KTH Machine Design

User Consideration in Early Stages of Product Development – Theories and Methods

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This is an academic thesis, which with the approval of the Department of Machine Design, Royal Institute of Technology, will be presented for public review in fulfilment of the requirements for a Doctorate of Engineering in Machine Design. This public presentation will be made at the Royal Institute of Technology, Salongen, KTH Library, Osquars backe 31, Stockholm, on 29 April 2005 at 10:00.

Abstract

Traditional design theories have focused on technical functions and more or less disregard a product's user involvement. The existing methods of ergonomic design are mostly intended for analysis activities. There is a need for new dynamic methods that focus on user-product interactions. The aim of this research work is to develop design methods for user-product interactions, which should support synthesis activities in early product development phases.

An observation study and a questionnaire survey were carried out in order to investigate product developers' work and relation to the users for providing background information about the research problem. Furthermore, student projects in product development were followed, giving essential input. After the theories and methods were developed, a retrospective interview study was carried out in order to confirm the need for the developed methods. The studies showed, for instance, that companies use few formal methods and almost none of these are directed towards the user. It is also indicated that the product developers' contact with users decreases with increasing company size. Few companies have a defined procedure for defining their intended users.

Six methods are developed. They embrace three ways of classifying the users and their relations to products and other users (*User identification*, *Use profile* and *User relations*), an analysis of the users' *Activities, goals and motives* behind their use of the product, a scenario technique (*User-technical process scenario, UTPS*), which shows the user process in parallel with the technical process, and a hierarchical decomposition of technical functions and user actions, which is named the *Function-action tree (FAT)*.

All the methods, apart from *FAT*, were tested in real product development teams. All the tested methods stimulate communication between the group members of various competencies in the design group. Most of the methods are easy to apply and are valuable for understanding the design problem. The *UTPS* is also useful for comparing design solutions and generates new ideas about the design task. The other tested methods did not generate many new ideas, but the reason is probably that they were mainly tested on products that are already on the market. Thus, the methods are most valuable in the early design stages, when trying out a product idea or a concept.

Acknowledgements

Many people, in the professional as well as the personal part of life, have been crucial for enabling me to carry out this work and I am extremely grateful to all of you.

First of all, I would like to express my warmest gratitude to my supervisor Professor Emeritus Karl-Olof Olsson, which initiated this work at Linköping University and who, after his retirement, has continued supervising me throughout the work. He has been a source of inspiration, support and encouragement at times of arduous as well as pleasant work. I am also very grateful to Professor Margareta Norell Bergendahl, who brought me under her wing to the division of Integrated Product Development at the Royal Institute of Technology after I had concluded my licentiate work at Linköping University. Moreover, I would like to thank my second supervisor, Doctor Lars Arne Hagman, for always standing up for me and supporting me in all the test studies.

Furthermore, I would like to thank my colleagues at the Department of Machine Design at the Royal Institute of Technology. In particular, my gratitude goes to my colleagues in Integrated Product Development, who have all supported me in various ways in this work and helped me go to work with a happy smile: Niklas Adamsson, my "old" room mate for inspiring discussions and cheerful pranks, Diana Malvius, the new room mate and a pleasant and fresh supplement to the room community, Per Sundström, who has been in the same boat of writing a thesis and is the best person to share the boat with, Gunilla Ölundh for pleasant chats also concerning matters outside the scope of my work, Sofia Ritzén for stimulating cooperation with teaching and Annika Zika-Viktorsson, for her bright sense of humour.

At the same time, my thoughts go back to the Department of Machine Design at Linköping University, where my work started. In particular, I would like to express gratitude to my closest research partners Per Johansson, Micael Derelöv, Sören Wilhelms and Mats Nåbo. I would also like to thank my research partners and co-writers, Anders Warell, Sara Persson and Peter Schachinger, at Chalmers University of Technology and Dan Högberg at the School of Technology and Society at University of Skövde.

