in detail, including material features such as shape, dimensions etc.
- Search for and select a checklist for concept development. Use more than one checklist.
- Systematically work through the checklist by answering the questions in the checklist. Note: this is a trial-and-error process; apply the question to the product idea and verify whether the product idea is improved. If not, try something else.
- Iteratively, improve your idea by answering the questions in the checklist over and over again.
- Present your developed idea in an explanatory sketch.

Tips and Concerns

- Checklists can be used to support group creativity and discussion, and can be referred to individually.
- Use more than one checklist; try to find more checklists yourself.

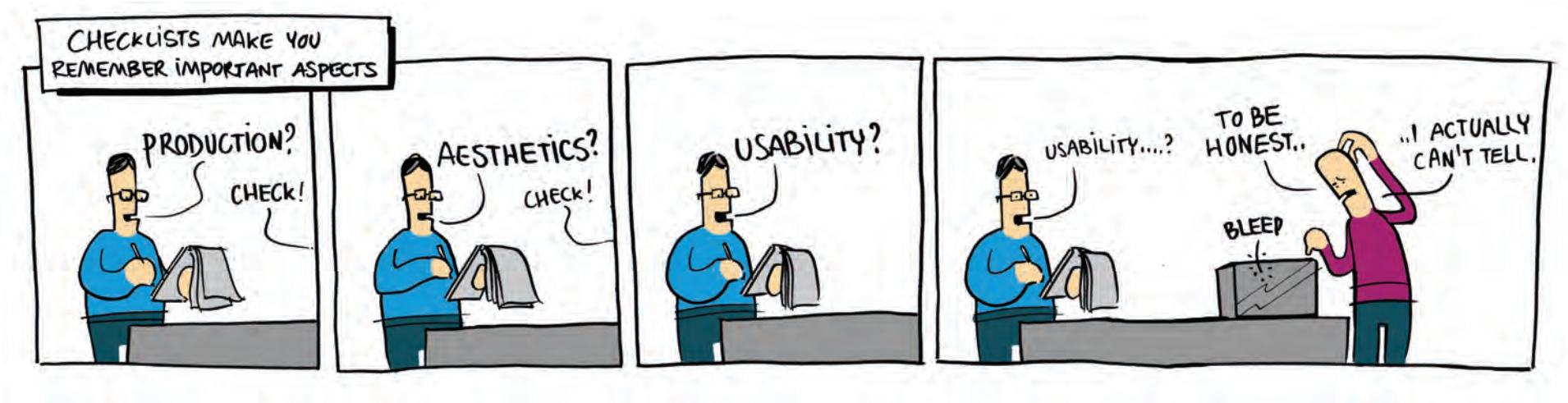
References and Further Reading

Osborn, A. (1957) *Applied Imagination: Principles and Procedures of Creative Problem-solving*, New York: Scribner.

Michalko, M. (1991) *Thinkertoys: a Handbook of Business Creativity*, Berkeley: Ten Speed Press.

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.



Keywords
Idea generation
Concept generation,
Sketch,
Drawing
Presentation
Detail

Design Drawing

When you enter a design studio you will find out that drawing by hand is an integral part of the decision-making process, used in the early stages of design, in brainstorm sessions, in the phase of researching and exploring concepts, and in presentation. Drawing has proved to be a versatile and powerful tool for exploring and for communicating. (see: Sketching, Eissen 2007).

Exploring

Explorative drawing enables the designer to analyse visually and to generate and evaluate ideas throughout the entire product design cycle, and especially in the synthesis phase (see section 1.3 - The Basic Design cycle).
That also includes:

- Analysing and exploring the perimeters of the problem definition
- Using drawings as a starting point for new ideas, by means of association
- Exploring shapes and their meaning, function and aesthetics
- Analysing and structuring principle solutions and visualising structural and formal concepts (see section 1.5 - The Fish Trap Model).

Hand drawing is also beneficial to the development of the designer's visual perception, his or her imaginative capacities and perceptiveness of form in general.

Communicating

Next to verbal explanation, a designer also uses drawing to interact and communicate with several groups of people, with different levels of understanding of professional jargon:

- Fellow-designers or team members
- Model makers
- Marketing managers
- Clients and contractors
- Public offices.

Effective Drawings

The significance of a drawing depends on the context in which it is made. A drawing serves its purpose when it is efficient. Therefore a certain phase in the design process may require a certain type of drawing. Time is an issue and in many cases, a quick, suggestive sketch is preferable to a more time-consuming rendering.

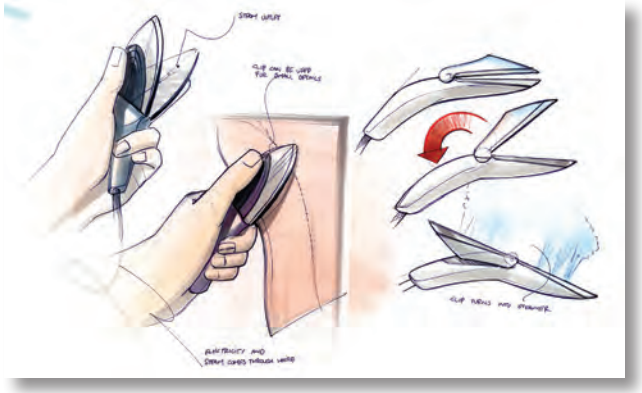


fig. 2.36

For generating and evaluating ideas, hand drawing is more versatile than CAD rendering and prototyping. A rendering can look very definite and unchangeable, which is not appropriate, for example, when a studio is still conferring with its client about design directions and possibilities.
A (brainstorm) sketch can also easily be upgraded into a more presentable drawing, on paper or digitally by using a tablet and e.g. Adobe Photoshop or Corel Painter.

Early Phase

In the early phase of the design process, drawing tends to be simple: basic shapes or configurations, (grey) shading and casting shadows (figure 2.37). This kind of drawing incorporates the basic skills and rules of perspective, construction of 3D shapes, shading and constructing cast shadows (figure 2.38). Colour is not always used and very often this kind of drawing will suffice for idea sketching or structural concepts (fig. 2.38, and see section 1.6 - The Fish Trap Model).

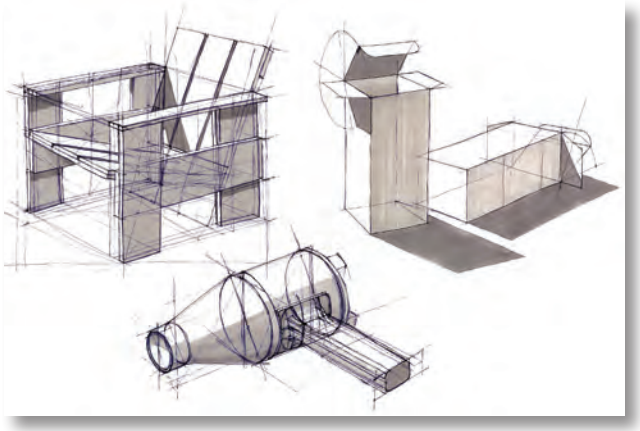


fig. 2.37

fig. 2.38

fig. 2.39

fig. 2.40

Preliminary Concept Sketching

When several ideas are combined to develop preliminary concepts, the designer has a general idea about the materials being used, the shape, its function and how it is manufactured. Colour and expression of the materials (e.g. matt or reflective plastic) become more important and drawings become more elaborate. (figure 2.39) Side-view sketching can be a quick and easier way of making variations in shape, colour, details, etc. (figure 2.40).

Mixed Media

With a PC and tablet the designer can easily adjust colour and shading in the (scanned) drawing and add textures or the brand name.
Computer sketching also has some advantages. It can speed up the drawing and enhance the designer's eye-hand coordination and muscular movement. A relatively new explorative medium in generating ideas is called Intuitive Sketching (van den Herik and Eissen, 2005). This method uses a simple doodle as a starting point (figure 2.41), as a means to break free from conditioning, to express feeling without hindrance, and to expand your visual language.

fig. 2.41

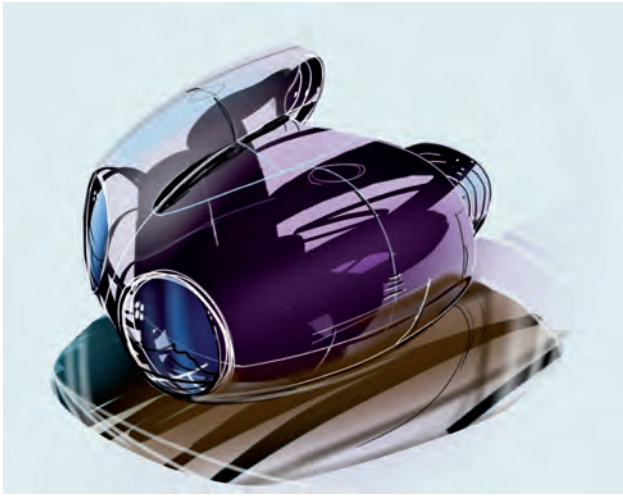


fig. 2.42a

fig. 2.42b

References and Further Reading

Eissen, J.J., van Kuijk, E. and de Wolf, P. (1984) *Produkt Presentatietechnieken*, Delft: DUP.

Eissen, J.J. and Steur, R. (2007) *Sketching: Drawing Techniques for Product Designers*, BIS Publishers.

van den Herik, Y. and Eissen J.J. (2005) Intuitive sketching: a new and explorative medium in generating ideas, CAID&CD' Delft 2005: *applications of digital techniques in industrial design engineering.* pp. 708-713. Beijing: International Academic Publishers

http://www.sketching.nl/ (retrieved May 2009).

see also www.designdrawing.io.tudelft.nl

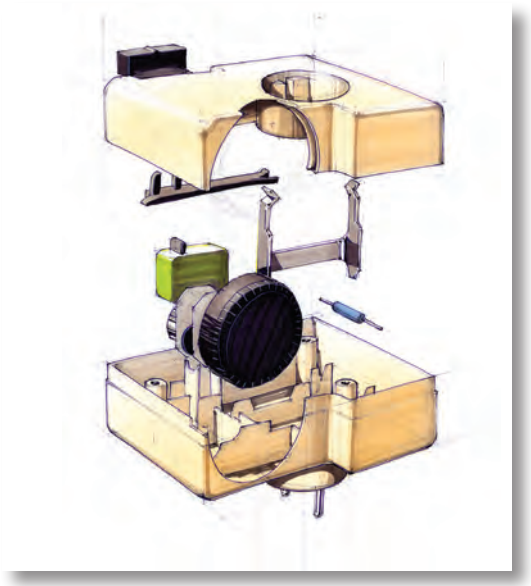


fig. 2.43

By combining or integrating several drawings with other types of images (figure 2.42a and b), layers of information can be presented in a coherent way and a suitable context can be provided: the meaning of the product, user environment, etc.

Material Concept Sketching or Preliminary Design

When concepts become definitive, when you want to explore or explain how different manufactured parts are assembled, or when you are communicating with an engineer, choosing an exploded view is effective (figure 2.43). Side-view drawings for exact dimensions, detail drawings, 'ghost' view or shaded cross-sections can also be very useful in communication. Drawings of user interaction can serve to get feedback from users, prior to the testing of prototypes (figure 2.44).

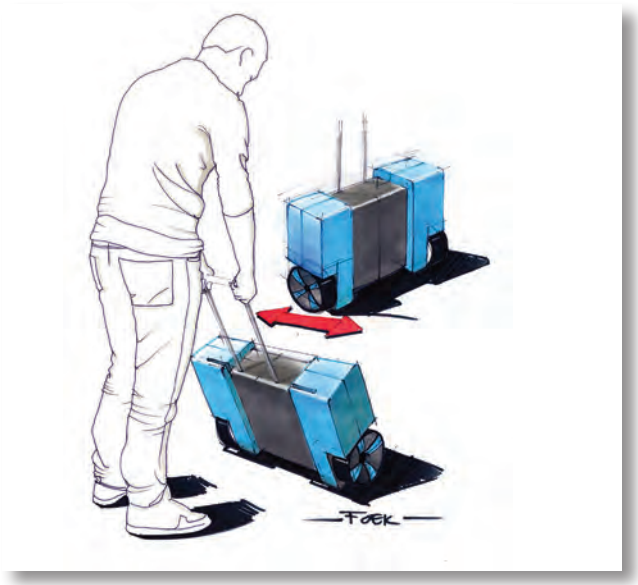
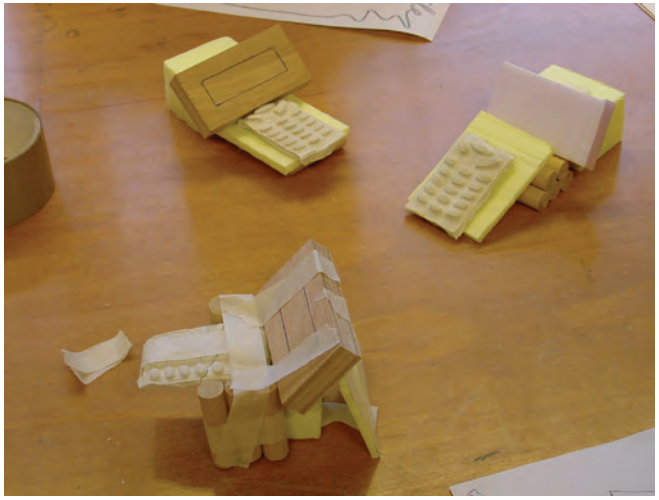


fig. 2.44

Three-dimensional Models

Watch interview with Bruno Ninaber van Eyben (studio Ninaber) via the OpenCourseWare version of this guide: http://ocw.tudelft.nl

fig. 2.45 Sketch Model



What Are Three-dimensional Models?

A three-dimensional model is a physical manifestation of a product idea. It is a hand-built physical model that represents a mass-manufactured product. In the design process, three-dimensional models are used to express, visualise and materialise product ideas and concepts. Three-dimensional models are also called prototypes: the word prototype comes from the Latin words proto, meaning original, and typus, meaning form or model. Thus, a prototype is an original form, a first-of-its-kind model.

Prototypes offer more than drawings. Prototypes are tangible, three-dimensional forms; they can be picked up, turned over and looked at from different points of view as opposed to drawings. With prototypes, tests and measurements can be carried out to verify whether a particular solution or solution principle works. And prototypes are effective tools to communicate product ideas and concepts. Building prototypes is a form of visualising the final product form. It is a technique just like sketching, making final drawings, photography or filming. In that sense, prototypes are tools that serve the design process. More specifically, prototypes serve the form-giving process in designing.
In the practice of design, prototypes are used as important steps in the product development process. Prototypes serve the industry to test product aspects, change constructions and details, and to reach consensus within the company on the final form.

In mass production, prototypes are also used to test functionality and ergonomics. Changes that need to be made after the production preparation are often expensive and time-consuming. The final prototype thus serves for the preparation and planning of production. The first phase in the production process is called the null series: these first products (still a sort of prototypes) are used to test the production process.

Prototypes are used in the generation of ideas and concepts for three reasons:

1 Generating and developing ideas and concepts
2 Communicating ideas and concepts in design teams
3 Testing and verifying ideas, concepts and solution principles.

Prototypes for Generating and Developing Ideas and Concept

Sketch models (see figure 2.45) are kinds of prototypes that are used frequently in the phase of generating ideas and concepts. Simple materials are used, such as paper, cardboard, foam, wood, adhesives, wire and solder. Sketch models are tools that are used to visualise early ideas and to develop those early ideas into better ideas and concepts.

Often you see an iterative process between sketching, making sketch models, drawing, and making a second generation of sketch models.

fig. 2.46 Proof-of-concept model or FUMO

fig. 2.47 Dummy (mock-up or VISO)

fig. 2.48 Final prototype

Proof-of-concept prototypes (see figure 2.46) are used to verify whether certain technical principles actually work. Materials such as technical Lego, Meccano or Fisher Techniek (prototype material) can be used. Proof-of-concept prototypes are simplifications; often details are left out, and only rudimentary forms and working principles are built. Proof-of-concept prototypes are also called FUMO's: Functional Models. Based on the moment in the idea generation phase, the level of detail is determined and the choice of materials. In the beginning of idea generation, prototypes are often built of paper, cardboard and foam. At the end of idea generation, prototypes of the concepts are made of foam, wood and metal.

A dummy (mock-up) (see figure 2.47) is a 1:1 scale model of the product idea. A dummy is a prototype that only has the external characteristics of the product idea, and not the technical working principles. It is often built at the end of the idea generation, to visualise and present final concepts. A dummy is also called a VISO: a Visual Model.

A detailed model is used in the concept generation phase to show particular details of the concept. A detailed model is much like a dummy; both are 1:1 scale models with predominantly external characteristics of high quality. A detailed model can also have some limited functionality.

A final model (see figure 2.48) often concludes the concept generation phase. The final model is a prototype that has a high-quality look, built of wood, metal or plastic, with real buttons and high-quality paint or finishing. The final model might also include some of the technical working principles.

Prototyping to Communicate Ideas and Concept in Design Teams

Prototypes are effective tools for communication purposes. When working in a team, prototypes help in building a shared understanding of the design problem and the solutions (ideas and concepts). Sketch models with increasing levels of detail help the development of product ideas and concepts within the team.

For the communication of ideas to parties outside the design process (for example stakeholders involved), prototypes are also a powerful tool. Often a dummy or a final model is used to present a product idea or product concept. Knowing the audience to whom you are presenting is important, though, in order to present an appropriate prototype built from the right materials and with the right techniques.

fig. 2.49 Model to test use

Prototyping to Test and Verify Ideas, Concept and Solution Principles

Prototypes also serve the purpose of testing and verifying ideas, concept or solution principles. (See figure 2.49, also see 'Evaluation of Product Features' in section 2.4).

There are generally three types of tests for which prototypes are used:

1. Testing technical – functional characteristics of a product idea. Often a sketch model is used with some working functionality, or functioning technical principle, based on the goals of the test.
2. Testing form characteristics. Often a detailed model is used for judging user preference.
3. Testing usability characteristics. Often a final, working model is used for testing the intended usability of a product concept.

When Can You Use Three-dimensional Models?

Prototypes can be used throughout the conceptual design process. In the beginning of idea generation, various types of sketch models are used. During idea generation a dummy or detailed models are used, and the concept generation phase is often concluded with a final model.

How to Use Three-dimensional Models?

Starting Point

The starting point of building models can be a (mental) sketch of a product idea (sketch model) or detailed drawings and a building plan (final model).

Expected Outcome

The outcome of building models are three-dimensional, tangible models of an idea, concept or solution principle.

Possible Procedure

1 Three-dimensional model building starts with some notion of an idea, concept or solution principle.

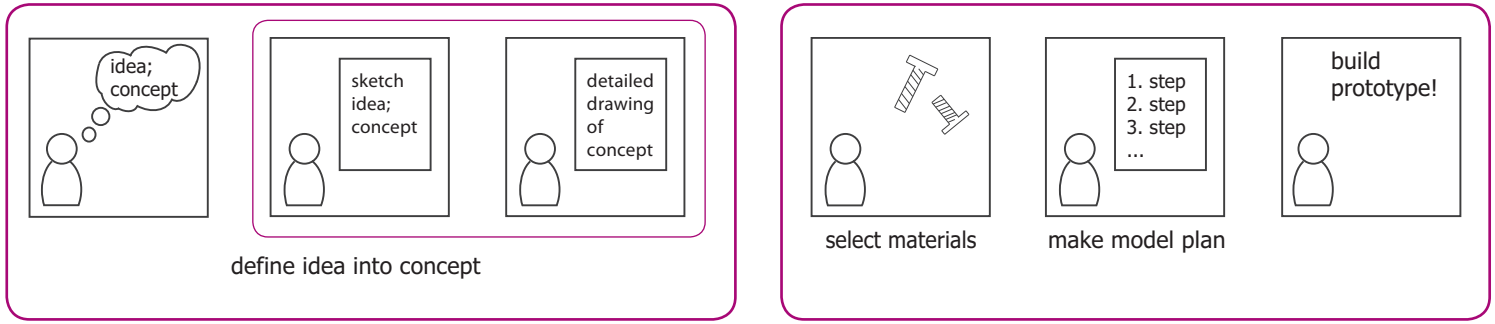
2 Based on the purpose of the model, some level of detail has to be determined prior to collecting materials, devising a plan and building the model. Simple sketch models at the beginning of idea generation only require a simple sketch, while final models (final prototypes) require a detailed plan of how to build the model.