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Furthermore, I am very grateful to everyone who has been involved in my research studies. Crucial for this work are the subjects for the observation, questionnaire and interview studies (who wish to remain anonymous), all the test persons from the companies BT Industries AB, DeLaval, Electrolux, ESAB, Husqvarna, ITT Flygt, and Volvo Construction Equipment and the students from the Mechanical

Engineering programs at Linköping University and the Royal Institute of Technology, who have also acted as test subjects.

Finally, I would like to thank my beloved family and friends for giving me support, encouragement and an enjoyable time outside the field of research.

STOCKHOLM, MARCH 2005
Jenny Janhager

Publications

The papers published or submitted for publication within this research work are listed below.

Appended Papers

Paper A: Janhager, J. [2001]: *An Approach to Design for Use*, Proceedings of the 13th International Conference on Engineering Design, Great Britain, August 2001, pp. 315-322

Paper B: Janhager, J. [2003]: *Classification of Users - due to their Relation to the Product*, Proceedings of the International Conference on Engineering Design, Stockholm, August 2003

Paper C: Janhager, J. [2003]: *Utilization of Scenario Building in the Technical Process*, Proceedings of the International Conference on Engineering Design, Stockholm, August 2003

Paper D: Janhager, J. [2003]: *Hierarchical Decomposition of Technical Functions and User Actions*, Proceedings of the 2003 ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference, DETC2003/DTM-48642, Chicago, Illinois, September 2003

Paper E: Janhager, J. and Hagman, L. A. [2004]: *Approaches for the Identification of Users and their Relations to the Product*, Proceedings of the TMCE 2004 - The Fifth International Symposium on Tools and Methods of Competitive Engineering, Lausanne, Switzerland, April 2004

Paper F: Janhager, J. and Hagman, L. A. [2004]: *User-Technical Process Supporting Scenario Building*, Submitted to Design Studies

Paper G: Janhager, J. and Högberg, D. [2004], *Product Developers' Relations to their Users - an Interview Study*, Proceedings of NordDesign 2004, Tampere, Finland, August 2004

Co-Author Statement

All the articles appended to this thesis have been written by Janhager. In Papers E and F, Hagman is co-author and has contributed by participating in all the tests and supported the author by handling the technical aids and giving his views on the observation results. Högberg is co-author of Paper G. Janhager and Högberg performed the planning of the study, interviews and copy typing of the interviews together. The analysis was carried out by Janhager.

Additional Publications

Janhager, J., Persson, S. and Warell, A. [2002]: *Survey on Product Development Methods, Design Competencies, and Communication in Swedish Industry*, Proceedings of the TMCE 2002 - The Fourth International Symposium on Tools and Methods of Competitive Engineering, China, April 2002

Janhager, J. [2002]: *Procedure for Design of Products with Consideration to User Interactions – Theory and Applications*, Licentiate Thesis, Dept of Mechanical Engineering, Linköping University, Linköping, Sweden

Terminology

Meaningful vocabularies for this research work are listed below in the sense they are used in this thesis. The vocabularies are either developed during the research process or defined by ENDREA (Engineering Design Research and Education Agenda) or other researchers.

Action	A goal-directed process, which is subordinate to the representation of result that must be attained; an action is subordinated to a conscious purpose (a specific goal) [Nielsen, 2001].
Artefact	Physical object which has been manufactured for a certain purpose or intentionally modified for a certain purpose [Hilpinen, 1992].
Cognition	The collection of mental processes and activities used in perceiving, remembering, thinking, and understanding, as well as the act of using those processes [Ashcraft, 1994].
Concept	See *product concept.*
Customer	The person who makes the purchasing decision [Grudin, 1995].
Design (object)	The result of a *design* process [Andreasen & Mortensen 1996].
*Design (process)**	To conceive the idea for some *artefact* or *system* and/or to express the idea in an embodiable form.
Designer	Comprises a person who is involved in giving the *product* a *design*, such as design engineers and industrial designers.
*Engineering design**	*Design* with particular emphasis on the technical aspects of a *product*. Includes activities of analysis as well as synthesis.
Ergonomics	Synonym to *human factors.*
*Function**	What an element (*system*, part, component, module, *organ*, feature, etc.) of a *product* or human actively or passively does in order to contribute to a certain purpose [Hubka & Eder, 1988].
Human factors	The conception for discovering and applying information about human behaviour, abilities, limitations, and other characteristics to the *design* of tools, machines, *systems*, tasks, jobs, and environments for productive, safe, comfortable, and effective human use [Chapanis, 1985].