3 Collect the appropriate materials, such as paper, cardboard, wood, foam, adhesives, plastics, metals, wire, and paint.

4 Devise a plan for building the model. For a simple sketch model, early idea sketches are often enough. Detailed or final prototypes usually require detailed drawing including dimensions.

5 Build the prototype (see figure 2.45).

How to
Three-dimensional Models



Tips and Tricks

- Look for examples of what different sketch models can look like. Sketch models as simple as paper and glue are often very helpful in the beginning of the idea generation. Try this yourself!
- Many examples can be found of final models, or detailed models.
- Use the expertise of the people working in model workshops.
- Select your tools for model making well

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

fig. 2.50 Select your tools for model making well

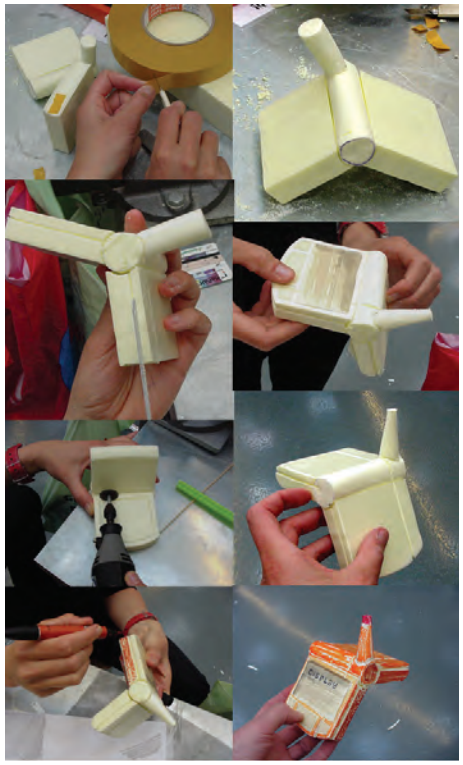


fig. 2.51 Building a model of foam

Biomimicry [1]

1 This chapter was written by McCauley Wanner

Keywords
Inspiration
Sustainability
Natural processes

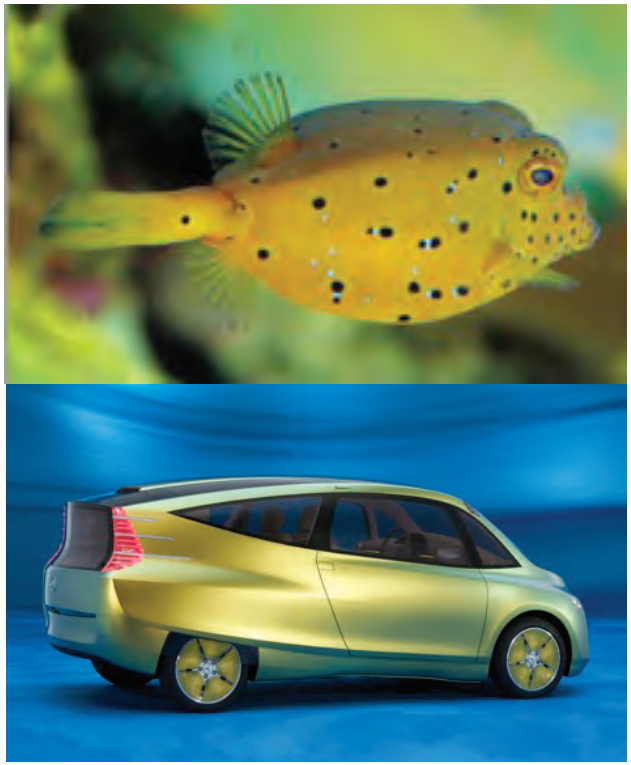


fig. 2.52 Example of Biomimicry; Mercedez-Benz concept car inspired by a boxfisch

What Is Biomimicry?

Biomimicry takes its inspiration from natural processes. It is an approach that searches for new ways of creating sustainable materials, products, services, and other solutions by learning how nature already works.
The Design Spiral, developed by the Biomimicry Guild (www.biomimicryguild.com), represents a design process from a biomimetic perspective.

As designers we have the job of coming up with new ideas and products in order to fulfil a particular need or function. What we have just recently begun to realise is that nature has already perfected and come up with all the answers. For as long as man has been on the earth, we have tried to figure out how to survive, using materials and different products to make our lives easier. However, we have never cared to understand that somewhere in nature something is doing it, making it, disposing it much better and more efficiently than we ever could. Nature has mastered productivity and disposal and figured out what works and does not in order to survive together in the most harmonious way. Biomimicry is just that. It takes the lessons and processes from nature in order to make the most efficient, sustainable, functional and aesthetically beautiful products. In other words, biomimicry references nature in order to design things that just seem to make sense.

A common example used to explain the current studies happening in biomimetic design is the Mercedes-Benz concept car. In order to make an efficient, safe and spacious vehicle, the company has come up with an idea that looks at the structure of the boxfish. Because of its large body shape and ability to swim extremely fast, researchers wanted to discover how to diffuse these lessons into a car design. This design proved to be successful in efficiency and drag tests, although the form remains outlandish for the probable consumers.

When Can You Use the Biomimicry Design Spiral?

The Design Spiral (figure 2.46) can be used from the concept generation stage to the detailed design stage. The Design Spiral is not terribly different from the process that you already engage in when designing. The Spiral expands the design brief through translation into similar biological processes.

How to Use the Biomimicry Design Spiral?

The Biomimicry Design Spiral in fig. 2.53 (on the next page) shows a step by step approach.

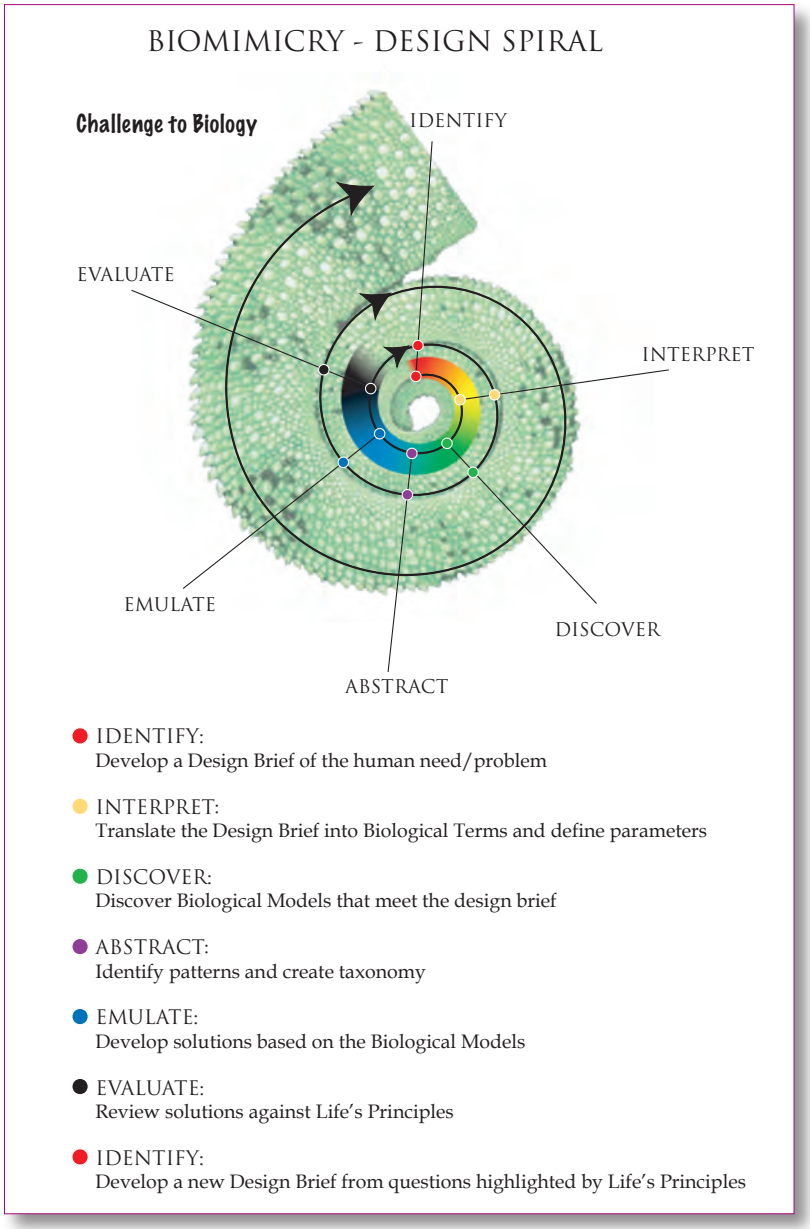


fig. 2.53 Biomimicry Design Spiral, developed by Carl Hastrich (www.biomimicryinstiture.org)

Tips and Concerns

- Biomimicry does not offer much guidance in terms of social or financial sustainability. It is primarily focused on environmental impacts.
- Using a biomimicry approach may lead you into unknown territory. You may have to do some serious research to find promising natural principles for your design problem.

References and Further Reading

Benyus, J. (1998), 'Biomimicry, Innovation inspired by Nature'.

http://www.biomimicryinstitute.org/

Contextmapping

What Is Contextmapping?

Contextmapping is a user-centred design technique that involves the user as 'expert of his or her experience'. By providing the user with design tools and approaches, he or she can express a particular experience.

In the past decades, the role of researcher within design has grown considerably. Previously designers could focus on the product with its additional inner technology, whilst these days design often begins with a thorough understanding of the user and the usability context such as the what, where, how, when, with whom etc, which surround the interaction between user and product.

The term *context* is defined as the context in which the product is used. All the factors that influence the experience of product use, such as: social, cultural, physical aspects as well as goals, needs, emotions and practical matters.

The term *contextmap* indicates that the acquired information should work as a guiding map for the design team. It helps the designers find their way, structure their insights, recognise dangers and opportunities. The contextmap is meant to be regarded as an inspiration, not a validation.

When Can You Use Contextmapping?

A Contextmapping study should help designers to understand the user's perspective and to translate the user's experience into a desirable design solution.

To design desired (product) solutions, designers create a vision for future use, which pays special attention to the deeper layers of meaning. These layers are expected to be valid in the long term and can be attained by calling up memories from the past.

How Can You Use Contextmapping?

Step 1: Preparing

- Determine what you want to learn
- Determine the topic of study
- Define the scope around the focus that is to be explored
- Capture your preconceptions in a Mind Map
- Start selecting participants in time
- Make a planning
- Conduct preliminary research (first interviews, study background literature)
- Design expressive tools such as workbooks or probes.

Step 2: Sensitising

Some time before the session, users receive a sensitising package, which helps them to observe their own lives and reflect on their experiences of the study topic. It can consist of various elements derived from cultural probe packages, such as an exercise book, postcard assignments, fill-in maps and cameras. Here are some tips:

- Make it personal but well cared for
- Make it inviting and playful
- Always conduct pilot tests before creating your materials

fig.2.54 Example of a sensitizing package

- Invite the user to extend rather than answer
- Meet your participants in person.
  The sensitising process takes about a week. The user is encouraged to spread the assignment throughout the week, which gives him or her the opportunity to generate memories and associations and sharpen their sensitivity to the topic.

Step 3: Meeting

After the sensitising step, the researcher and user meet. This can be in a group session with typically up to six users, or an interview at the user's home or work location, whereby one of the researchers facilitates the process and the other makes notes and observes. In the session a number of exercises are done to gradually deepen the insight into the topic. Here are some tips:

- Record it on video if possible
- Write down your impressions immediately afterwards

Facilitating

- Instruction: 'you are the expert of your experience', 'anything goes', 'respect each others' stories'
- Ask questions like 'how do you feel about it?', 'what does it mean to you?'

Exercise

- Use diverse images and words (nature, people, interactions) 80-90 words/ pictures often work well
- Select ambiguous pictures
- Balance between positive and negative emotions
- Invite
- Don't make it too beautiful.

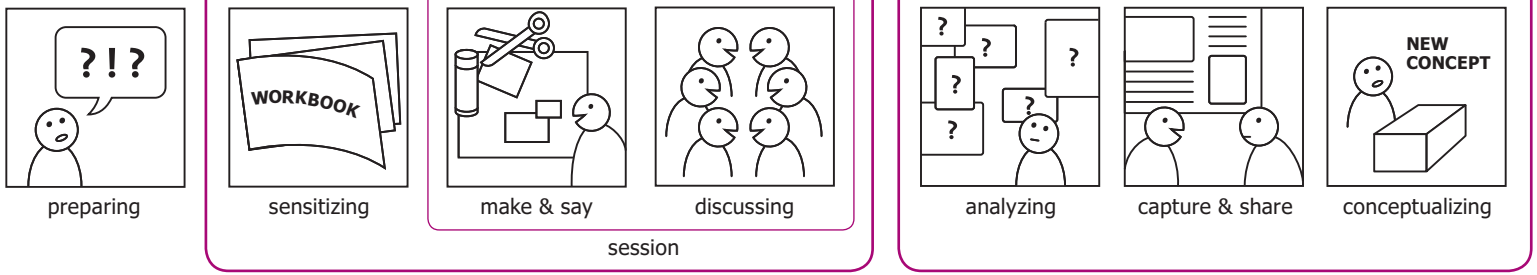
fig. 2.55 Users create expressions of their experience, which are presented to - and discussed with their peers

fig. 2.56 Analysing; Selecting and interpreting chunks of data, often a group activity

Step 4: Analysing

Sessions and workbooks provide large amounts of data, which must be interpreted to find patterns and possible directions. The data contain photographs and workbooks that participants have made, expressive artefacts from the session and often a video recording and full-text transcript from the session. Quotes are selected from the transcript, interpreted and organised. On the basis of the first impression, a qualitative analysis is performed.

How to
Contextmapping



Researchers sift through the material, make selections and interpretations and try to find patterns of similarities and differences.

The researcher typically creates a rich visual environment of interpretations and categories which he or she then analyses. Here are some tips:

- Immerse yourself in the data
- Clarify your interpretations
- Give it some time
- Do it together (triangulate)
- Be surprised
- Find patterns.

Step 5: Communicating

In practice, designers often do not meet the users. Therefore the researchers have to translate the 'user experience' to the designer and convey the user's perspective, needs and values. Here are some tips:

- Do a workshop
- Sensitise the designers

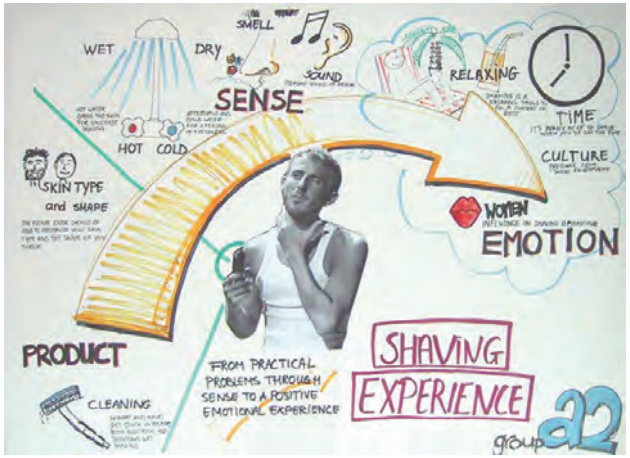


fig. 2.57 Example of an Infographic; to communicate insights

- Leave room for users' own interpretations
- Make it personal
- Show that your contact was real
- Show real people
- Combine raw data with interpretations
- Combine results with other (market) research results.

Watch interview with Sanne Kistemaker (Muzus) via the OpenCourseWare version of this guide: http://ocw.tudelft.nl

Step 6: Conceptualising and beyond

Communications often serve to improve idea generation, concept development and further product development. Users are often highly motivated to look at the results again and can build on the knowledge they generated many weeks after the original study. In the meantime they often have become aware of the new insights into their experience which they enjoy sharing.

fig. 2.58 'Piece of Family' (graduation project)

Here are some tips:

- Keep user and experience in mind
- Tell stories
- Make storyboards
- Do role-playing.

References and Further Reading

Sleeswijk Visser, F., Stappers, P.J., Lugt van der, R. and Sanders, E.B.-N. (2005) Contextmapping: Experience from Practice, CoDesign, 1(2), pp.119-149.

www.contextmapping.com

http://maketools.com

2.3 Decision and Selection

Design is a process of diverging and converging.
The design of a product grows from a product idea via solution principles, concepts and preliminary designs to a detailed definitive design. Design is also a process of working from a large number of ideas to a single detailed design. Designing without intuitive decisions is inconceivable. But for new, complex or unknown decision problems, intuitive decision-making is not always successful. Decision methods aim to help people in making a decision.
In decision methods, you compare alternatives on predefined criteria. You look at how well an alternative performs 'on the criteria' and assign a value to this performance. By bringing together the totality of the values of each of the criteria, you calculate an overall score of the alternative. Calculating the overall scores of each of the alternatives and comparing the alternatives facilitates a decision-making process. This is what decision methods are about.
The manner in which the overall score of an alternative is calculated is called the value function, or decision rule. However, these functions and rules are full of fallacies and pitfalls. Therefore, in using a certain method, you should really see whether the specific decision problem does indeed answer those assumptions, for only then does it make sense to use this method. Decision methods do not guarantee a sound answer! They are mere aids in the process of coming to a sound and well-considered decision.
The decision-maker should always reflect on the verdicts/decisions reached, bearing in mind the initially stated goals and aims of the projects.

C-Box

Keywords
Clustering
Evaluation
Intuitive
Brainstorm
Idea selection

What Is a C-Box?

We use a C-Box to generate an overview from a multitude of early ideas. The C-Box is a 2 x 2 Matrix. Two axes are determined that represent criteria according to which the ideas are evaluated. In a C-Box usually the criteria 'innovativeness' (for the users) and 'feasibility' are used. A C-Box has four quadrants based on these axes. You are able to judge quickly whether ideas are immediately feasible or not, and whether they are highly innovative or not.
A C-box is commonly used in a brainstorm workshop in order to judge the numerous ideas that are generated in such a workshop. This method also works effectively when you are eager to drop highly innovative ideas. This method could also be seen as a first cluster activity of early ideas. However, the clusters are predetermined by the axes you choose. It is possible to vary the meaning of the axes, for example 'attractiveness' and 'functionality'.

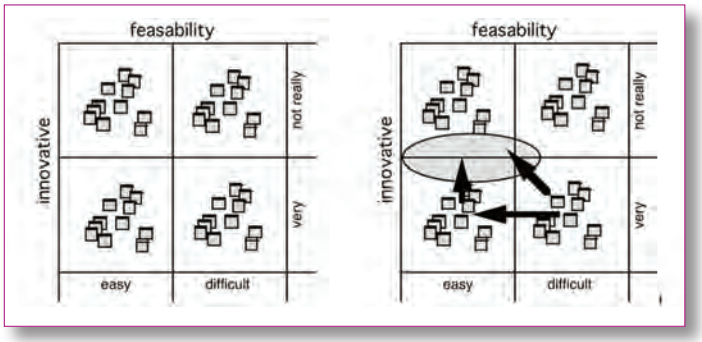


fig. 2.59 Example of C-Box (from student report)

When Can You Use a C-Box?

A C-Box is commonly used in early idea generation, in case of a surplus of early ideas (for example 40+ ideas) generated in a brainstorm session.

How to Use a C-Box?

Starting Point

The starting points of a C-Box is a multitude of early ideas (40-60 ideas).

Expected Outcome

The outcome of a C-Box is an overview of the early ideas, clustered in four groups based on criteria set to the axes of the C-Box. Effectively, you have created a first rough distinction between ideas in four groups.