*Industrial design**	*Design* with particular emphasis on the relation between product and man, e.g. semiotic, *ergonomic* and aesthetic aspects of the *product*.
Interface function	What an element (*system*, part, component, module, *organ*, feature, etc.) of a *product* actively or passively does in order to contribute to the interaction between *user* and *product*. The interface function is an integral part of the *technical functions*.
Means	General designations for the solutions to a problem, particularly an object, apparatus, or mechanism of a physical/technical nature, but can also refer to mathematical, financial, etc., including software and hardware systems for information filing and retrieval, modelling, representation, reproduction, calculation etc. [Hubka, 1987].
Method	A way of working, which has a purpose and describes what to do in order to achieve that purpose.
Operand	The object being transformed by a *technical system* and directly or indirectly by one or more *users*. It may consist of material (including biological material, e.g. a human), energy or information [expanded from ENDREA, 2001].
Organ	A material element or an interaction between several material elements based on a physical regularity, which create the desired effect [Andreasen, 1992].
*Product**	*System*, object or service made to satisfy the needs of a customer.
*Product concept**	Description of the technology, working principles and form of the *product.*
Product developer	A person involved in any type of *product development* activities, e.g. a design engineer, a marketing representative or an industrial designer.
*Product development**	All activities in a company aimed at bringing a new *product* onto the market. The term normally involves *design*, marketing and manufacturing functions in the company.
Product synthesis	The activity of creating a specific *product* from the formulation of a task [Andreasen, 1991].
Scenario	A narrative description, i.e. a story, of people and their activities, which consists of at least one user/actor, who has particular goals, a work context and a sequence of *actions* and events [a hybrid of Nardi, 1992 and Carroll, 2000].
Semantics	The study of the messages of signs [Monö, 1997].
Synthesis	See *product synthesis.*
*System**	A structure which is separated from the surroundings by a borderline.
*Technical function**	A *function* performed by a *technical system*.

Technical process	Graphical representation of transformations of *operands* through various operations (partial transformations) and their sequence as determined by the selected technology [Hubka, 1987].
*Technical system**	A manmade *system* that is capable of performing a task for a specific purpose.
User[1]	Any individual who, for a certain purpose, interacts with the *product* or any realised element (*system*, part, component, module, feature, etc., manifested in software or as concrete objects) of the *product*, at any phase of the product life cycle [Warell, 2001].
User process	The sequence of the *actions* and/or the operations performed by the user in line with the *technical process* to attain a common goal.

* The terms marked with an asterisk are defined according to the nomenclature for ENDREA – Engineering Design Research and Education Agenda [ENDREA, 2001].

The remaining terms, which are not referenced, have been developed during this research work.

[1] When the term *user* is employed in this thesis it is mainly aimed at the *primary user*. Other users defined in this work are *secondary users*, *side users* and *co-users (Section 4.3.1)*. A *side user* may not, unlike the definition of a user, have a certain purpose by interacting with the product.

Table of Contents

1 Introduction

In this chapter the research issue is introduced and the background to the problem is described. Thereafter, it gives the purpose, objectives and delimitations of the research. Finally, in order to give a general picture of the whole thesis its structure is presented.

1.1 Introducing the Problem

As technology advances, both the complexity of products and the number of functions they comprise are steadily increasing. This leads to more opportunities for using the products. When making a telephone call in Sweden in the end of the 19th century, it was only necessary to lift the receiver; a switchboard operator then connected the call to the desired subscriber by plugging in a wire. Today, there is no need for wires, and apart from the oral communication function the cellular telephone offers, it contains numerous other functions such as information acquisition, payment services, games and message handling. Naturally, more complex products lead also to increased intricacy of use, thus reflecting the difficulties of developing user-friendly products. Moreover, the product designers' distance to the user has increased, partly as an effect of growing company organisations and expanding globalisation [Ekström & Karlsson, 2001]. At the same time, there are continuously increasing demands from users, who expect not only excellent functionality and usability [Grudin, 1995], but also pleasure from product use and ownership [Jordan, 1998]. At the beginning of the telephone era, there were only a few types of telephone. One of the first had a wooden receiver, which was used for both talking and listening. After that, the black ebonite or sheet metal telephone was developed. Today, competition has taken another dimension and the product developing companies are having to struggle hard to maintain their position in the market. The importance of product developers' awareness of and focus on the product user has increased over time, resulting in product developers needing support to handle all these aspects.

1.1.1 Product Development - a Complex Process

Every design project is unique since the aim is to create a product (or a product variant) that does not yet exist. In addition, the design work is influenced by the differences in the context in which it takes place, such as company organisation, strategies, procedures, market, legislation, society, technologies and knowledge, and the knowledge and experience of the team members [Blessing, 2002]. Thus, design is a complex process. Many interested parties and activities have to be organised and coordinated in order to drive product development forwards. In order to manage this, numerous product development processes, working procedures and methods have been proposed. Some of these are described in Chapter 2.

Communication and cooperation between the different disciplines, such as marketing and R&D, have an essential role in the design process and improve the prospects of success for the product and product development project [Souder, 1988; Griffin &

Hauser, 1996]. Cooper & Kleinschmidt [1995] and Cooper [1999] suggest organisations of cross-functional teams, with members from various functions and with complementary skills, to achieve successful products and projects.

Another approach intended to maintain rewarding product development is to get things right from the beginning in order to avoid expensive changes and delays. To do this, it is important to choose useful methods and ways of working, and at an early stage to engage different competencies and incorporate requisite knowledge and experience in the product to be developed [Norell, 1992].

At the beginning of a design assignment, knowledge about it is relatively limited, while the degree of freedom is large. As development progresses, experiences and facts regarding the design problem are built up, whereas the designers, who have to make strategic choices along the way, become increasingly bound to a particular solution, since late changes are expensive. To avoid being confined to a particular outcome in early design phases with high risks for which it is possible to find better solutions, it is advisable at the beginning of the design process to investigate and analyse the design task, the users and the use situation, and to develop and try out a large number of concepts in order to broaden the solution space. Thereafter, the concepts may be evaluated and some of them chosen for further development. Hein [1994] states that product developers tend to hasten through the concept stage and make the product very concrete and detailed early in the product development process, with consequent decreases in competitive power and cost control.

1.1.2 User Focus in Product Development

Developing successful products requires the product developers to know the target group for whom they are designing [Gould, 1995; Margolin, 1997; Preece, 2002]. Thus, a clear definition of the target market, i.e. exactly who the intended users are and what customers' needs, wants and preferences are, before the project is approved, increases the prospects of a successful product [Cooper & Kleinschmidt, 1990]. It is also better to define the users in early design phases, even if the user group eventually is going to expand from the initial definition. Otherwise, the design work is likely to become vague when it comes to consideration of user aspects [Gould, 1995]. If the product instead is designed for everybody or an average user, it may not suit any real users, since that average user does not exist [Friedman, 1971]. Moreover, the risk of disregarding detail in the user task and environment, which is important when it comes to working with usability, is also increased when the design work is directed towards an average user [Buur & Nielsen, 1995].

Awareness of the importance of a user/customer focus has increased in recent years. However, there is a lack of support for handling this. Moreover, the enhanced technology of products and the increasing number of functions they contain may lead to more time and resources being needed for concentration on technological development, which competes with regard to the time that can be spent on working with user aspects.