Possible Procedure

1 Create two axes (innovativeness and feasibility) on a large paper and construct the 2 x 2 C-Box with those two axes, for example using Scotch tape on a wall surface.
functionality: one end is the familiar, the other end represents highly innovative.
feasibility: one end is not feasible, the other end represents immediately feasible.
2 Make sure all ideas are written down, or drawn on a small piece of paper, for example on a post-it or an A5/A4-size paper.

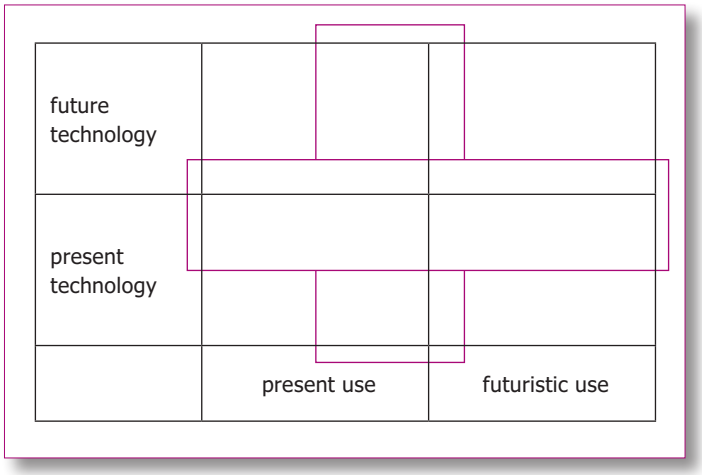
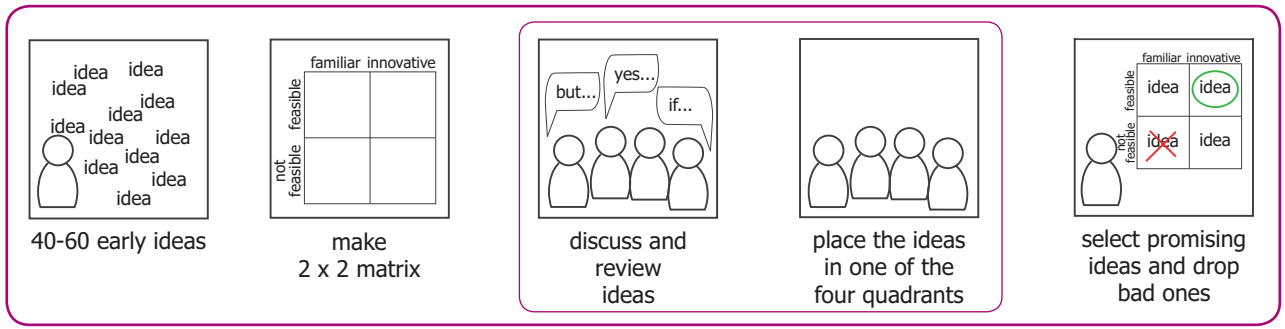


fig. 2.58 C-Box extended (from PO3 course 2008-2009)

How to
C-box



3 With a group, review and discuss the ideas, and place the ideas in one of the four quadrants.
4 Make sure that ideas in one quadrant are situated closely to the criteria they meet best.

Once all ideas are placed in the C-Box, a first overview is created, and following steps can be made. These steps consist of working out the most promising ideas and dropping the bad ideas (not innovative and not feasible).

References and Further Reading

Tassoul, M. (2006) *Creative Facilitation: a Delft Approach*, Delft: VSSD.

Itemised Response and PMI

Keywords
Idea selection
Synectics
Intuitive
Brainstorm

What Is Itemised Response?

The Itemised Response Method is used to judge ideas quickly and intuitively. For each idea, the positive and negative features are listed. These positive and negative features can serve to elaborate on the positive aspects (make the idea's positive aspects stronger). Also, the negative aspects can be evaluated and improved.

This method is used to evaluate and work out a moderately large selection of ideas. Once all pluses and minuses are listed, a decision can be made as to which ideas will be used further throughout the design project. The Itemised Response Method originated from the Synectics Method, a systematic approach to creative thinking that uses metaphors and analogies (see 'Synectics' in section 2.2).

What Is PMI?

The PMI Method (Plus, Minus, Interesting) is used to evaluate early design ideas in a quick and systematic way. PMI is essentially a tool that helps to bring structure to a set of early ideas. Per idea the pluses, minuses and interesting aspects are listed:

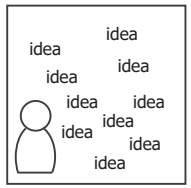
1 Plus (+) – positive aspects,
2 Minus (-) – negative aspects, and
3 Interesting (I) – interesting aspects and features.

PMI can be used in combination with itemised response.

When Can You Use Itemised Response and PMI?

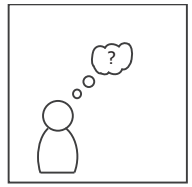
The Itemised Response Method can be used to select ideas for concept developments. The method works best when a manageable number of ideas need to be screened. The PMI method is essentially a technique used in a brainstorm setting. Because of its quick and

How to
Itemised Response and PMI



maximum 10 ideas

for each idea make a list of features



decide if you develope good ideas into concept or keep on generating ideas

intuitive nature, the PMI method is best applied in the beginning of the design process, during early idea generation.

How to Use Itemised Response and PMI?

Starting Point

A limited number of ideas, resulting from the stage of idea generation (not more than 10).

Expected Outcome

Evaluation of ideas and a decision as to which ideas could go into concept development.
Better understanding of the solution space, i.e. more insight into valuable directions for solution finding.
Better understanding of interesting and promising ideas, but also of bad ideas.

Possible Procedure

1 For each idea, list the positive features and the negative features in the form of a list with pluses and minuses. Per idea, answer the following questions:
   a. What is good about the idea (Plus)?
   b. Which aspects would you need to improve (Minus)?
   c. What makes the idea interesting (Interesting)?
2 You now have per idea:
   a. Plus: these are the good aspects of the idea, worth developing further (into concepts) or taking advantage of.
   b. Minus: these are bad aspects of the idea, not worth developing further.
   c. Interesting: these are interesting aspects of the idea, but they need more development in order to become good ideas.
3 Decide upon your course of action: do you develop the good ideas into concepts (how many concepts? Maybe combine certain good ideas?), or do you continue with the early idea generation (seek more ideas? Combine interesting ideas with the good ideas? Explore within the group of interesting ideas?).

Tips and Concerns

- Working with Pluses and Minuses invites people to take decisions, but you don't want that too quickly. C-Box, Itemised Response, PMI and vALUe are all meant to get acquainted with all the ideas before throwing any away (see sub-sections on each topic in this section).

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Gordon, W.J.J. (1961) *Synectics*, New York: Harper and Row.

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vALUe

Keywords
Evaluation
Intuitive
Brainstorm
Idea selection

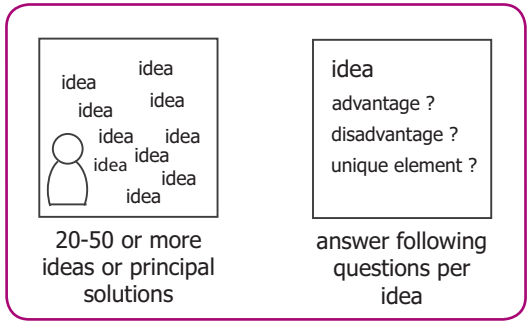
What Is vALUe?

The vALUe Method (Advantage, Limitation, Unique Elements) is used to evaluate a large set of early design ideas in a quick and systematic way. The vALUe method is an inventorying method: it allows a (team of) designer(s) to review and validate the ideas. By explicitly writing down the ideas in terms of advantages, limitations and unique elements, the ideas have a common vocabulary which makes further selection easier. After applying this method, the decision maker has to decide what to do next: look for more ideas, or make a decision as to which ideas will be developed into concepts.

When Can You Use vALUe?

The vALUe method is essentially a technique used in a brainstorm setting. Because it allows ideas to be described in common terms, the vALUe method is best applied in the beginning of the design process, during early idea generation. The vALUe Method works best just after selecting from among a large number of ideas (20 to 50 or more back to 7 +/- 2).

How to
vALUe



How to Use vALUe?

Starting Point

A large number of early ideas or principal solutions (20 to 50 or more).

Expected outcome

A common description of early ideas.
Better understanding of the solution space, i.e. more insight into valuable directions for solution finding.
Better understanding of interesting and promising ideas, but also of bad ideas.

Possible Procedure

1. Generate a large set of early ideas or principal solutions. For idea generation techniques that can be used, see 'Creativity Techniques' in section 2.2.
2. Per idea, answer the following questions:
   a. What are the advantages of the idea (A)?
   b. What are the limitations of the idea (L)?
   c. What are the unique elements of the idea (U)?

References and Further Reading

Isaksen, S. et al. (1994) *Creative Approaches to Problem Solving*, Dubuque: Kendall and Hunt.

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Harris Profile

Keywords
Intuitive
Concept selection

What Is a Harris Profile?

A New Product Profile (or Harris Profile, see figure 2.60) is a graphic representation of the strengths and weaknesses of design concepts. Originally, a New Product Profile is applied as a useful tool to evaluate and select development projects (ideas for new business activities). This method can also be used to evaluate and decide in later phases of product development. Per design alternative a Harris Profile is created. A number of criteria are used to evaluate the design alternatives. A four-scale scoring is used for all criteria. The decision-maker himself/herself should interpret the meaning of the scale positions (i.e. -2 = bad, -1 = moderate, etc.). Thanks to its visual representation, decision-makers can quickly view the overall score of each design alternative on all the criteria, and compare these easily.

fig. 2.60 Example of a Harris Profile

	concept 1				concept 2				concept 3			
	-2	-1	+1	+2	-2	-1	+1	+2	-2	-1	+1	+2
controlable on velocity and direction	■	■					■	■			■	
safe		■					■	■			■	
gain enough speed	■	■					■				■	■
basis construction simple			■			■					■	
well accesible parts			■	■			■	■		■		
well replacable parts			■				■			■		
distinct	■	■					■	■		■		
stable			■				■		■	■		
compact		■				■					■	
springs			■				■	■			■	
price			■				■	■		■		

When Can You Use a Harris Profile?

Whenever a number of alternatives of product concepts need to be compared and consensus/ an intuitive decision needs to be reached/made, the Harris Profile can be used. Typically it is used after a diverging stage of the process.

How to Use a Harris Profile?

Starting Point

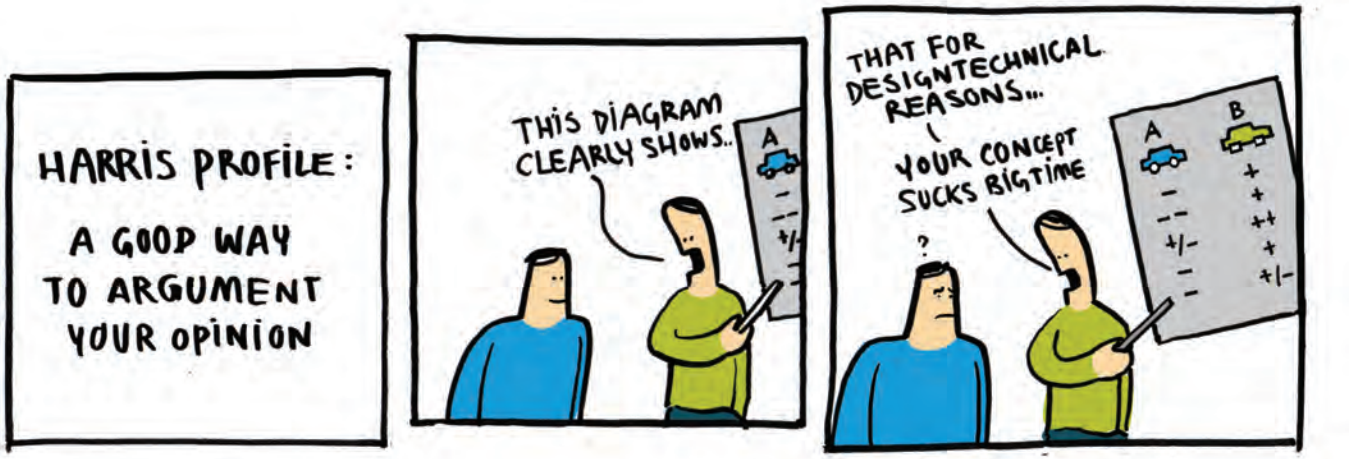
Alternatives for a product (in some stage of development).
Criteria that are applicable to the alternatives on the specific level of development.

Expected Outcome

One chosen/selected alternative from a group of alternatives.
Overview of the advantages and disadvantages of the selected alternative.
More understanding of the problem and criteria.

Possible Procedure

1. Criteria should be selected according to which the design alternatives should be compared (be sure to cover all important aspects of the product development project with the selected criteria).
2. List the criteria and create a four-point scale matrix next to it (see figure 2.60). The scale is coded -2, -1, +1, and +2.
3. Create a Harris Profile for the design alternatives you want to compare. Draw the profile by marking the scores in the four-point scale matrix for all the criteria.
4. When the Harris Profiles of the design alternatives are completed, the profiles can be compared and a judgment can be made as to which alternative has the best overall score.



Tips and Concerns

- If possible cluster the criteria.
- The four-point scale should be interpreted differently for each criterion: the criteria cannot be compared equally, and therefore all criteria have different meanings on the scale. Make sure that you standardise the meaning of the four-point scale for all the design alternatives.
- When attributing the -2 or +2 values to a criterion, be sure to colour all the blocks in the Harris Profile. Only then do you create a quick visual overview of the overall score of a design alternative.
- Give -2 and -1 another column than +1 and +2 in order to create a visual overview.

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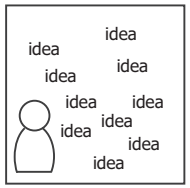
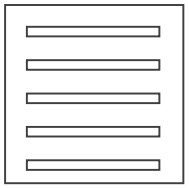
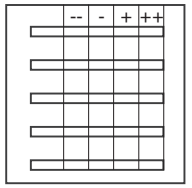
How to
Harris Profile

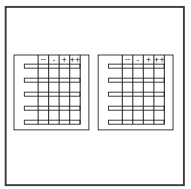


to help make design choices make a list of criteria


list criterias

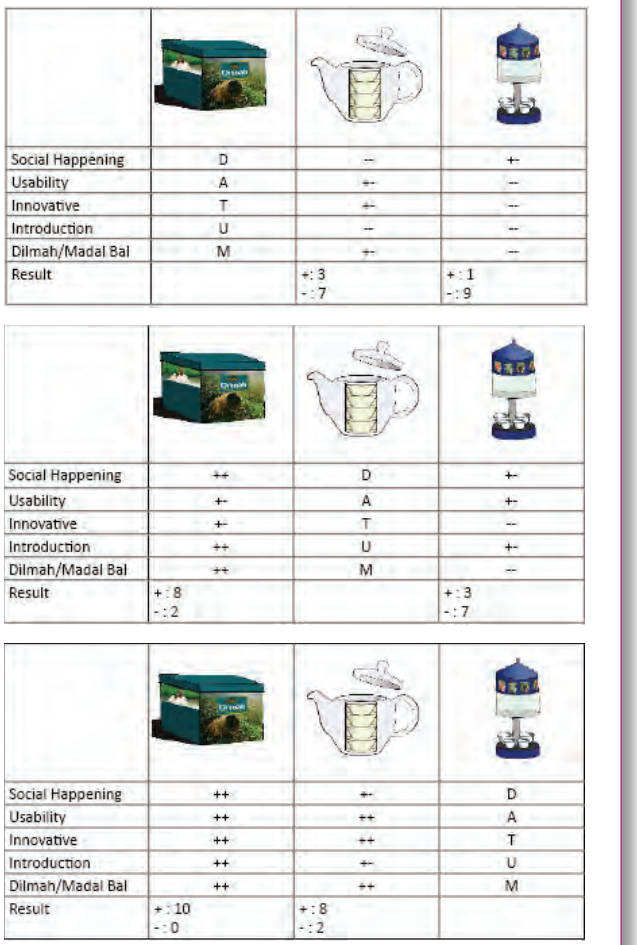


make a Harris Profile, four-point scale matrix


compare and judge profiles to choose

Keywords
Intuitive
Comparison
Concept selection

Datum Method



Social Happening	D	--	+-
Usability	A	+-	--
Innovative	T	+-	--
Introduction	U	--	--
Dilmah/Madal Bal	M	+-	--
Result		+: 3 -: 7	+: 1 -: 9

Social Happening	++	D	+-
Usability	+-	A	+-
Innovative	+-	T	--
Introduction	++	U	+-
Dilmah/Madal Bal	++	M	--
Result	+: 8 -: 2		+: 3 -: 7

Social Happening	++	+-	D
Usability	++	++	A
Innovative	++	++	T
Introduction	++	+-	U
Dilmah/Madal Bal	++	++	M
Result	+: 10 -: 0	+: 8 -: 2	

fig. 2.61 Example of Datum Method (from student report)

What Is a Datum Method?

The Datum Method (see figure 2.61) is a method for evaluation of design alternatives. One of the alternatives is set as datum to which the other alternatives are compared for a range of criteria. Three judgements can be given: 'worse', 'same' or 'better' expressed in '–', '0' and '+'. The sum of each of these three values will then help to make a decision. The value of the alternatives is guessed on the basis of the 'intuitive' judgements of the decision-makers.

The method aims to provide the decision-makers with confidence through a systematic discussion of the criteria and by eliciting the advantages and disadvantages of the alternatives.

When Can You Use a Datum Method?

Whenever a number of alternatives of a product concept need to be compared to reach consensus in the evaluation or to make an intuitive decision, the Datum Method can be used. Although it can be used throughout the whole design process, commonly it is used to select concepts.

How to Use a Datum Method?

Starting Point

Product concepts, developed to an equal, and thus comparable, level of detail.

A list of criteria suitable for use in this stage and in relation to the level of detail.

Expected Outcome

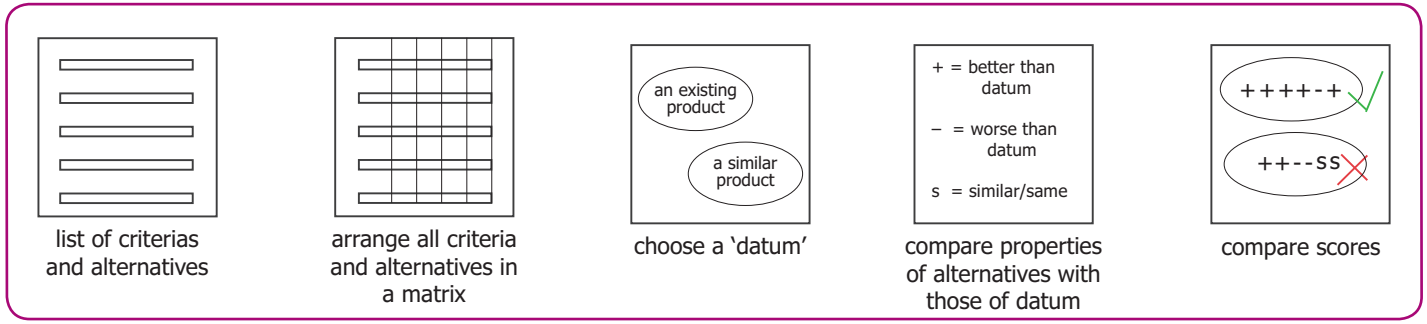
One or more strong concepts for further development, confidence in the decision for the chosen concept(s).

More understanding of the value of all the concepts, more insight in the problems still to be solved and a simple matrix to discuss with others and convince third parties.