1.1.3 Need for Design Methods with Focus on the Users

Traditional design theories concentrate on the technical artefacts and more or less neglect their interaction with the users [Buur & Nielsen, 1995]. For example, theories of Hubka & Eder [1992] and Pahl & Beitz [1996] focus mostly on the technical functions and structure of the product, and omit the product's relation to the users. Some of the design literature, e.g. Pahl & Beitz and Ullman [1997], provides hints on how and where in the design process work with the users should be dealt with, e.g. identifying and understanding the customers and their needs. Buur & Nielsen [1995] state that the traditional design models are too static for expressing the interaction between user and product, and call for new dynamic techniques for modelling user-product interactions to enhance the usability of the products, such as scenarios and computer simulation of user interfaces. Other authors, such as Carroll [1995] and Clarkson & Keates [2001], also emphasise the need for use-oriented representations and methods in design. Fulton Suri & Marsh [2000] maintain that the existing methods and tools relating to user-product interaction, whether they have a quantitative or qualitative characteristic, are mainly intended for analysis or evaluation. Carroll [1995] also highlights the importance of enhancing the product developers' awareness of the importance of user-oriented approaches and supporting them in the adoption of such methods in their work.

The methods for understanding the users and working with user data throughout the design process are not suited for designers in their way of working [Roussel & Le Coq, 1995; Hasdoğan, 1996; Teeravarunyou & Sato, 2001b]. One reason is that many methods that focus on the user aspects are taken from areas of social science, such as ethnography. Also, they mainly concentrate on user behaviour and have weak applications to product development work [Teeravarunyou & Sato, 2001a]. Stanton & Young [1998] state that in a survey (presented in Stanton & Young [1995]) they have identified over 60 methods for introducing ergonomics in product development, but that most of the methods are used by their inventors only. This indicates also a gap between ergonomists and designers, since it seems that the methods either do not suit the designers' way of working or are not communicated to the designers.

Consequently, there is a need for design methods that support the synthesis activity in early product development stages and take user aspects into consideration. The methods may very well join the different product development disciplines that are working with user aspects, or at least it should be possible for all of them to utilise the methods.

1.2 Purpose and Objectives

The purpose of this research is to develop theories and design methods that will take into account the interaction between user and product in early design stages. Furthermore, the aim is for the methods to support synthesis and teamwork activities and to be easy to use for product developers. To attain this goal, various objectives are set.

- One objective is to examine how people in companies conducting product development talk about, think of and work with the users and the user aspects in order to realise what kind of support is needed. Questions that need to be answered are: "What methods do product developers use today" and "How are new methods going to suit the current work situation?".

- The intention is also to find different ways of classifying the users and their relations to and interaction with the product, and to investigate whether the classifications can be used as methods for building up a common picture of the users within the design team.
- The established starting point is based on the theory of technical systems, which describes the artefact as a system that delivers effects. However, since a product often must be seen in relation to its users, this model needs to be supplemented with user actions. It is desirable to investigate whether an artefact can be described in the relations to its users as a user-technical system and in that case how this model could support the designers in focusing on the users during early product development phases or be used for synthesis work.
- From a technical point of view, a product can normally be described as a system with a hierarchical structure of subsystems. Can the user–product interactions be described in a parallel hierarchical structure, or are they completely different from the technical structure? When it comes to developing synthesis design methods, this may be a suitable approach.

The overarching objective of this thesis is twofold:

1. To provide industry with valuable and usable design methods which will deal with user-product interactions.
2. To contribute to the branch of science with new theories and models or supplements to existing theories concerning the treatment of user aspects in design work.