Possible Procedure

1. Arrange the concepts and criteria in a matrix (see figure 2.61).
2. Choose one of the concepts as 'datum'. Compare the other concepts to this datum and give a score for each criterium at the time (+ = better than datum, – = worse than datum and s = similar/same).
3. Indicate ∑+, ∑S and ∑–.for each concept. Usually at least one concept will show more '–' and less '+'. Usually a few concepts have minor differences. Discussion can start. An equal spread of pluses, minuses and similars indicates vague and ambiguous criteria.
4. When the outcome does not distinguish enough, the process should be repeated until it does. Each time another concept should be taken as datum, leaving out the concept which was definitively worse.

How to
Datum Method



Tips and Concerns

- Sometimes the designer will not only totalise the score in ∑+, ∑S and ∑–, but also adds up the totals. Like each '+' for one particular concept is compensated by each '-' given to the same concept. A concept with two '+', one 'S' and two '-' will have an end score of zero (0). Although it is a way to have some outcome, one must realise that this will fade away the results and doesn't help to discuss the concepts or criteria. Another concept might score zero (0) also, thus leading to the assumption that both concepts are equal, while the second concept initially scored one '+', three 'S' and one '-'. It all depends on the weight of each criterion and the possibility to change a '-' into 'S' or '+' by redesign. The method is therefore not to be seen as a sort of mathematically justified process, but as an aid to the decision making.
- Another aspect is the selection of criteria. Usually there are a lot of criteria to which the concepts do not comply to, yet. A criterion stating that the product should cost no more than 15 Euro's, or weigh max 800 grams, cannot be judged in the early stages of the design process. However one may have some ideas about the relative difference in cost price. E.g. one concept seems to be more expensive than the other one, because of a larger number of parts or a more complex construction. In choosing the (more general reformulated criteria) it seems logical not to have more than eight to ten criteria.

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Keywords
Concept selection
Ranking

Weighted Objectives Method

	weight	concept 1	concept 2	concept 3
controllable on velocity and direction	2	5	2	2
safe	3	6	3	3
gain enough speed	4	3	4	4
basic construction simple	1	7	5	1
well accesible parts	2	8	5	2
distinct	4	4	7	4
stable	3	3	8	3
compact	1	6	3	1
springs	1	8	2	1
price	3	7	5	3
total score		125	130	89

fig. 2.62 Example of Weighted Objectives Mehtod (from student report)

What Is the Weighted Objectives Method?

The Weighted Objectives Method (see figure 2.62) is an evaluation method for comparing design concepts based on an overall value per design concept. The biggest disadvantage of using the Datum Method or the Harris Profile is that the scores per criterion cannot be aggregated into an overall score of the design alternative. This makes a direct comparison of the design alternatives difficult. The Weighted Objectives Method does exactly this: it allows the scores of all criteria to be summed up into an overall value per design alternative.

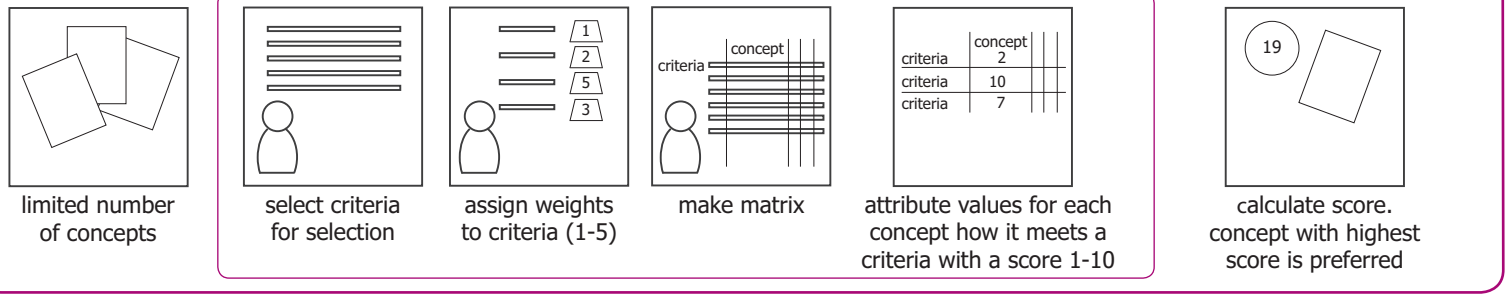
The Weighted Objective Method assigns scores to the degree to which a design alternative satisfies a criterion. However, the criteria that are used to evaluate the design alternatives might differ in their importance. For example, the 'cost price' can be of less importance than 'appealing aesthetics'.

The Weighted Objectives Method involves assigning weights to the different criteria. This allows the decision-maker to take into account the difference in importance between criteria.

When Can You Use the Weighted Objectives Method?

The Weighted Objectives Method is best used when a decision has to be made between a select number of design alternatives, design concepts or principal solutions. Usually, the Weighted Objectives Method is used when evaluating design concepts, and to make a decision as to which design concept should be developed into a detailed design.

How to
Weighted Objectives Method



How to Use the Weighted Objectives Method?

Starting Point

A limited number of concepts.

Expected Outcome

A chosen concept.

Possible Procedure

1. Select the criteria according to which the selection will be made. These criteria should be derived from the programme of requirements (note that probably not all requirements are applicable at this stage of the design process).
2. Choose 3 to 5 concepts for selection.
3. Assign weights to the criteria. The criteria should be appointed weights according to their importance for the evaluation. To determine the weight factor of the criteria it is recommended that you compare the criteria in pairs to attribute a weight factor. Rank each of the weights on a scale from 1 to 5 (you can also decide on a total sum of the weights of the criteria, for example 100). Make sure you discuss the trade-offs between the criteria. Trade-offs will have to be made when weights are assigned to the individual criteria (when you are determining which of the weights are more important).
4. Construct a matrix, with the criteria in rows, and the concepts in columns.
5. Attribute values to how each concept meets a criterion. Rank the scores of the concepts from 1 to 10.
6. Calculate the overall score of each concept by summing up the scores on each criterion (make sure you take into account the weight factor).
7. The concept with the highest score is the preferred concept.

Tips and Concerns

- This method should be carried out intelligibly, while discussing and reviewing both the weights assigned to the criteria and the scores of the concepts according to all the criteria.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

Roozenburg, N. and Eekels, J. (1998, 2nd ed.) *Product Ontwerpen: Structuur en Methoden*, Utrecht: Lemma.

2.4 Evaluation of Product Features

Introduction

The analysis of the design problem, the formulation of a design goal and the development of product ideas and concepts are actions aimed at providing a solution to the design problem. To verify, or test, whether the solution is the correct one, an evaluation of product features is important. Generally, testing the result provides confirmation whether the proposed solution is the right one. Within the design process there are different forms of testing a product idea. During the design process, ideas need to be tested to find out whether they work. The technical functionality of a product needs to be verified. Investigations have to be made to determine which of the proposed solutions the user group prefers. Also, there is a need to verify whether the proposed solution is usable, and whether the user groups understand how to use the product.

In this section we differentiate between three general types of testing: product simulations and testing, product concept evaluations, and product usability evaluations.

Product simulations and testing take place during the design process, and are directed at gaining an understanding whether the product functions the way it is intended to do. These types of tests are simulations on paper or on a computer, or even tests with different forms of prototypes. Through product simulations and testing, designers try out their ideas to see whether they work as intended.
Product concept evaluations are used throughout the design process to gain understanding of the user group's responses to ideas and concepts developed in the design process. These types of tests investigate what ideas and concepts are preferred by the user group. Product concept evaluations are used to optimise product concepts on the basis of the user group's responses, or to make go/no-go decisions in the design process.
Product usability evaluations take place near the end of the design process, and are aimed at understanding whether the user group is able to use the designed product concept. These types of tests are more intensive, directed at verifying and optimising the usability of the product.

Product Simulation and Testing

Keywords
Simulation
Product test
Verification
Scientific problem solving

What Is Product Simulation and Testing?

Product simulations and testing aim at gaining an understanding whether the product functions the way it is intended to do. New product ideas and concepts are created through finding and describing the functions and the use of those functions. The functions are materialised/embodied with technical solutions principles. Designers try to find the best technical solution principle that can make a particular function, or set of functions, work. Several (existing) technical solution principles are possible for a (set of) function(s), and sometimes a new technical solution principle must be found. In the creative phase of the design process, it is your job to find the most appropriate technical solution principle for the desired function(s). Simulation plays an important role: in order to judge the solution principles found, you have to determine the 'quality' of your design and gain insight into the functioning of your design through simulation.

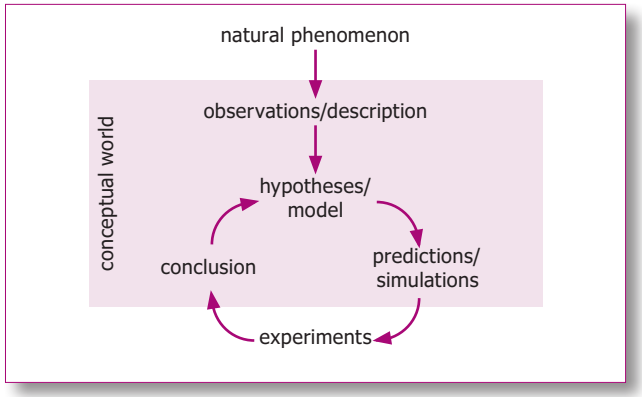


fig. 2.63 Scematic representation of Product Simulation and Testing

In order to perform a simulation, you first need to construct a model of the desired function and technical solution principle. A model is a simplified representation of a real-world phenomenon, which is not reality itself, but can be used as a way of describing, explaining and making predictions. Within the design process, many different types of models can be used for simulation and testing purposes: dummies, mock-ups, prototypes, but also drawings and diagrams. Using the models, you can test your assumptions; modelling allows for experimenting and testing whether the solution principles behave as intended.

The process described above shows great similarities with the 'scientific method', which is typically used in scientific research (see also Roozenburg and Eekels, 1998). In this context, design can be seen as a process of making predictions. First, designers hypothesise about how a certain technical solution principle fulfils one or several predetermined functions. Next, they construct models to make predictions about this process and through simulation with the model, they investigate whether the predictions sustain the hypothesis. Experiments are then needed to validate the model and check whether the accuracy of the predictions is sufficient. In other words, through experimentation, designers determine whether the developed model proves that the principle behind the product or function is indeed as they had hypothesised. Modelling, simulating and validation through experimentation are important aspects of the design process.

Models

Models can be classified in various ways. Here, we distinguish between material and symbolic models. Material models are various sorts of prototypes, such as sketch models, detailed models, dummies, mock-ups and final models. Symbolic models are diagrams and mathematical models. Another classification of models is according to the type of simulation: (1) simulation with structure models, (2) simulation with iconic models, and (3) simulation with mathematical models.

1 Examples of **structure models** are flow diagrams, circuit diagrams and function block diagrams. Sketches and dummies are also included in this group. Structure models are qualitative and are used to assess the qualitative structure of a product or a process. They give a quick first impression of the appearance and functioning of the product (see figure 2.64). Structure models are often the first step to more advanced models.

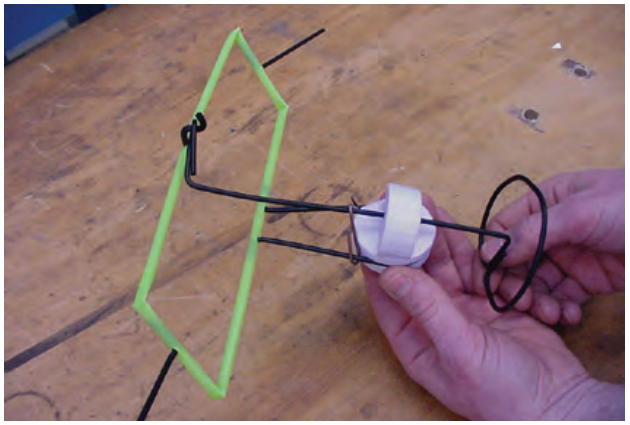


fig. 2.64 Example of a structure model for product testing (student work)

fig. 2.65 Example of an iconic model (student work)

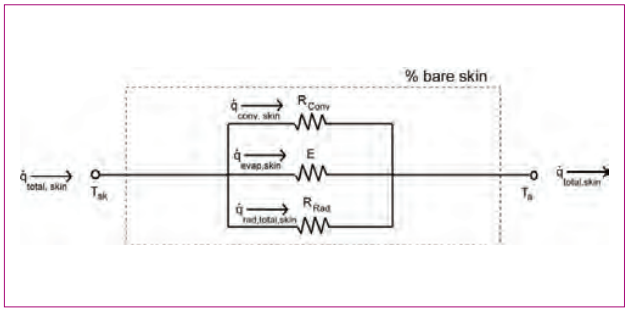


fig. 2.66 Example of a methematical model (from student report)

2 Examples of **iconic models** are pictures, drawings, dummies (see figure 2.65), mock-ups, and prototypes. Iconic models have a similar geometry to their design: simulation with iconic models is more realistic, concrete and quantitative. Three-dimensional models form an important group: dummies, mock-ups, sketch models, detailed models and prototypes. Functional prototypes enable designers to test the functionality and usability of the design with a high degree of realism.

3 Examples of **mathematical models** are mathematical formulae, such as Newton's law, to determine the physical characteristics of the product. Mathematical models can be used to evaluate the physicochemical parameters of the design in question. These models help you to quantify and determine the parameters of the components and the dimensions of the product. They give an objective view on the problem in hand and the results are fully quantitative (see figure 2.66).

Simulation

By means of models, described in the previous paragraph, you can perform different simulations, depending on the information required. The questions that you try to answer could be as follows:

1 What constitutes the function that the product must fulfil?
2 Does the product perform as intended; will it fulfil its functions?
3 Can the product be manufactured in the planned quantity, and at an acceptable quality and price?

The following list provides some examples of simulations for 'answering' specific questions. These particular simulations have become well-known thanks to their extensive use in design practice:

1 Failure models and effects analysis and fault tree analysis
Failure models and effects analysis (FMEA) and fault tree analysis are two qualitative methods for analysing the reliability of a new product. Applied early in the design process, they can help you to find the possible causes and effects of failure. Through FMEA an answer to two questions is sought: (a) in which manner can the part fail, and (b) what happens if the part fails? The result of the analysis is a list of critical points and an indication of what should be done to reduce the chance of failure.
In a fault tree analysis (a structure model) you look for the causes of a presumed failure mode of the product. The advantage of fault tree analysis is that it indicates how the reliability of a complex product depends on the functioning of the separate parts.

2 Experiments with prototypes (material models)
In early phases of the design process some insight needs to be gained, in order to be able to abstract a function or product into a mathematical model. What factors are relevant is often not known in advance and will become apparent in practice. Given this experience, further investigation can be performed to find out which parameters have an important influence. Also, at the final stages, proof of principle of critical parts is often tested in a trial set-up, using detailed or final prototypes. They play an important

role in the simulation of the manufacturing process to discover lacking features. Then the dimensions of the product have to be completely defined.

3 Finite element method (FEM)
Science provides a variety of mathematical models to describe physical phenomena. FEM is an example where the mathematical model becomes so complex that the simulation can no longer be done by hand. The principle of FEM is that an object or system is divided into small cells. The interaction between two aligned cells is modelled through the laws of nature. Depending on the level of detail, the number of cells is large and calculations have to be automated. Several computer programs are available that can apply FEM on a geometry. However, the models or the form of the cells used in these programs are often hidden. Therefore, a critical view on the outcomes is important and should ideally be checked through (simple) manual calculations.

4 Scaling up to mass production
At the end of the design process, only one product is designed. When mass-produced, this product needs to be modified. By means of prototypes and trial runs, the product can be prepared for mass production. Usually a prototype is followed by a trial run of a batch, the null series, to see if no problems occur during production on a large scale.

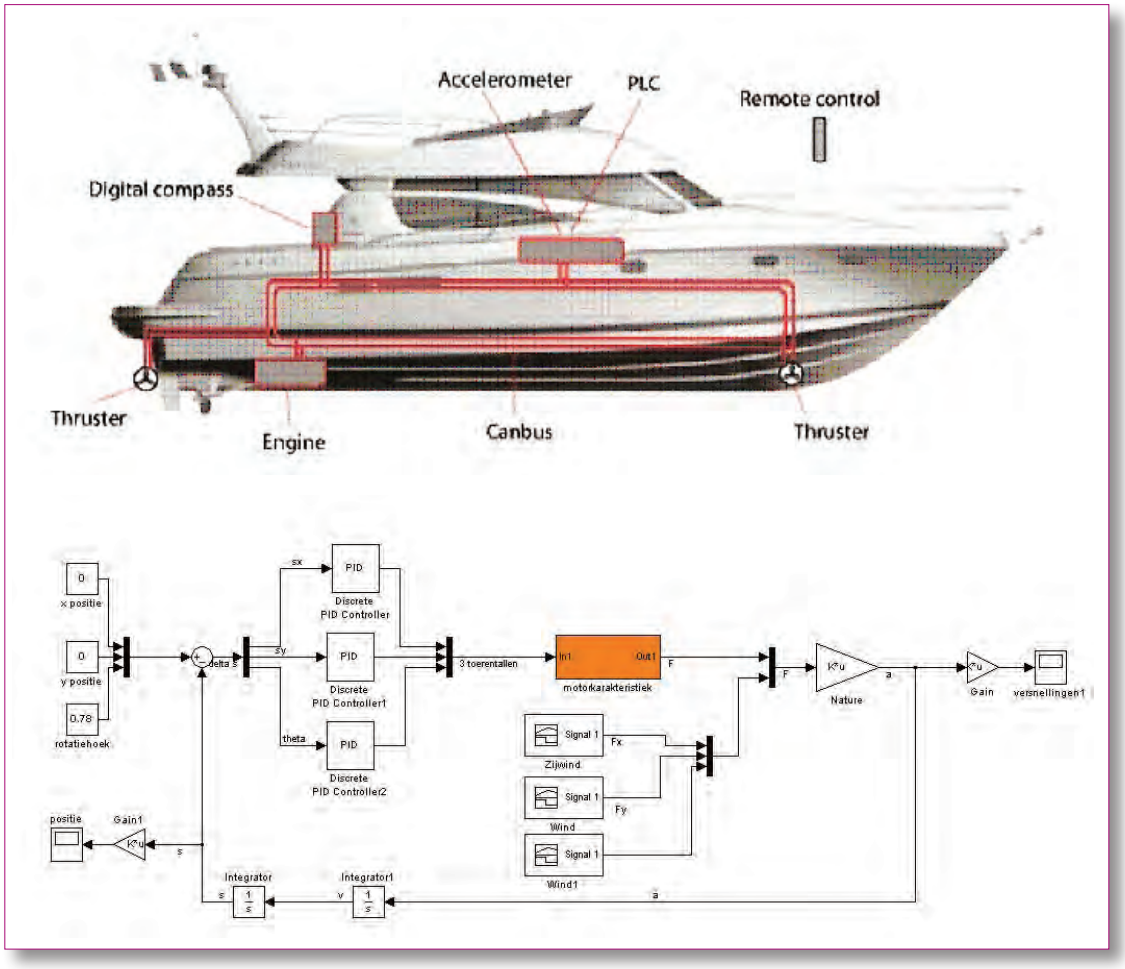
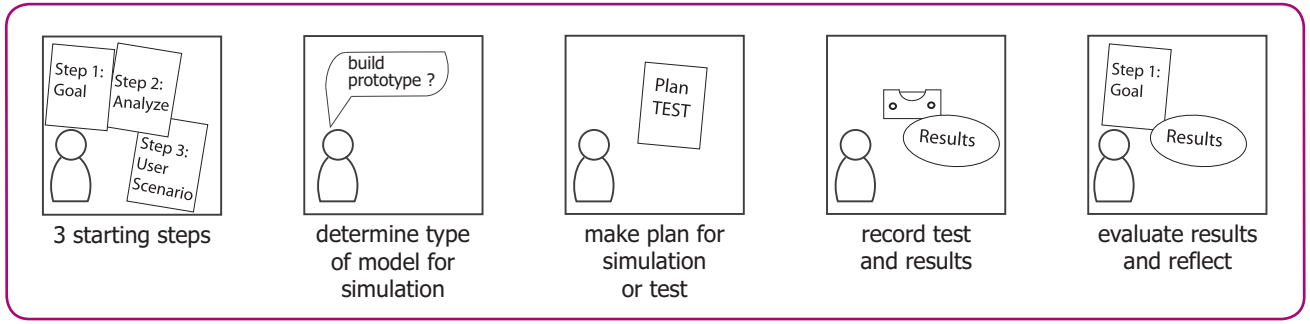


fig. 2.67 Example of a simulation with a methematical model (Graduation project Marco Koekoek, TUDelft, 2007)

How to
Product Simulation and Testing



5 Logistics and quality analysis
During the manufacture of a product, materials, parts, and subassemblies 'flow' from one workstation to another. These material flows can be visualised and analysed using network-like graphic models (analogue models) such as in 'routing analysis', the `Sankey diagram', and 'failure rate analysis'.

6 Design for Assembly (DfA)
A widely known and applied analytical tool is Design for Assembly. The assembly process of products is simulated by means of a mathematical model in the form of a system of tables that connects form features of parts to the estimated assembly time.

7 Value analysis
Value analysis is the analysis of the functions and subfunctions of a product, and the comparison of the value of those functions with regard to their costs. For that purpose the value of a function is equated in principle to the price of the cheapest 'carrier' of that function available in the market. By systematically setting values and costs off against each other, you can see which parts of an existing product, or new product design, are likely candidates for improvement. Unfortunately, value analysis is often wrongly associated with cost reduction only and not with quality improvement at equal costs.

8 Ergonomic Simulation
Designers want to know what kind of user behaviour their design provokes, so that they can improve their design, if necessary. As you never have the whole population for which the product is intended at their disposal, a model of the design is tested on a 'man model' (mannequin). A mannequin is a representation or imitation of ergonomically relevant features of a certain population. The most important man models used in anthropometric ergonomics are tables and layout drawings (of work spaces), two-dimensional manikins, computer models of human beings, and test subjects (see figure 2.68).

9 Business-economic simulation
The attractiveness of the business potential of a design is another type of simulation that plays an important role in a design process. Cost price calculations are often made in a design process.

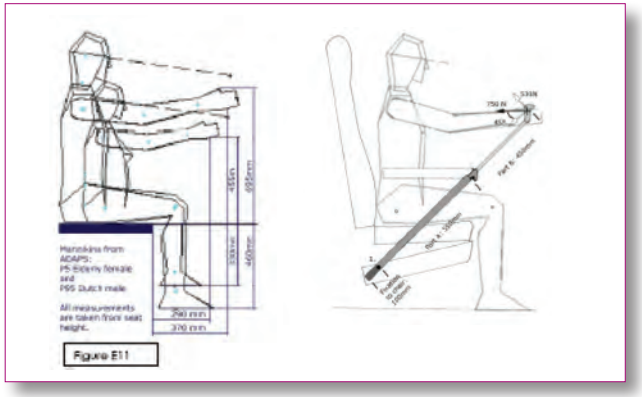


fig. 2.68 Example of an ergonomic simulation (Student work)

For cost price calculations, most of the design must be known: what type of components, materials and production techniques. With cost price calculations it is possible to make profitability calculations. In profitability calculations the general profitability of a design project is calculated, on the basis of which calculation a go/no-go decision can be made regarding the continuity of the project. Forecasting methods help in making a prediction about the number of users that will buy the new product.

10 Social and Ethical Simulation
You could formulate social and ethical criteria in the design specification, and take these into account using the various decision methods presented in section 2.3. and applying social and ethical simulation. These simulations are not performed by means of mathematical formulae or experimental methods, but by means of conscientious thinking, logical reasoning, and common sense. For that purpose check lists can be useful, as can be found in Roozenburg and Eekels (1992).

11 Simulation of Environmental Effects
Product design always leads to unintended environmental side-effects in the production, distribution and use of materials. They are caused by the withdrawal of raw materials and energy, and emissions into air, water and the soil. You as a designer have an important role in decreasing the impact on the environment and creating sustainable products. In the design process, therefore, a designer should be interested in the impact of his/her design on the environment. In order to obtain a clear understanding of the environmental impact, a you could do an environmental effect simulation, for example by using a MET Matrix (see 'EcoDesign Strategy Wheel' in section 2.1). Another point to be taken into consideration is to deploy various EcoDesign Strategies, based on an analysis of the Product's Life Cycle (see 'EcoDesign Checklist' in section 2.1)

When Can You Use Product Simulation and Testing?

Product Simulation and Testing take place throughout the design process, with increasing levels of concreteness, of detail and of accuracy of the models used. However, some types of simulation are applicable in the beginning of the design process, others near the end of it.

How to Use Product Simulation and Testing?

Starting Point

The starting point of simulation is an aspect, either a functional aspect or a material one, of the design that needs testing to verify its underlying assumptions on functionality, construction and materialisation. In other words, a feature of the design needs testing in order to prove its workings.

Expected Outcome

The outcome of simulation is a confirmation whether a particular aspect or feature of the design works or functions as intended.

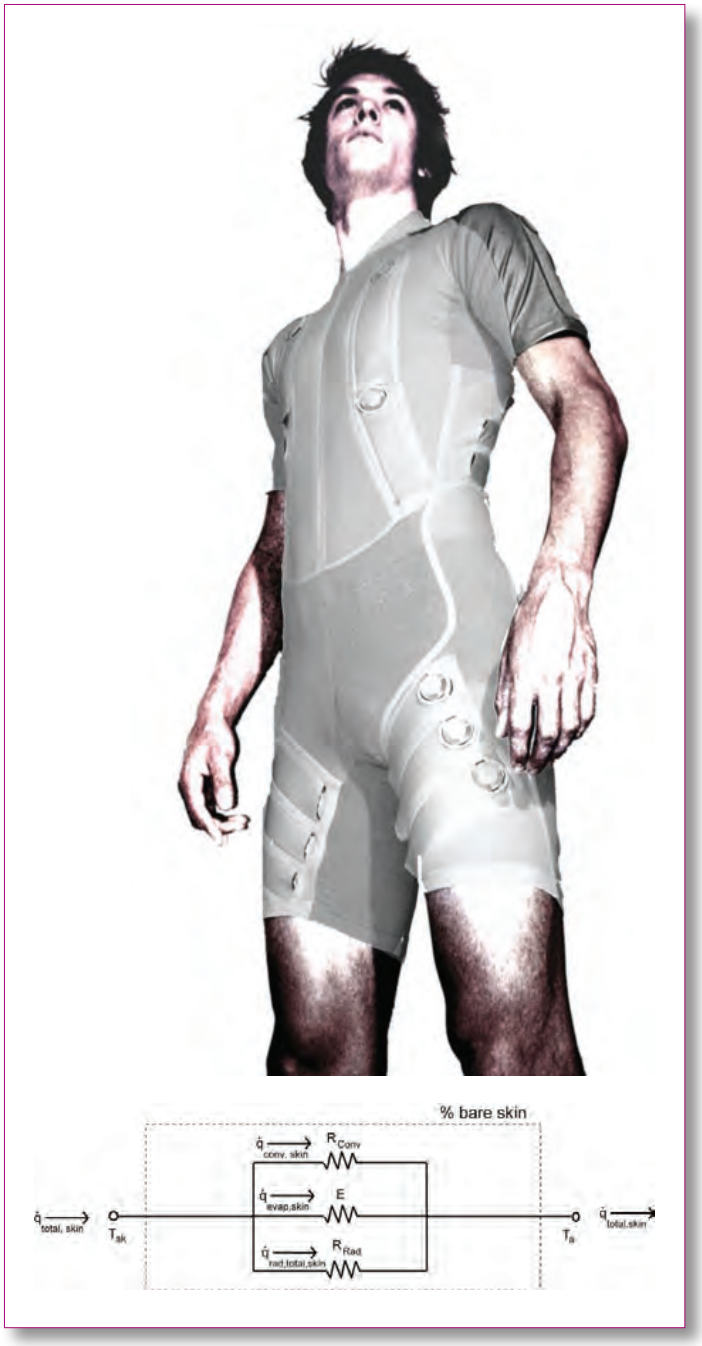


fig.2.69
Example of a simulation
(Graduation project Willemijn Verduijn, TUDelft/TNO, 2007)

Possible Procedure

Note: the following procedure is not necessary for all types of simulations described above.

1. Describe the goal of the product simulation. Analyse the existing situation, and determine the various scenarios of use.
2. Determine the type of model you will be using. Make the model; abstract the product idea into the symbolic language of the model. Build a prototype, if necessary. Select or construct the appropriate mathematical models.
3. Carry out the simulation or test. Set up a plan for the test. Record the test and the results of the test.
4. Interpret the results.
5. Evaluate the results, and reflect the results upon the goals stated earlier. Also, reflect the result upon the initial product idea.

References and Further Reading

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Keywords: User preference, User panel

fig.2.70 Example of product concept evaluation by means of a design sketch and a scenario/ storyboard (Nomad/ Zilver Product-ontwikkeling, 2001)

Product Concept Evaluation

What Is Product Concept Evaluation?

A product concept evaluation is a type of evaluation in which the product concept developed so far is reviewed by the user group. Generally, these evaluations are aimed at selecting or optimising product concepts on the basis of the preferences of the user group and other stakeholders. The product concepts that are evaluated can have different forms (descriptions, drawings or prototypes). Typically, these evaluations take place in a controlled environment, where a panel of people judges product concepts based on a list of predetermined issues. These evaluations serve different purposes: concept screening, concept optimisation, and go/no-go decisions (Schoormans and de Bont, 1995).

Concept screening is aimed at selecting worthwhile product concepts. It is necessary when a large quantity of product ideas or product concepts has been generated. From these product ideas and concepts a selection has to be made for further development. Often, it is experts (managers, engineers, marketers) that are invited to do a concept screening rather than representatives from the user group, because it often involves evaluating product ideas and concepts in light of the formulated requirements.

Concept optimisation is aimed at determining which aspects of product ideas and concepts need further improvement. These tests are not directed at judging the total concept, but rather parts or elements of product ideas and concepts. The assumption is that preferred aspects or elements of the individual product concepts can be connected with each other, yielding a concept that is regarded as optimal.

Product concept evaluations for go/no-go decisions are aimed at validating important design decisions. These decisions often involve the choice between two or three product concepts. Designers can make decisions based on the programme of requirements, but sometimes it is necessary to have these decisions validated by the user group.

Types of concepts, selection of respondents, types of evaluation

The **types of concepts** that you can use for product concept evaluations are the following:

1 Textual concepts: descriptions of the product idea, which generally consist of a description of what you can do with the product idea. There are roughly two forms of textual descriptions: a scenario of how a person can use the product, or an enumeration of the aspects of the product idea.
2 Pictographic concepts: visual representations of the product ideas (see figure 2.70). Depending on the design process, these visual representations are highly detailed visualisations or simple representations. Since sketching and visualisation are so important during the design process, pictographic concept evaluations are most common. In recent years, computer graphics have enhanced pictographic concept evaluation through easy manipulation of the perspective of the visualisation.
3 Animations: moving visual representations of the product idea. Thanks to computer graphic software it has become quite easy to make a simple animation of how the product can be used in a particular context.
4 Mock-ups (dummies): three-dimensional, tangible representations of the product idea (see figure 2.71). Mock-ups are a kind of prototype that only shows the external (form) characteristics of a product idea (see 'Three-dimensional Models' in section 2.2).

fig.2.71 Example of a mock-up (student work)

The **selection of respondents** is an important aspect of product concept evaluations. Respondents that are invited belong to one or more of the preformulated user groups. You can make a selection based on the sociocultural characteristics or on demographical characteristics. An important issue to be taken into account is the respondents' level of knowledge of the product category. To assess this level of knowledge, you could simply ask respondents about their experiences with similar products. Another important issue when selecting respondents is related to psychological aspects such as tolerance and innovativeness. Questions that are important are: how tolerant are the respondents towards new products and new situations? How innovative, or conservative, are the respondents? Such psychological aspects have a big influence on the results of the product concept evaluations.

Different **types of evaluations** can be used for product concept evaluations. One of the commonest methods used is the personal (individual) interview. Another form can be focus groups, or discussion groups. In focus groups, a product concept evaluation takes place with a small group of people, and has the form of a group discussion. Product concept evaluations are structured according to preformulated lists of questions. In the evaluation of the product concept, the respondents are asked about their judgments. Respondents can give their judgments using rating scales, or ranking scales. When rating product concepts, respondents attribute scores to several aspects of the concepts. When ranking, respondents are asked to order the concepts according to their preferences.
Product concept evaluations often take place in a controlled environment such as a laboratory. The reason for this is to ensure that there is as little distraction as possible. The evaluations are recorded using video and audio equipment. Often questionnaires are used to capture the evaluations.

When Can You Use Product Concept Evaluation?

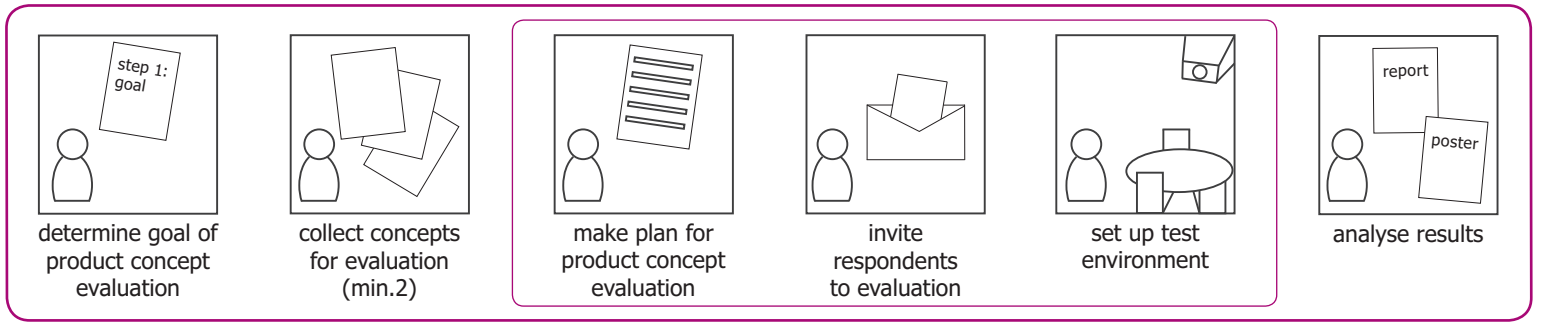
Product concept evaluations take place throughout the design process, based on the purpose of the evaluations. Concept screenings usually involve large numbers of product ideas and concepts, and therefore are more frequent in the beginning of the design process. Concept optimisation takes place near the end of the design process, when aspects of the concept need to be improved and optimised.

How to Use Product Concept Evaluation?

Starting Point

The starting point of a product concept evaluation is a number of concepts to be judged (with a minimum of two), and a reason for conducting the evaluation. The reasons determine the type and purpose of the product concept evaluation.

How to
Product Concept Evaluation



Expected Outcome

The expected outcome is a validated choice between a number of concepts in case of a concept screening or a go/no-go decision, or a better understanding of what aspects require improvement/optimisation.

Possible Procedure

1. Describe the goal of the product concept evaluation.
2. Determine what type of product concept evaluation you want to conduct.
3. Gather or create the appropriate concepts for the evaluation.
4. Create a plan for the product concept evaluation. This plan should include: the goal(s) and type of evaluation, a description of the respondents, questions you want to ask the respondents, aspects of the product concept that need to be evaluated, a description of the test environment, the means of recording the evaluation, a plan of how you are going to analyse the results.
5. Search for and invite respondents to the evaluation.
6. Set up the test environment, including recording equipment.
7. Conduct the concept evaluation.
8. Analyse the results, and present the results concisely, using either a report or a poster.

Tips and concerns

- Make sure that you search for a valid representation of the user group when inviting respondents (don't forget to provide them with some form of compensation).
- Make sure you structure the evaluation systematically with the questions you want to ask the respondents.

References and Further Reading

Roozenburg, N.F.M. and Eekels, J. (1995) *Product Design: Fundamentals and Methods*, Utrecht: Lemma.

van Raaij, W.F. et al. (1999) *Product en Consument*, Utrecht: Lemma.

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fig.2.72 Example of a three-dimentional model used in a panel evaluation (student work)

fig.2.73 Example of an animation; a car simulator (from student report)

Keywords: Usability

Product Usability Evaluation

What Is Product Usability Evaluation?

A product usability evaluation is an evaluation intended to validate the product-user interaction. Product usability evaluation, or usability testing helps us to understand the quality of your designs (ideas or concepts) according to usage. Usability is defined as the effectiveness, efficiency and satisfaction with which specific users achieve specific goals in a specific context of use. Product usability evaluation is primarily done by means of observation techniques. Users are invited to complete tasks while talking out loud, or discussing their motivation with the researcher, rather than showing users a rough draft and asking, "Do you understand this?",
Setting up a usability test involves carefully creating a scenario of use tasks, or a realistic situation, in which the person performs a list of tasks using the product being tested while observers watch and take notes. Several other test instruments such as scripted instructions, paper prototypes, and pre- and post-test questionnaires can be used to gather feedback on the product being tested. The aim is to observe how people function in a realistic manner, so that you can see problem areas, and what people like. It is important to set up usability evaluations systematically, and to approach the evaluations as formal research projects.

fig.2.74 Example of a product usability evaluation (from student report)

An important aspect of product usability evaluations is verifying presumptions regarding the use of a product. Presumptions that are investigated in product usability evaluations are the product characteristics (materials and shapes) that provide the users with "hints" as to how to use the products. These product characteristics are also called use cues. Use cues are meaningful product characteristics that are given to products to show users what functionalities a product has and how these functionalities can be used. Some use cues are deliberately designed, and some use cues are discovered in the usability evaluation. One of the goals of product usability evaluations is to test designed use cues, and discover the unobvious use cues.

fig.2.75 Example of a product usability evaluation by means of Emo-cards, developed by Pieter Desmet (from student report)

The elements of a product usability evaluation are the product, the respondent, the test setting and the type of evaluation. The product is often a prototype, either with limited functionality or almost full functionality. The choice of respondents depends on how they represent the user group. As product usability evaluations are very time-consuming, often a limited number of respondents is chosen. The test setting can be either a controlled environment such as a laboratory, or one in which users act in their natural environment. The type of evaluation could be self-completion reports, where users are asked to report on their usage of the product (for example by thinking aloud, or through retrospective interviews). Evaluation can also take the form of asking questions to users while performing tasks, or even measuring human characteristics (for example eye tracking).

fig. 2.76 Example of a product usability evaluation (from student report)

When Can You Use Product Usability Evaluation?

In the design process, product usability evaluations can be conducted at several moments. The nature of the usability evaluations depends on the moment in the design process:

1. Evaluation of the use of existing products, which typically takes place in the beginning of the design process to analyse existing, analogous products.
2. Evaluation of simulated use of concepts, which typically takes place with the use of sketches of ideas and concepts, and with scenarios or storyboards (see sub-sections on these topics in 2.2).
3. Evaluation of use of final designs, which typically takes place with three-dimensional models that have a limited functionality. These types of evaluations take place during the design process.
4. Evaluation of use of prototypes, which typically takes places at the end of the design process. These types of evaluations make use of almost fully functioning prototypes.

During usability testing, the aim is to observe people using the product in a situation that is as realistic as possible, so as to discover errors and areas of improvement.

How to Use Product Usability Evaluation?

Starting Point

The starting point of product usability testing is the need to investigate the usage of existing products or verify (test) the usage and ease of use (usability) of new product ideas and concepts.