1.3 Delimitations

The initiation of this work was relatively free from restrictions. However, in order to make the problem tangible and to keep within the frameworks regarding time and resources set for this work, the following delimitations have been made:

- During development of the theories and creation of the examples, the focus has been placed on physical products, i.e. artefacts, and in particular mechanical products, with a great deal of interaction with the users, such as consumer products, tools and public products. Service, software, consumer goods, etc. do not fall within the scope of this research work.
- The focus is on the early phases of product development. Detailed design, production and assembly are not treated.
- The development and investigation of the methods concentrate on how they are to work and what kind of result they provide. However, investigations of the dynamics of the groups, i.e. the relations between the members in the groups utilising the methods, or any psychological effect due to use of the methods, are outside the scope of this work.

1.4 Outline of the Thesis

The thesis begins with an introduction and background to the research problem, and a presentation of the purpose, objectives and delimitations of the work (Chapter 1). Chapter 2 presents the frame of reference for the work. The research approach in Chapter 3 describes a background to design science and the current approach for this work. The chapter provides an insight into theories behind this research work and how it was performed. Thereafter, in Chapter 4, the empirical and theoretical results of this work are presented. The chapter begins with an outline of the results obtained and a presentation of how they fit into a model of design science. The findings from the introductory studies and an interview study are then presented, followed by a discussion of these. The chapter concludes with a presentation of the developed theories and methods, and a procedure in which the methods are placed. Chapter 5 includes an evaluation of the developed theories and methods, which comprises verification of the developed theories and methods, as well as validation, with tests, of the methods. Further findings and discussions of the test results are also presented. A summary of the appended papers is included in Chapter 6 and the results of this research work are summarised in Chapter 7. Finally, in Chapter 8, suggestions for future research are given and the thesis ends with a number of recommendations to the industry.

A list of the terminology used in this thesis is given in the preface to the treatise preceding Chapter 1. The thesis is complemented with seven papers (A-G) as appendixes.

2 Theoretical Framework

This chapter describes the theories on which this interdisciplinary research work is based. The main scientific area is design science, since this was where the work started, in particular theories from the WDK school [e.g. Tjalve, 1979; Andreasen, 1980; Hubka & Eder, 1988], such as theories of the technical system and the design process. Other included theories that better consider user aspects are taken from the fields of ergonomics, industrial design and psychology.

2.1 Design Science

Design science comprises various types of theories, such as theories describing the artefact structure and methods suggesting how to perform design work. This work is mainly focused on those theories that describe an artefact and their application to synthesis methods for designing the artefact.

2.1.1 Product Development

Products are often referred to as anything (e.g. an object or service) that can be offered to a market in order to satisfy a customer's want or need [Kotler et al., 1996; ENDREA, 2001]. Product development comprises a broad spectrum of activities, which have to be correlated and unified in order to attain a satisfactory process. Ulrich & Eppinger [2003] declare it as *the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product*. Apart from the activities, there are many elements, such as design engineers or other practitioners, management and goal system, working means, tools and equipment, information system and environment, identified by e.g. Hubka & Eder [1992], which affect the product development process. However, product development work is even more complex, since there also are external aspects (i.e. aspects that are not inherent in the organisation) to consider, such as the market (in which the user can be included), legislation and society that influence the product development process [Blessing, 2002].

To support coordination and planning of all these activities and elements, ensure product quality, and identify possible problem areas or improvements, a suitable, well-defined product development process is needed [Ulrich & Eppinger, 2003]. Andreasen & Hein [1986] have suggested an ideal model for product development activities, see Figure 2.1. The *Integrated Product Development* model is based on the three elements; market, design and production, and the results of their activities need to be unified. The market should be investigated and defined, and a product, which is intended to satisfy the market, should be designed and eventually manufactured by the second and third elements.