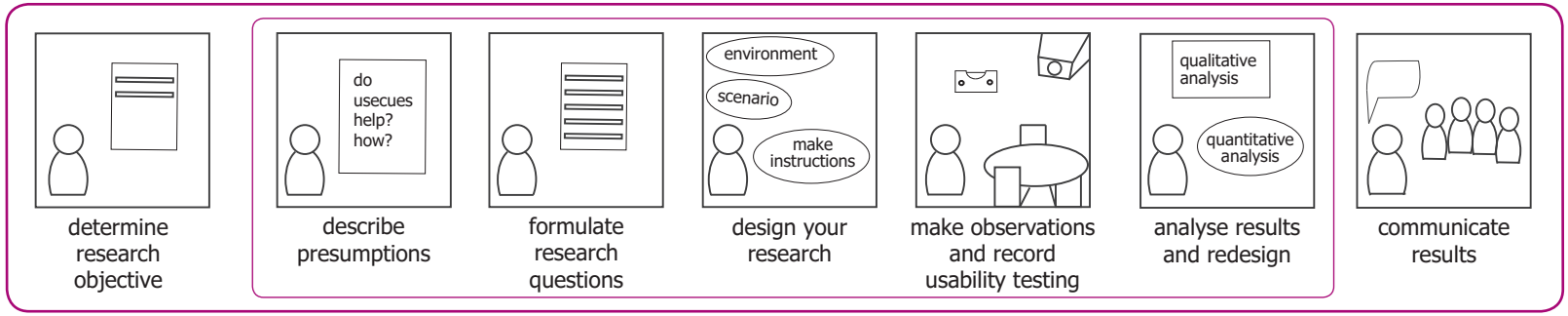
Expected Outcome

The outcome of product usability evaluations with existing products is often a list of requirements with which the new product must comply. Product usability evaluations with new products result in a list of useful aspects and issues about the use of the new product and improvements that could resolve those issues.

Possible Procedure

1 Determine the research objective.
2 Describe the presumptions, in other words: in what way do the use cues designed by the designer help the user in using the product? Describe the presumptions very explicitly. Presumptions are not predictions, though!
3 Formulate research questions.
4 Design your research. Think about: what type of models are you using (scenarios, storyboards, prototypes), the research environment, make instructions, determine the type of evaluation.

How to Product Usability Evaluation



5 Do the observations. Record the usability evaluations.
6 Analyse the results. You can choose to do a qualitative analysis or a quantitative analysis.
7 Redesign the product on the basis of the results. Often improvements are suggested in the evaluation.
8 Communicate the results.

Tips and Concerns

- You may include a limited number of qualitative questions that will help inform future design research, but don't let these questions sidetrack the users from their primary tasks.

- Employ guerrilla testing techniques if money and time are limited. You don't always need formal recruiting or testing facilities. Use your personal network to find unbiased people to test. Use a conference room as a test lab. Any testing you can do is better than no testing at all.

References and Further Reading

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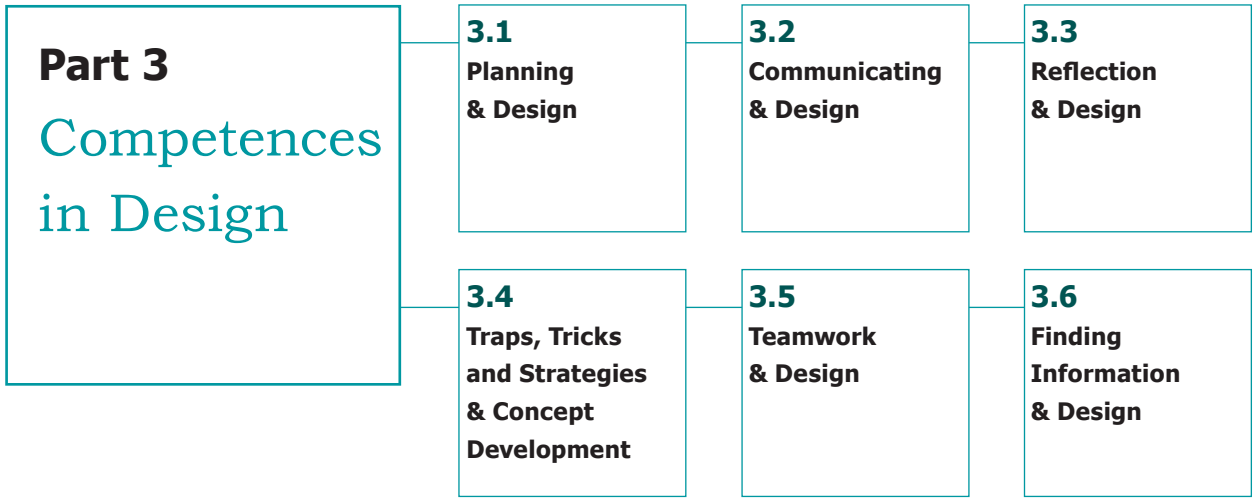

In this part of the Delft Design Guide we present some methods, tips, deliberations and so on, on more generic topics that are of interest while learning and practising design. The topics are not specifically attributed to one particular phase in the design process, but useful and applicable in a more general sense. As for the other parts of this Design Guide, the reader should be aware that this material offered does not cover all the knowledge of these topics but serves as a starting point for further study.

Part 3 Competences in Design

3.1 Planning & Design

What Is Planning?

A planning is a schedule of activities placed in time. Planning involves scheduling your activities in time in order to manage, adjust and adapt activities that need to be carried out during a project. You have for instance Network planning, Timetable planning and 'To-do lists'.

When and Why Planning?

Always…working with a good and flexible planning facilitates a design process (or any other process). Good planning is important when your task is complex and too large to get the overview in advance. Setting up a good planning can be difficult and complex, but investing time surely pays off when a project is completed. Especially when working in a team, planning is important in order to divide the activities within the team and to manage the cooperation of the team members.

How to Make a Planning?

Planning can be done either very extensively, planning all activities up front, or more flexibly by making little to-do lists at the beginning of a day. Different tools exist, which will support setting up complex and simple planning. Every planning starts with setting up clear goals of what needs to be obtained and the specific results that should be produced. After that you should define the design approach (which can be manifold, but is often prescribed by others). Then you should identify and schedule your activities in time. The real challenge lies in maintaining and managing a planning throughout the process of completing the activities.

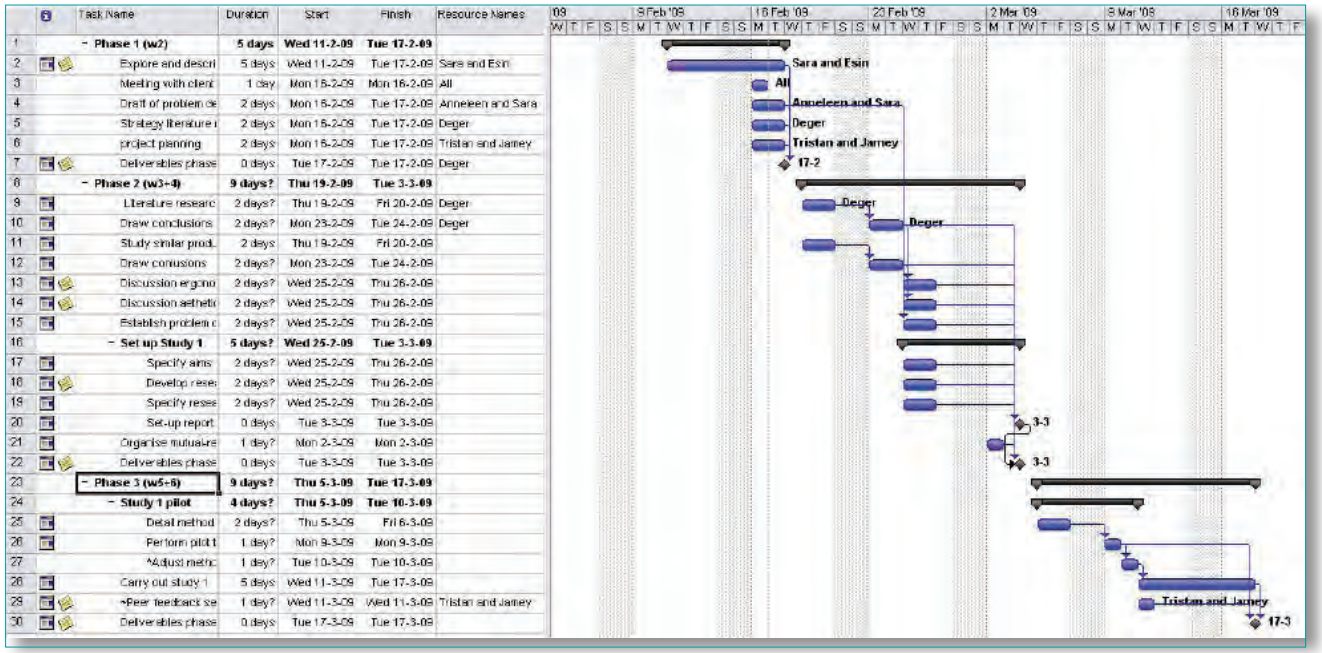

fig. 3.1 Example of Project Planning

Possible Procedure

1 Study the project assignment carefully.
2 Determine the end result and also the intermediate results.

Think about what your final result will look like. Will it be a physical product, or a digital one? Will it involve a service?
Think about what shape it will be.
Think about the quality of the final and intermediate results.
Think about the intermediate results you need to show during your project. What is expected from you? What do you need to present at intermediate presentations?

3 Determine the form of the end result (determine the deliverables)

Write down what you will deliver (make a statement about the deliverables) and in what form. Will you end up with a bunch of drawings, or with a complete report? Will you deliver a prototype? Will you give a presentation, a poster or a film? (this depends on the availability of time)

4 Determine the activities (Plan of Action)
Think about the activities you need to set up in order to come to the intermediate and final results defined earlier. Describe these activities on different levels of abstraction.

5 Plan the activities in time
Schedule your activities in time. Make sure that you take into account the intermediate results, and plan for contingencies.

6 Identify important milestones in your planning
Identify when you need to have completed certain aspects in order to complete your (intermediate) results in time.

7 Determine and identify interdependencies between your activities
Identify what activities are related to each other and need to be carried out in sequence. Other activities can be done in parallel.

8 Manage and safeguard your planning
During your project, manage your planning by checking your schedule with reality on a regular basis. Check whether you are still on time.
Check whether activities are completed on the desired level.

For the planning of the end results and intermediate results you can use the SMART method:
S - specific: The desired results should be formulated specifically, and not too generally (e.g. 'I want to make a better world' instead of 'I will design something to give users x the opportunity to y').
M - measurable: The results should be formulated in such a way that it is possible to measure whether they have been completed ('I will produce at least 5 ideas' instead of 'I will produce several ideas').
A - acceptable: Be sure that there is consensus (among the members of your team or with your tutor) on what the results involve or try to accomplish.
R - realistic: Results should be feasible; they can be completed within the scope of the project (if you do not have experience, ask for support!).
T - in time: It should be clear when (day, hour) the results will be completed.

Tips and Concerns

- Working in groups: make your planning visual, plan your meetings.
- Regularly, be clear about responsibilities (who is responsible for what?!).
- Refine your planning on a daily or weekly basis.
- A planning is not strict or rigid. We recommend you set up a planning at different levels of abstraction: first you start with an abstract planning of large-scale activities; second you break down the large activities into smaller ones; third, on a weekly (or daily) basis you write down a 'to-do list', based on the first two steps.

References and Further Reading

Smulders, F., Brehmer, M., & van der Meer, H., (2009) *TeamWorks: Help Yourself, By students for students*. Mosaics Business Publishers and Delft University of Technology. Chapter 4, H2 get organised through planning.

3.2 Communication & Design

In product design, communicating the results of a design process is unmistakably a very important part of a designer's work .There is a wide variety of *means* designers use to communicate their design results. It depends on the *purpose* of the communication which means are suitable to apply. For example: when you have to convince a client and you want the client's commitment for a next step in the product development process, you will need other presentation techniques than when discussing a production plan with a production engineer.

How to Communicate Design Results?

The mode of communication depends on your purpose or *objectives* e.g. to *convince*, to *explain*, to *instruct*, to *document* or to *discuss* design results and to whom: the *target group* e.g. the audience. It is also important to know how much *time* you have to prepare and how much time the audience would like to spend. When you communicate your design result, conveying the content of your story is most efficient when paying extra attention to the form and structure of your communication. Consider what main points and minor points you want to make, and in what order.

Communication of design result can have the following forms:

1 An **oral presentation**: e.g. using digital text and images projected with a video projector, on a laptop or flatscreen; poster(s) on a wall; 3D models.
2 A **written report**: e.g. text and drawings, an executive summary for quick readers, annexes for detailed information.
3 **Technical documentation**: e.g. total assembly, mono drawings, 3D renderings.

Elements of successful communication

The most important aspects that should be distinguished and questions that should be answered before working on a means to communicate design results are:

1 Objective: What is the purpose of the communication? E.g. to convince, to inform, to explain an idea, a concept, a product-user interaction… In *informative* presentations you present only the facts, often because your audience needs that information to make a decision or form an opinion. In *persuasive* presentations you present evidence to underpin and stress your own opinion. In *instructive* presentations your aim is to increase the audience's skills in a particular field.

2 Target group: Who will be the audience and what is the interest of the audience? E.g. a client, engineers, a financial manager, a large group or a single person, culture… The more uniform your audience is, the easier it is to adjust your presentation. If you have a mixed audience, they will have less in common and share a smaller common frame of reference.

3 Context: What is the location and how much time and which means are available? E.g. a studio with tables, a congress hall, a chair in a waiting room at the airport, 1 hour, minutes…

4 Means: Which means are appropriate? E.g. posters, 3D models, beamer, role-play, movie, sound, collages, design drawings, technical documents, report…

5 Feasibility: What can be realised within the time, by the means etc. that are available?

Oral Presentation

Designers often have to do oral design presentations for small groups, e.g. a client (i.e. a team with a project manager, a marketing manager, an R&D employee and an assistant). When listening to oral presentations people have some general preferences:

- **Appreciations**: Clear structure, to-the-point content, a gripping, enthusiastic style, with a sense of humour, 3D objects…
- **Annoyances**: Unclear structure, difficult to hear, bad slides, reading from a written text, lack of time or enthusiasm…

Some guidelines for an oral presentation

Content & Structure:

1 Make the objective of the presentation explicitly clear
2 Make and use high-quality visual and oral means
3 Prepare a good introduction (how to get the attention of the audience?)

4 Prepare a clear structure of the content
5 Prepare a good closing of the presentation (e.g. summary or message…)

Presentation Technique:
1 Keep good contact with the audience
2 Use good speaking skills (practise!)
3 Listen to your voice: the right volume, intonation, articulation, speed
4 Use suitable body language (for a big audience use large gestures)
5 Show involvement, enthusiasm
6 Use the right means at the right place
7 Give examples and/or checklists

Written Report

Designers often have to present their work in the form of a document or a report. In the setting of a study, reporting on the process and the progress of the design is very important in order to receive constructive criticism from coaches and teachers. A written report can have the objective of explaining a design (process) or convincing an audience of the value and quality of a design. When explaining the process of design, a chronological order is suitable. When aiming to convince your audience, the structure of a report can be different, e.g. in a logical order.

Some guidelines for writing a report

1 Structure: Every report contains an introduction, a body and a conclusion.
2 Content: The content of the report serves the purpose. When explaining a design process, you should pay attention to the relevant stages of the design process. Make sure that you remain to-the-point.
3 Layout: By paying attention to the layout of a report, you contribute to the readability and appeal of the report.
4 Visualisation: When explaining a design, make sure to use self-explaining, clear visuals (2D and 3D sketches and renderings). Do not forget to explain how the intended users in the intended context will use your design.

Technical Documentation

The most important objective of technical drawings is: Unambiguous recording of a design in order to:
1 Evaluate the design result (discussing with yourself and other parties)
2 Explain the production of the product, including assemblies (to production engineers)
3 Control dimensions/measurements
4 Calculate and discuss sales (e.g. quotation)
5 Communicate maintenance and disassembly
6 Certify the product.

In order to be understood by all parties involved, the technical documents have to meet the TecDoc international norms, these are conventions for:
1 The way of drawing
2 The representation of parts
3 The recording of parts.

There are 4 types of drawings to be distinguished:
1. Total assembly (according to conventions!)
2. Mono drawings (according to conventions!)
3. 3D renderings
4. Animations.

The 10 TecDoc commandments for Bachelor students at the faculty in Delft are:
1 The identified parts should be fully described
2 Scales should be clear
3 It should be clear who the draughtsman is (name)
4 Projections should be right
5 The number of views should be limited
6 Lines should be clear
7 Symmetry should be obvious
8 The shape should be established
9 Parts should be detectable
10 The parts list should be complete.

References and Further Reading

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For IDE staff and students:

Werkboek Technisch Documenteren IO1010/IO1050/IO2050 (2009-2010) (Workbook Technical Documentation IO1010/ IO1050/IO2050)

See: http://www.microwebedu.nl/bestellen/tudelft (Printing on Demand).

This workbook includes a CD-ROM with Tips & Tricks (including the 10 TecDoc commandments) and a selection of relevant norms of the digital reader "Technisch Documenteren" (Augustus 2004).

See: http://blackboard.tudelft.nl/bbcswebdav/orgs/tud-ed-io-tecdoc-snaps/Dictaat%20TecDoc.pdf

3.3 Reflection & Design

What Is Reflection?

Reflection is reconsidering or pondering on something (an experience, a theory, an event etc.). In the context of design education, reflection is an essential instrument in the learning process. Learning is a cyclic process: performing, becoming aware of what we do or think, understanding it, imagining what to do in a future situation, performing, becoming aware again and so on. In order to become aware of what is successful and what not, we have to look back and forth and reconsider what has happened and what might happen. This whole process we call 'reflection'. In the context of the design courses we distinguish between 'reflection on design methods' and 'reflection on personal design behaviour'.

Why Reflection?

Learning how to design is a complex process: designing is an activity that requires a multitude of skills, techniques and methods and uses various disciplines. Learning how to design implies mastering the skills, techniques and methods, and learning about the various disciplines involved in designing. You master the skills, techniques and methods by applying them in design projects. Through reflection on your project and learning process, you are able to design more efficiently and improve your skills in each consecutive design course. Using various reflection techniques helps to extract important learning based on experience, which is unaccountably richer than can be described by some theory. Of course, both are important, and it is through reflection that a conversation can develop between experience and more general theoretical models and theories.

Reflecting on Design Methods (the Process)

Some examples:

1 A specific design method at some point appeared not to be as successful as expected and needed some changes in order to be useful for the project. For example, the morphological chart is normally used to find basic solutions for technical problems. When used for other, less technical problems (for instance for the inventory of subsolutions for a specific idea), the morphological chart is useful but not in the way as intended. You might miss the profit of this method. In order to understand the method it is therefore useful to reflect after using it by asking questions such as: How did I use the method, what is the difference with the original idea of the method, did it work and can it be done again under the same conditions?

2 A specific design approach does not produce satisfactory results. For example, you start to draw design solutions for an initial problem, but cannot think of more than three solutions. Design methods such as brainstorming can be helpful. However, methods are often used the wrong way and may thus lead to inappropriate or dissatisfactory solutions. The solutions are rejected and the method used is blamed wrongly as 'not useful'.

3 When using an LCA (Life Cycle Analysis) you may not be able to maintain the discipline to ask yourself over and over again: "which process is influencing the product during the previous main process or subprocess". Due to the lack of discipline the LCA becomes corrupted and incomplete. You then tends to reflect on this method as 'not suitable for me'. The design method is wrongly rejected.

Questions that are helpful to reflect on the design methods used are:

1 Which method have I been using, what was my experience with it, what aspects triggered my mind and do I have any recommendations?
2 What has happened so far, how did I use the method and did it lead to satisfactory results?
3 How will I proceed and why adopt this particular way forward?

Reflecting on Design Behaviour

Two examples of personal behaviour that do not lead to satisfactory outcomes:

1 You are generating lots of ideas and gathering more and more information while running out of time. This might be due to the inability to make decisions. In the section 'Traps' this is called the trap of 'postponing decisions'. Reflection on your personal behaviour can help to gain insight in order to develop strategies to replace your unsuccessful behaviour by successful behaviour.