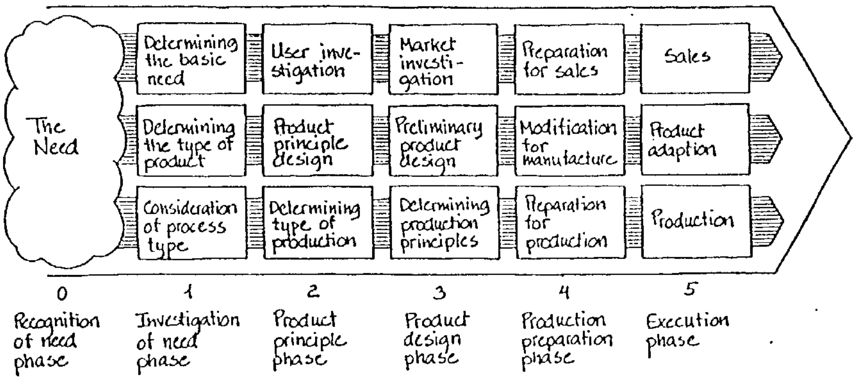


Figure 2.1 *Model of Integrated Product Development [Andreasen & Hein, 1987]*

Ulrich & Eppinger [2003] also present a model of integrated product development - a generic development process, which describes the sequences of activities or steps that marketing, design and manufacturing in a company may carry out in order to transfer a product from the planning phase, which precedes the actual product development process and whose output is the mission statement[2], to production ramp-up (Figure 2.2).

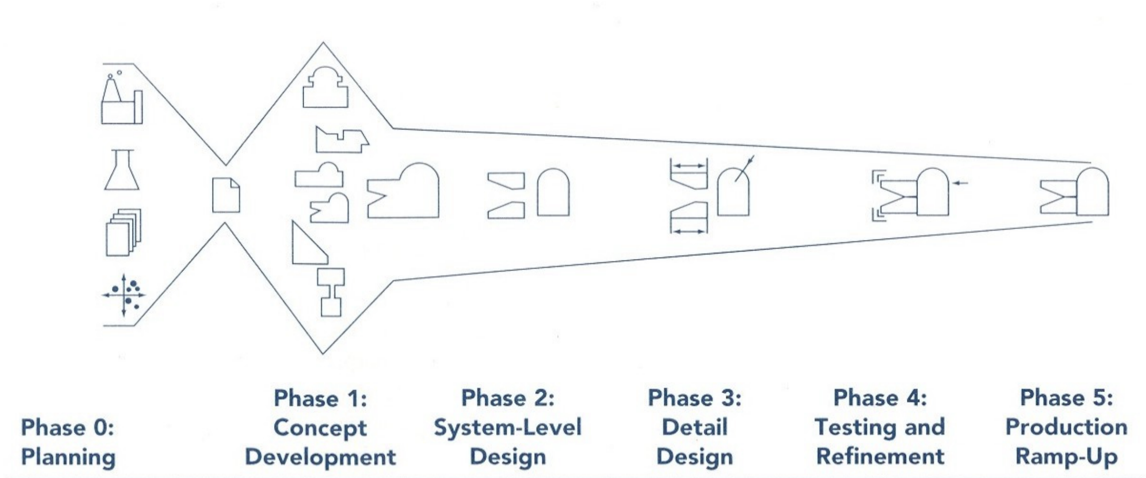


Figure 2.2 *A generic development process [Ulrich & Eppinger, 2003]*

2.1.2 Design

A principal activity in product development is *design* (the middle process in Figure 2.1), which is of major interest in this research. Alexander [1964] describes the process of design as *the process of inventing physical things, which display new physical order, organization, form, in response to function*. Another definition of

[2] A mission statement specifies which direction to go in a *product development* project, but generally does not specify a precise destination or particular way to proceed. The mission statement may include a brief description of the *product*, key business goals, target markets for the *product*, assumptions that constrain the development effort and stakeholders [Ulrich & Eppinger, 2003].

design is *to conceive the idea for some artefact*[3] *or system and/or to express the idea in an embodiable form* [ENDREA, 2001]. Both these definitions correspond to the process of design, i.e. the activity. Design can also imply the object – *the result of a design process* [Andreasen & Mortensen 1996]. Baldwin & Clark [2000] define design (the object) as *a complete description of an artefact* and state that a design can be broken down into smaller units, called *design parameters*, e.g. colour, height and weight of the artefact, and that the *design task* is to choose these parameters.