2. A student is getting lost in details (a trap) and thus losing the overview of the design task. Reflection will help to become aware of this behaviour and to look for new, more successful behaviour. In the section 'Tricks' the advantage of having a 'helicopter view' is explained.

Theory

Kolb has published some literature about reflection, for example the 7 steps: *Learning to reflect*, November 2000 Source: www.oro.hva.nl

1 How did I perceive the situation and how did I interpret it?
2. Which goals did I set on the basis of step one?
3 Which approach did I choose and on the basis of which considerations?
4 How did the situation develop and what was the outcome?
5 What were my thoughts and feelings directly afterwards?
6 Which questions and insights arose from this?
7 Searching for improved action

Kolb presents these steps as a learning cycle. In the first stage the student starts from a concrete experience and reflects using steps 1 to 6. With step 7 he asks himself "How do I continue?" In the second cycle the student starts with the result of the first cycle and reflects on it by again using steps 1-6, making it possible to adjust things if and when necessary.

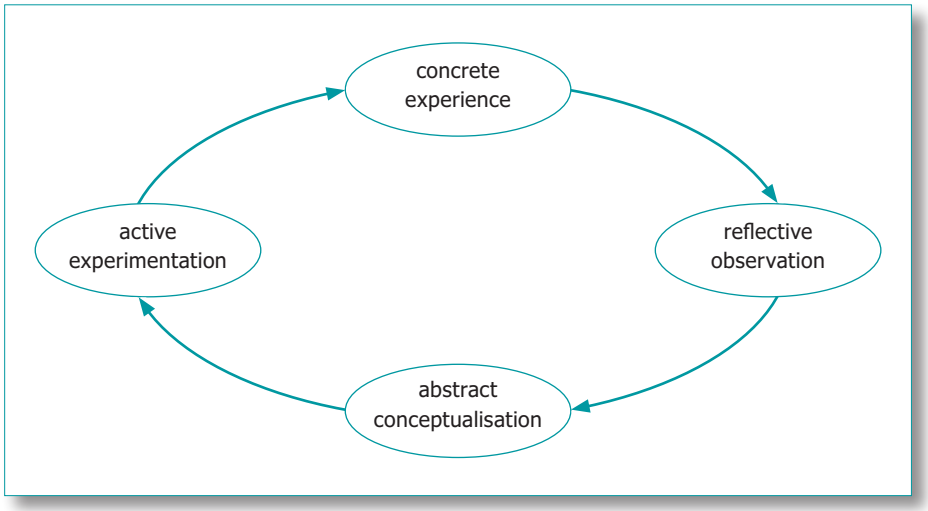


fig. 3.2 Kolb's experiential learning process (Buijs, 2003)

When Can I Use It?

It is important to reflect in time (just after the subject you want to reflect on) in order to remember the important aspects. You can use the reflection method just after completing a specific activity. This activity can be an applied design method (for instance a brainstorm session) but also a range of activities, for instance one completed in a specific design phase. Reflection on a regular basis, for instance every last day of the week, can also be very useful.

How to reflect?

Possible Procedure

1. Experiencing (awareness)

Make notes of your remarkable events, they might have been difficult or are worth thinking over for some reason. This might be directly related to design methods, but may also be related to a specific event, design challenge or problem. By reporting your experience you strengthen your awareness.

2. Understanding (analysis)

'Unpack' the events by questioning yourself. What causes can you distinguish for your results? Which theories are supporting you? What is your personal opinion? Do you know comparable situations?

3. Imagining continuation (synthesis)

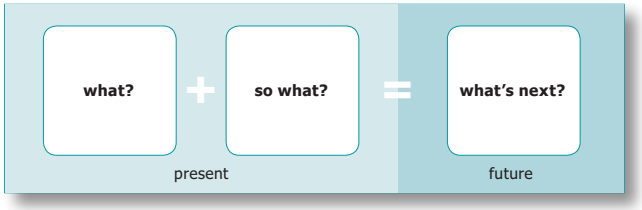
Question yourself and look for answers that are useful for the next steps in your project or in a new project. How will you approach a comparable situation? When have you achieved what you want? And how will you achieve what you want?

4. Applying (performance)

Use your insights in a next design activity, phase or project. And so on with step 1 (it is a continuous cyclic process!).

Step 4 is actually not part of a written reflection, but of course it is an important step of the learning cycle.

A shorthand version of the above process is: What, So What, What's Next? (Developed by Marc Tassoul)



1. What?

What events and items do you remember? List all the things that you have noticed, without any explaining or elaboration. It is just a list of possibly interesting subjects to reflect upon.

2. So What?

First, select a limited number of most interesting or relevant items from the above list (often somewhere between 3 and 7 items) – and 'unpack' each of these with questions such as 'Why did I notice it? What was the effect? Was it a good step? Was it fruitful? Did I run into trouble? Why was it successful?' and so on. In this way you are building an understanding of the event or item.

3. And Now What?

What will be your next action in relation to the considerations generated in '2'? These can be learning how to approach some question next time, it could be a change in your process, it could also just be the discovery that your approach did work, and that for next time, you need to remember this procedure when you get into a similar situation.

Tips and Concerns

- Reflect on the right moment, not at the end of a project, but immediately after using a method, or at moments when the design process exhibits remarkable changes. You should report your reflections in text (usually once per week) to show how the process took place, what methods you used, how you experienced them and where they were used differently. In other words: "What, How, Why and Where from here?"
- Make a distinction between reflection on design methods and a reflection on personal design behaviour.
- When reflecting on design methods, refer to the literature you studied in order to understand the design method.

Your tutor will assess your reflection by answering the following questions:

1 Does the reflection show that you understand the method?
2 Have you explained why a certain procedural step was taken?
3 Have you properly reflected on all relevant steps during the design process?
4 Do you exhibit an insight into the usability of the method?
5 Have you used the method correctly and, if not, has the student properly described and explained any alterations?
6 Have you displayed a capability for self-assessment using a certain helicopter view?

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By Stefan van de Geer. As a senior design tutor, Stefan experienced many obstacles students face during concept development. This collection of traps, tricks and strategies will support your learning process.

3.4 Traps, Tricks and Strategies & Concept Development

Introduction

At our faculty, and specifically in our design courses, we devote considerable attention to the *process* of designing. Methods and techniques are described, experienced and used. They result in a well-defined and developed product. The basic cycle of designing, which involves structured phase models of the design process, morphological analysis, evaluation strategies (Roozenburg, 1991), helps the designer to achieve the desired result. One of the most important phases is the period in which the product is conceived.
This period starts after the analytical phase (defining the problem, analysing the target group, etc.) and ends somewhere in a phase of materialising the final concept. During this period, many decisions are made that have great impact on the outcome.
If we divide this phase into two sections, we can derive concept-forming and concept development elements. For concept formation, several techniques and methods are available to generate ideas, such as brainstorming, morphological charts and Mind Mapping. Eventually, this path will lead to a basic concept. However, there is a shortage of supporting techniques for concept development. Trial and error seems to be the guideline in a phase in which uncertainty, change and stress are key issues. It is a phase that ends with a feeling of 'Eureka!' if everything comes together and the balance sought is found. Complex integration problems occur and there is a need for detailed information. We are still able to use the aforementioned methods and techniques in parts of this process, but reality is far more complex and every single action will affect the overall outcome. Considerations of price, manufacturability, material selection, construction, usage and form all interact with each other and put pressure on the designer's responsibility. In contrast with the many methods and techniques for idea generation, there is a lack of similar methods for developing the concept into an end product that satisfies the defined requirements.
Delft's experience of teaching design has enabled us to identify some 'traps' that constitute obstacles for students in making the right decisions at the right time. Obtaining an insight into the traps and devising 'tricks' to overcome them will help you to complete this phase successfully.

Traps

Narrow View

When confronted with multiple design problems, you may often be inclined to focus on one specific aspect or problem if it happens to be the easiest part of the total. You may put all your energy into tackling the problem, but at the same time forget about its relationship with other aspects of the design. Once discussed with the tutor, these relationships can be pinpointed and the enormous amount of energy spent on the single problem may turn out to have been a waste of time. You had too narrow a view. A narrow view can occur, for example, when operating in only one field. An example is focusing on shape and forgetting to consider the production method or usability. A narrow view can also occur in designing some specific activity, such as the rather quick choice of one particular principle of operation without identifying its influence on other matters. The danger is that this influence will not become apparent until the end of the project or until a discussion with the tutor at a point in time when the chosen solution has already been detailed. It would be far better to recognise the influence earlier, before a lot of time and effort has been invested.

Compensating Behaviour

Uncertainty, a lack of experience, a lack of knowledge and a lack of information – combined with the project deadline – may force you to adopt compensating behaviour. Although you realise that the problems are complex and difficult to solve, you are reluctant to force yourself to tackle the problem. You know you should, but you don't. Instead, you fill your reports with copied information and treat a simple problem extensively on the assumption that the tutor will accept it as proof of your capability. An example is

extensive research into operating handles, knobs and push buttons, which are copied from literature accompanied by handwritten text, which amounts to an exact copy of the original literature.
It is understandable why you could adopt this approach. You avoid the real problems, do not see any way to get to grips with them but want to produce something all the same. This behaviour sometimes acts as a decoy, in spite of the fact that it might help to set the mind at ease. Simply staring at a blank piece of paper is no help at all.

False Solutions

One of the most significant 'traps' is the development of false solutions. Given a certain design problem, most of you know that alternative solutions should be developed to allow an evaluation as a stepping-stone to the right choice. We know from experience, however, that students first report all possible solutions, including theoretical ones, only to discard all of them except one. If a hinge has to be designed, for example, you may typically produce a complete list of solutions for a hinge, like a hinge for the cover of a piano, a hinge for normal doors, welding hinges, a snapping hinge for plastic boxes, a simple pin-and-bushing, a plastic hinge made of POM like the ones used in cheap suitcases and so on. After making this list, your rejects the welded hinge because the product is made of plastics, the piano hinge is rejected because of time-consuming mounting, the snap hinge is rejected for its poor strength, the simple pin-and-bushing hinge is discarded because of its poor shape, the door hinge because it needs too much room. The last remaining solution is chosen because it is simple, cheap and fits very easily to the plastic base of the product. All of the rejected solutions are actually 'false' solutions. In effect, you automatically include solutions that are not solutions, on the pretext of allowing a responsible choice to be made.

Clamping

Clamping occurs when you have developed a part but does not wish to relinquish it. To some extent, this is due to a narrow view, but your stubbornness or fixation can also play a role. It is not easy to let go of a solution once it has been developed, because other problems not yet recognised remain attached to the solution. Clamping often happens unconsciously. This may be the case if the design has been examined initially and judged to be more important than construction, cost price, assembly, ergonomics and so on. A single aspect is given dominance above all other aspects, creating the danger that you must exercise all kinds of manoeuvres to find halfway decent solutions to the other aspects. Sometimes you will recognise that the dominance of the single aspect is wrong, but will know that a lot of energy has already been devoted to it, the result being a tendency to avoid redesign.

Suppressing Individual Development

Another trap when developing concepts - more specifically in the early years of study - is that you play yourself entirely at the service of the design tutor because of the complexity of the matter. This creates a classroom approach where the tutor is often asked questions like "What should I do?", "How far should I go in working it out?", or "Is this OK?". The report is produced for the tutor, because the workbook says this is what should happen. However, designers need to bear in mind that not all methods are equally usable at all times. Compiling a list of requirements using 'process trees' (LCAs) may result in a large degree of completeness, but it is cumbersome and time-consuming. What is more, after reading the report, people could be discouraged from using process trees. Slavishly integrating anthropometric data in a design may look tempting, but in many instances there are also other factors that influence dimensional characteristics. People usually wear shoes, they are clothed and the optimum ergonomic dimensioning is not always meaningful. Everybody will recognise that fold-up seats in trains are not intended to be sat on for hours on end. Matters of this kind result in dutiful activities in which a person's own contribution is suppressed and thwart individual development.

Postponing Decisions

Putting off decisions can be right in many cases, but they do have to be taken as time progresses and the deadline appears on the horizon. Repeatedly postponing decisions can result in delays. If a tricycle has to be designed, it seems to make sense to decide right away to equip the vehicle with three wheels rather than two wheels or more than four wheels. If costs are an issue and the client does not wish to invest in producing wheels, an immediate step can be taken to obtain information about existing, obtainable wheels and a decision can be made fairly quickly.

Lack of Argument

Very often, a design tutor is unable to see why a decision is being taken. All the way through to later years, decisions are taken that appear to be based on nothing. An example is a student who has drawn eight different screws and then declares to have opted for screw A. That's it. No further explanation. A decision sometimes stems from a gut feeling, but the point is that some kind of motivation and argumentation must always be given to support the decision. This matter is obviously related to a predefined basic principle, an analysis conducted earlier or a certain philosophy.

Some tutors say that during the course you must ask yourself "Why?" before everything that you do. There is usually a justification, but it is not always made explicit and in such cases the tutor has no option but to conclude that no arguments exist. The situation may be different after your study, as in the case of the celebrated designer who had designed a wonderful product, and when asked about the underlying motivation replied: "I may have laid the egg, but I'll leave the cackling to others."

Tricks

Helicopter View

One of the most important attributes of the designer is the helicopter view. From time to time, it will be necessary to step away from the elaboration of a certain problem in order to zoom out to a higher level so as to survey the consequences of possible decisions in other areas. Only with such an overview you will be able to integrate your solutions and combine them into a whole. This applies to product properties, but importantly also to the path being followed and the process. Adopting the helicopter view early on in the development of the concept also promotes the will to change, helps to distinguish primary matters from secondary ones and thus to determine a strategy. Similarly, a helicopter view is indispensable when evaluating solutions for product properties. Everything is interconnected and the right decision can only be taken if you have an overview. The method of presentation - the illustration of the brainchild - can also have an influence in this regard. So show where the details are located in the design, make complete cross-sections instead of zoomed-in sketches that 'conceal' the rest of the product. This is advantageous not only for the design tutor, who needs to form an impression, but also for you as a student, because it facilitates a far earlier discovery of other problem areas.

Change

Be aware that theoretically anything is still possible during the development of a concept into a sketched design. During the process, you obtain a progressive insight, more information and more experience, meaning that changes occur. Reference was made earlier on to the 'trial-and-error' aspect of designing. Still more slogans are conceivable, like 'Designing means falling and getting up again', 'Designing is always two steps forward and one step back' and 'Designing is a jigsaw puzzle'. Choosing a certain principle does not mean you have to stick to it no matter what.

Structure

Complexity sometimes makes it necessary to inject a little structure. As a concept is developed, the paths that need to be followed become visible, allowing a conscious choice to be made about the direction to be taken – just like a certain distance can be covered during a walk by following a route marked by one particular colour. Following all the colours during the same walk will give rise to the danger of getting lost or going round in circles. So examine beforehand how much time there is and what goals must be achieved. A different analogy is the one with a jigsaw puzzle. When people tackle a jigsaw puzzle, they will not pick up an arbitrary piece to compare it with all the other pieces until they find one that fits it. Usually, people will create a framework, sort the pieces according to colour and try to form an impression of the result. Green pieces will generally be placed at the bottom and blue pieces at the top. However, a prearranged structure can also have a slowing effect. It often happens that a person has worked correctly in terms of structure and process, but that the product turns out to be unsatisfactory. From time to time, therefore, it can be beneficial to depart from the structure to examine the matter from entirely different vantage points. This, too, has to do with the helicopter view - step away and allow yourself to become detached.

Analyse

A tool for injecting structure is formulating basic principles at every level of the design process. Performing a shape study is not merely a question of

drawing all kinds of shapes and then choosing one. It can be preceded by formulating basic principles like "What impact do I want the design to make on the user and how do I translate that?", "At what levels can I view the design and at what level should I start?" Try to define a certain philosophy on which to base the shape study. At a constructional level, too, it can be useful to formulate basic principles. And in almost all cases, an initial analysis of the problem or subproblem can be instrumental in demarcating the scope for a solution and in creating a framework from where solutions can be generated. Conversely, it can sometimes be more comfortable simply to start sketching to form an impression of the possibilities that exist. As you sketch, a philosophy will unfold that can serve as a basis for taking decisions.

Balance

Taking all disciplines into account - designing is a multidisciplinary activity - the key to success is to find a satisfactory answer to all the aspects involved. Everything is connected with something else and the art is to dilute certain aspects in order to make others tastier. It is about finding a good balance between design, cost price, usage, production and so on. Few people are capable of excelling in all aspects, and it is an almost impossible task in Bachelor design projects within the allowed period of time. Striving to achieve the balance and the will to make concessions should obviously not result in a design in which everything just barely comes up to standard, because an excellent design can counterbalance a high cost price. The efforts must result in a design in which everything has been optimised. This optimum must be achieved within the defined requirements and wishes, while fulfilling the formulated basic principles and goals.

Knowledge, Information and Communication

It may be assumed that knowledge will always fall short of what we need and there will always be a need for information. Although a very large volume of information is available, we again have to contend with pressure of time and the goals to be achieved. But one thing is certain: during the development of a concept there will be a need for relevant information and specific knowledge. The strength of an industrial designer lies not so much in his own knowledge as in communicating with specialists and finding information. The products around us are a permanent source of information. When confronted with design problems, an analysis of existing products can yield immediate solutions or generate solutions. Similarly, by disassembling and reassembling products we can gain an insight and practical know-how that will undoubtedly prove useful at some stage. The design tutor will in some cases obviously be able to impart knowledge, or in any event provide advice on where information may be found. The technical documentation centre possesses a great deal of information and there is no ban on consulting a specialist or other design tutor at Delft University of Technology or at a company. Very often, short but informative telephone calls can be very helpful. On the process side, too, knowledge is necessary; carrying out a shape study or developing theoretical solutions can be preceded by an examination of the related literature.

Dreaming

Daydreaming is a final "trick" worth mentioning, obviously in the context of solving design problems. Design is more than a nine-to-five desk job, because a design problem should go around in your mind 24 hours a day, sometimes unconsciously but very frequently consciously. Just as the sleep cycle kicks in, the brain can briefly be reactivated to re-examine the design problem from every angle. Imaging is a good term for describing this activity. By calmly thinking through a problem once again, a new impression or image will often emerge, which may lead to a solution to problems. The designer will go to sleep with a satisfied feeling and immediately work out the details next day. This involves the well-known helicopter view. An example is a designer who is snowed under with problems during the day, holds meetings, hears counter-arguments to his proposals, has received more information that makes the problem even more complex and so on. Precisely at a quiet moment, at the moment of relaxation, the designer has an opportunity to ask himself whether his approach is correct and what the core question is. He may realise that the product must above all be extremely easy to operate. This boils down to a kind of proposition: "Let's say that the user needs to perform only one action" or "Let's say that the user needs to do nothing and that the..." and "Let's assume that the entire product consists of only three parts...". Based on basic principles of this kind, a door can suddenly open to all kinds of decisions, and problems disappear. This is obviously just an example, intended to demonstrate that dreaming can be a tool for tackling the design problem.

Strategies

Awareness of the aforementioned traps and the informative comments made in the second paragraph should lead to a degree of reflection, but the question that obviously remains is this: "Is there a certain method or strategy for developing a concept?" Should you start with a rough idea and work it out in increasingly greater detail as you head towards the final goal, or is it wiser to attempt early on to make allowance for everything? Given the idea chosen at an earlier stage, it is first advisable to indicate why that particular idea was adopted. Which objectives will be achieved by means of this idea? Is there anything unique about the idea? And has the thing that makes this idea unique actually been requested in the assignment? Ideas are often challenging, because ultimately "they are just ideas" and it is true that just about everything is possible. When developing a concept, the important thing is to go on demonstrating or examining the possibilities of the idea. This makes the beginning of development clear and it is unwise to predetermine the end of development. Some information about this matter can be found in the workbook or is obtainable from the tutor, but to some extent the person involved will have to indicate how far a design will be elaborated and how this must be recorded.

The 'Fish Trap model' of Wim Muller

One of the few people to devote attention to the development of concepts is Wim Muller in the description of his 'Fish Trap model' *Order and Meaning in Design (Muller, 2001)*. Muller describes the method, distinguishing three phases: the structural, formal and material phases. In each phase, variants (sketches) are drawn, which are subsequently categorised. By tracing common features within the categories, it is possible to develop representations into concepts in each category. In the formal phase, a start will be made on materialising the structure developed earlier as a basis. This is the phase where the product is given shape, based on a certain material embodiment. In the material phase, the production of the idea is once again the central consideration, with variation occurring particularly in the 'making' aspect. By categorising and estimating the use and treatment of the 'solution types' developed from the categories, this procedure leads to one or more sketched designs. Muller thus describes a method but the use of this method is no guarantee against avoidance of all the dangers described earlier. However, the method in itself does minimise 'clamping' and a 'narrow view', although if you slavishly follow this method without self-criticism you run the risk of ultimately being faced with a product that is far from ideal.

Describing Design by Kees Dorst

Designer and researcher Kees Dorst examines the properties and limitations of the present design methodology (Dorst, 1997). He developed a methodology that devotes attention to the practical side of designing, with subjects like learning through experience during design projects, the designing of an integrated product and the approach to a concrete design assignment. The thesis describes and examines five strategies against a backdrop of an actual design assignment given to nine experienced designers for completion within a limited time.

a Abstract – Concrete

This strategy is built on a certain level of abstraction, where it is possible to define a central but rather abstract basic idea and to make allowance for all aspects of the design problem at that level. From there, the designer 'descends' to a more concrete level where reality starts to play a role.

b Divide – Solve – Reconnect

This strategy first divides the problem into distinct subproblems, which are then solved before being reconnected to each other. This strategy appears eminently usable for the concept development phase, because the kick-off idea can easily be divided up into aspects that must then be elaborated in greater detail and, as such, can be regarded as subproblems. Experience in design education, however, is that 'reconnecting' frequently gives rise to problems. The individual parts can be solved, but forging them into a whole is not always a simple matter.

c Adopt – Adapt

This strategy is based on adopting a certain solution structure, which is then transposed to the design problem. A comparison is possible with synectics, where you first distance yourself from the original problem in order to discover analogies and then reconnect them by means of a 'force fit' to the

original problem. Dorst (3) does point to the danger that, without a thorough analysis of the design problem, all kinds of assumptions will quickly be made and conclusions will be drawn hastily.

d Prioritise – Solve – Adapt

To obtain a properly integrated design, this strategy first splits up the design problem into elements that have different priorities. It is obviously important first to solve the problems with the highest priority before making the fit with problems with a lower priority. Interestingly, dominance is held to be a trap in 'clamping'. Apparently, the priority will have been set incorrectly in such a case.

e Start – Correct

This strategy simply starts by taking a problem and correcting your standpoint as soon as a problem occurs. It resembles a glass maze, in the sense that you will get out of it sooner or later, but it can take a long time if you are unlucky.

Evaluation of the Strategies of Kees Dorst

Both of the first two strategies are particularly useful if it is necessary to limit the volume of information that has to be processed in one go. The 'abstract - concrete' strategy is used very little for the design of products. The last three are especially handy when there is a need to limit the number of connections between all aspects. The strategy of 'adopt - adapt' obviously requires previous experience of product design, which at the start of the second year of a design course is barely present if at all, while the 'start - correct' strategy is by definition highly untargeted and inefficient. The research conducted by Dorst demonstrated that the two best designers (of the nine) used 'prioritise - solve - adapt'. This method therefore produces good results. At the same time, however, Dorst mentions that the strategies can also occur as a mix within one and the same design assignment. Moreover, it is not automatically so that the last strategy always results in a poor design. It is important to recognise that Dorst in his research advocates making a designer aware, by means of reflection, of his pattern of actions so that, if necessary, the right course can be set.

Conclusion

It may be clear that there is more than one road leading to Rome. It makes sense to use a process framework - like the edges of a jigsaw puzzle - within which a design must be created. A frame of this kind is formed on the one hand by the list of requirements and on the other by the designer's own vision, making it possible to determine whether the chosen idea will fit into the frame. From there, it appears wise to divide the chosen idea into distinct subproblems. No matter what design problem is involved, a prior analysis of the problem appears to be essential.

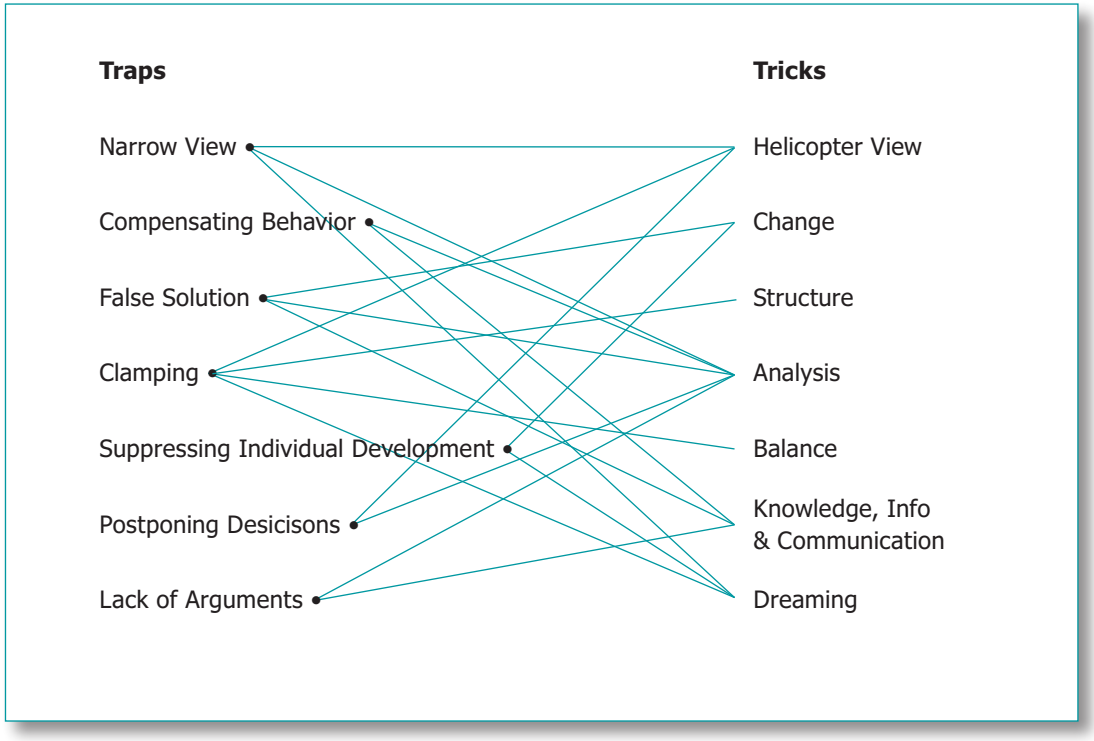

fig. 3.3 Find your own 'tricks' to overcome your 'traps'

Such an analysis must answer the question of "What are all the things that are related to this problem?" Matters like ease of operation, manageability, assembly or safety are examples of questions that must be solved integrally.
A problem is never a stand-alone affair. The second step is to find solutions to the subproblems. Various solutions are naturally possible, but they must not be 'false solutions'. The choice of solution then depends in part on the other subproblems. The choice will sometimes be postponed until all subproblems have been resolved. Information plays a crucial role when looking for solutions, while customary methods for generating ideas are usable, like brainstorming, morphology, synectics and similar ones. It is always useful to include existing solutions (adopt-adapt) and solution structures. The helicopter view needs to be maintained at all times. It is necessary permanently to consider whether the path taken is the right one. And it will repeatedly be necessary to take decisions as soon as they can be taken. After all of the solutions have been identified and integrated with each other, there will be a feeling of 'Eureka!' and the development of the concept can be considered completed.

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3.5 Teamwork & Design

Why is teamwork important?

Sometimes great inventions are the result of the ingenuity and effort of an individual. But in most cases designers do not work on their own. Francis Jehl, one of Thomas Edison' long-time assistants, once explained that, "Edison is in reality a collective noun and means to the work of many men". He referred to the team of engineers that worked with Edison (Hargadon & Bechky, 2006).

Today, products become increasingly complex and therefore cannot be designed by one person alone. They require diverse expertise in different fields of technology, in user research, in manufacturing and production technology, and in marketing and distribution. This is normally too much for one person. More people can also share the workload and thus develop products in less time. Hence the normal way of developing products is in teams where different people contribute part of the knowledge and effort (Lauche, 2007).

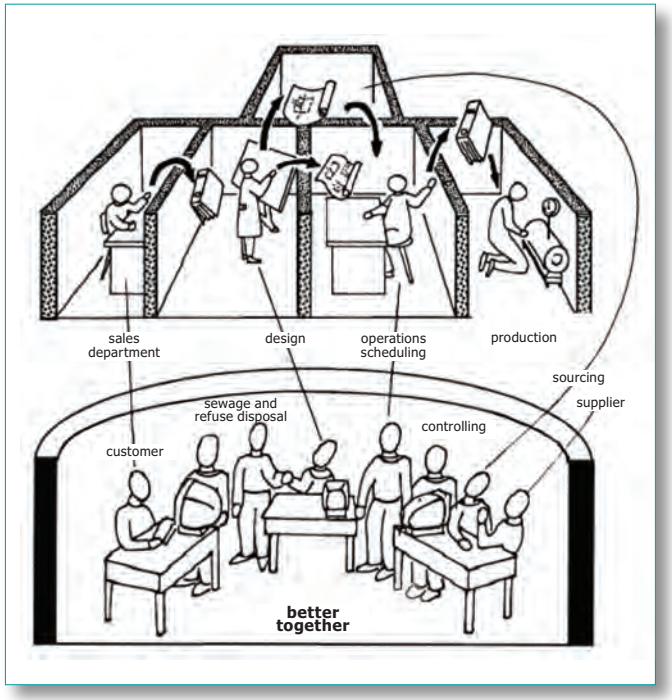

fig. 3.4 Integrated product development (Ehrlenspiel, 1995)

The better the team works together, the more efficient they will be. The idea of integrated product development is that people from different functions and areas of expertise collaborate early in the process so that the requirements of users and of production can be considered in the concept stage (see fig. 3.4). Spotting potential problems early means they can be fixed before it becomes labour-intensive and expensive. Thus cross-disciplinary collaboration helps to shorten time-to-market and to reduce development costs.

Our education at IDE is aimed to prepare you for this kind of collaboration by exposing you to a lot of project work in teams. At the best of time, teamwork is fun: it can be inspiring and stimulating, it motivates you to give your best and there are other that can support you and from whom you can learn. But it doesn't always work that well: teamwork can also be very demanding if you have different perspectives, and it can be frustrating and unfair if you have to sacrifice good ideas for an unhappy compromise or not everyone is really contributing. Teams can be less effective than an individual and they can develop very unproductive dynamics.

The good news is that team working is a skill that can be learned and practised. Even if your team is not working as well as it could, there is usually a way to improve things. Teamwork in New Product Development is especially challenging, because projects are complex and team members fluctuate – but it also offers very good changes for developing team skills (Edmondson & Nembhard, 2009). The following sections explain what you should be aware of and what you can do to improve teamwork.

What to keep in mind?

1. **Teams are often the only option to get a job done, but doing everything with everybody might not be the most efficient way of working.**
   In the same way that too many cooks can ruin a meal, too many people on a job can mean that nobody really feels responsible. If everybody thinks that somebody else will do it, then often nobody actually does anything. This is called "diffusion of responsibility" and is more likely to happen in large teams.
   What you can do to prevent diffusion of responsibility it to clarify roles and responsibilities and to make

sure that no more people are assigned for a specific task than are actually needed. If you look closely at figure 3.4 on integrated product development, you can see that two or three people are working together at a specific task – not everyone with everyone.

2. Teams need time before they can perform at their best.

Before you can be really productive in a team, you need to get to know each other and establish a common way of working. Tuckman's model of team development says that teams go through phases: in the forming phase, people are polite and careful and want to get to know each other. In the storming phase, they will start to explore what is possible and acceptable in the team and how dominant, how laid-back or how cheeky they can be. Once the boundaries have been tested, the group enters the norming phase in which it establishes its own norms and standards of behaviour. Only after that a group will reach the performing phase and will be able to operate at their full potential (see Lewis). Not all groups go through all stages, or they might encounter conflicts and storming again at a later stage. But it is good to keep in mind that establishing a good basis for teamwork takes time. You can shorten the time by doing activities together that help to get to know each other, and you can discuss goals and expectations to make the storming and norming more explicit.

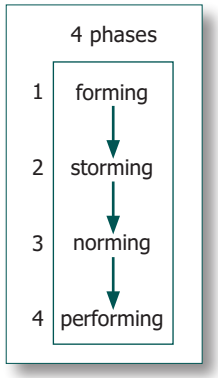

fig. 3.5 Phases of group development according to Tuckman's model

3. Diversity usually helps to be more creative, but can make coordination and shared understanding more challenging.

There has been a lot of research on the effect of diversity in teams in terms of gender, age, educational or cultural background, and the findings are mixed. The consensus that seems to be emerging is that diverse teams come up with more diverse and more innovative ideas, because they have a broader range of experiences to draw on. But they find it more difficult to create shared understanding about the task and communication is more difficult. The effect of diversity also depends on people's personal preferences: those who enjoy complexity and don't mind if it gets more difficult, also work better in more diverse teams. Those who prefer the world to be simple and straightforward can find diversity disturbing and frustrating.

So to make the most of diversity, invite people to bring in their varied experience when generating ideas and diverging. For converging and decision-making, try to establish a shared goal and a procedure that all team members feel comfortable with. This wil allow you to become more cohesive and effective.

4. Groupthink can happen

Groupthink refers to a very cohesive group where people become so focussed on a consensus within the group that they are uncritical and forget what is happening around them. The historical example for this is Janis's analysis of the Cuban missile crisis in the 1960s (see (Levi, 2007) in which the advisors to the president became very inward-oriented and failed to consider the adverse consequences of their decisions. Groupthink means that teams consider themselves invulnerable – nothing can go wrong –, they think of themselves as much higher than everyone else, can belief they are inherently right. They therefore fail to think in alternatives and do not seek the advice of outside advisors.

Examples from new product development include a case where a whole team working on a plastic bag dispenser did not properly analyse the market needs because they were so focussed on the technical problems. The best precaution against groupthink is to be open to criticism and to reflect and question what the team is doing on a regular basis.

What you can do?

There is no recipe that leads to guarantee success in teamwork. But there are a number of things that you can do to build a good basis or to deal with problems if they arise.

1. **Clarify your goals**: It is always a good idea to make sure that all group members have the same goal and vision of the project – it helps to maintain motivation and to sort out misunderstandings early. Discuss the requirements of your assignment together and question the task: what is it that you are trying to achieve? Also talk about your expectations: What do you personally want to get out of this? How good is good enough for each team member?

2. **Create an open atmosphere in the team** where people feel safe to say innovative, weird, new, critical or awkward things. The more open your team is, the more likely it is to be really innovative. You can contribute to this by phrasing your own criticism as constructive suggestions and by taking other people's comments as feedback and further development of your ideas, not as an attack. Design teams are at their best when you can no longer distinguish who contributed what to the final solution (Hargadon & Bechky, 2006).

3. **Use a combination of techniques and creativity methods** and alternate between working with the whole team and assigning tasks to individuals. This will enhance your creative output (Paulus, 2000), and it also provides different ways of working to suit different personal working styles.

4. **Hold regular review meetings within the team** where you discuss the progress on the task and the quality of the teamwork. This helps to get feedback and to spot potential problems early. Regular self-evaluations help teams to learn what they are doing well and how they can improve, and they have been shown to lead to better outcomes (Busseri & Palmer, 2000).

5. **If there is a conflict, talk about it.** If you have different ideas about the design or the process that should be followed, or some people in the team do not feel valued or well integrated, it is best to address this. Some conflicts disappear over time simply by waiting, but most can be solved faster and more productively if you talk about the differences. The best strategy is to be polite and friendly in tone, but clear in what you want to achieve. Remain fair and treat the other side with respect – this makes it more likely that they will do the same with you. You can then explore options that ideally meet the needs of both sides.
Usually conflicts can be solved within the team. If you find yourself in a situation where you have tried your best without a satisfying solution, it is a good idea to look for outside help, such as the course coach or the student counsellor.

Watch interview with Abke Geels and Mark Assies (Flex/the Innovationlab) via the OpenCourseWare version of this guide: http://ocw.tudelft.nl

References and Further Reading

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3.6 Finding Information & Design

Industrial designers have to familiarise themselves with a new industry time and again. Furthermore, you often find that you need to use (standard) parts from an entirely different industry. Vacuum-cleaner hoses are sometimes used in toys, for example. For many designers, this regularly creates the need to find information in fields entirely different from the ones they are accustomed to. You can approach searches of this kind from various angles. Avoid spending too much time searching unsuccessfully in one particular way; if one avenue of searching does not yield the required information, switch to a different avenue in good time.

The most successful method of searching is a combination of a search for theoretical information and documentation supplemented by face-to-face talks with experts. So besides looking for the theory, you will need to find suitable persons or companies who can tell you more, either over the phone or during a visit.

Examples of Search Methods

The Library

This is a general source of information that needs no further explanation. But do not forget to look in other libraries of a specialised nature (construction, mechanical engineering) for extra information. Libraries have other search avenues apart from 'just' the books on the bookshelves.

Old Theses

Every graduate starts with a thorough analysis of his or her subject. The analysis is often far wider than the subject itself. The target group analyses, appendices and lists of references are often extremely useful sources of information, both as a direct source of knowledge and for pointers as to who to approach for a particular problem.

Reference Works

Lecture notes from your own subjects and lecture notes from optional subjects in the field of industrial design. Similarly, lecture notes from other faculties can sometimes be very enlightening. Also, check whether you can find lecture notes in one of the special subjects.

Experts

As a Delft student, you are in a privileged position, because throughout the campus and in the faculty building you can find many people who are highly expert in specific fields. These fields include ergonomics and areas like flow technology, bearing technology, pressure technology, tactility and so on. Experts can also be found outside the university - at your home, among your family, or at companies you can find on the Internet. Think of places where there are people who may know more about the problem facing you and get in touch with them. Prepare your conversation with them thoroughly; ensuring among other things that you already know the requirements the part must satisfy (what kind of load, speed, conditions, size do you need?). The more accurately you know what you want, the faster you will find somebody who is prepared to help you, and also somebody who is capable of assisting you in solving the problem.

The Internet

The Internet is the medium students use most to search for information. In order to use the Internet to good effect, however, you do need to approach your search in the right way. There is loads of information on the Internet, but whether or not you find it depends on how you conduct your search. Here are some tips:

1. Keywords. Choose your keywords carefully; change them if they fail to lead to the information you want, add to them if you get too many hits, make them more general if they produce too few hits.
2. Search engines. No two are the same. Ilse typically gives more Dutch hits than Metacrawler or Google. Yahoo extracts hits differently from Lycos and so on. Switch search engines if you cannot find what you need.
3. Look for umbrella sites: do not search for one specific part (like an L section), but search according to industry associations: aluminium organisations, the Wood Association, playground equipment associations, etc. From these umbrella sites, links will

often lead you to a particular part you are looking for. Organisations like the Aluminium Association can probably tell you more about the standard parts that occur in the industry.

4 Do not forget to consult the Delft University sites! The Industrial Design website will often take you to valuable databases, sometimes via the blackboard. Ask the library how to reach "Standards Online" via the Internet, for example.

5 Combine your searches with telephone calls: on the Internet a designer seldom finds all the information that he/she needs. Numerous companies (engineering and otherwise) do not yet have their entire range of products on the Internet. So use the Internet to get an overall picture of the market in which you are looking for information and to identify useful people to contact.

Use of References

Be sure to state clearly in your document which references you have used. Look in other courses to see how this can best be done. Plagiarism is punishable!