The Design Process

There are several models of the design process. Pugh [1990], Hubka & Eder [1992], Roozenburgh & Eekels [1995], Pahl & Beitz [1996], Ullman [1997] and Ulrich & Eppinger [2003] are significant authors who have treated the design process.

The representations of the design process are divided up into various phases, which have been given a variety of names. However, these are not unlike each other. Basically, four main phases are treated in these representations. Pahl & Beitz [1996] have designated them as:

- *Clarification of the task:* The design problem is analysed and information about it is collected. Requirements and constraints are established and listed in a requirements specification.
- *Conceptual design:* Essential problems are identified, function structures are established and concept variants are elaborated and evaluated in order to determine the principle solution.
- *Embodiment design:* Preliminary layouts are established. Technical and economic considerations are taken into account in order to evaluate and reject and/or combine the preliminary layouts so as to produce a definitive layout.
- *Detail design:* Production documents are produced implying an entire specification of arrangement, dimensions, materials and tolerances of all the parts in the product.

The Concept Phase

Since the early phases in product development are of particular interest in this work, the concept phase is further treated. Many authors, e.g. Hein [1994] and Perttula & Sääskilahti [2004], emphasise the importance of a well-accomplished concept phase. Most of the cost of a product life cycle is determined in the early design stages. According to Nevins & Whitney [1989], about 60 percent of the life cycle cost is settled during concept formulation. If the concept phase is not assigned sufficient attention and resources, there is a risk that the project goal will not be clarified and that product development ends up in no more than basic adjustments of a known product's performance and cost [Hein, 1994]. Furthermore, if no alternative concepts are presented, the underlying motives for the developed concept may be undocumented.

In Figure 2.3, Ulrich & Eppinger [2003] illustrate the front-end product development activities in the concept development phase, which implies the activities from mission statement to development plan.

[3] In this work, an artefact is defined as *a physical object which has been manufactured for a certain purpose or intentionally modified for a certain purpose* [Hilpinen, 1992].

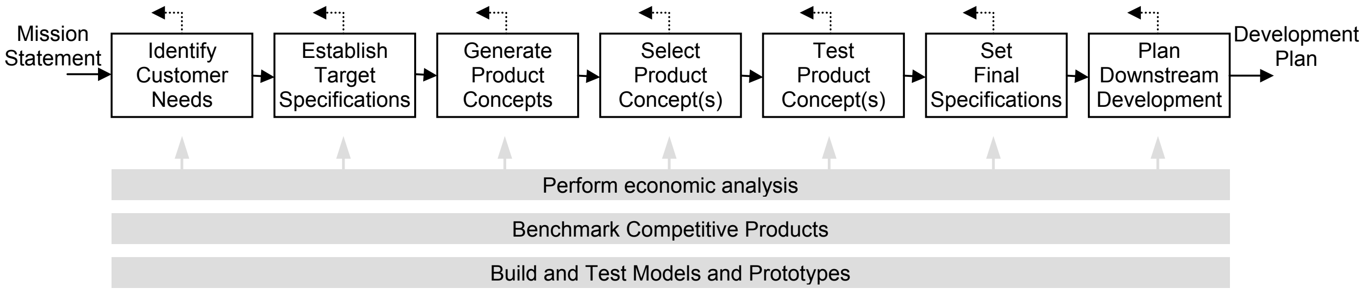


Figure 2.3 *Concept development phase [Ulrich & Eppinger, 2003]*

According to Koen et al. [2002], a concept has *a well-defined form, including both written and visual description, that includes its primary features and customer benefits combined with a broad understanding of the technology needed*. Another, more technically oriented definition of a product is *a description of the technology, working principles and form of the product* [ENDREA, 2001]. Hansen & Andreasen [2003] state that there are three different ways of describing a concept, depending on the authors' background. They may focus on the technical side, the market-oriented side and the two sides in combination. Hansen & Andreasen [2003] advocate the last-mentioned view and state that it is important for the design team to adopt this shared view during the conceptual design phase. To correspond to this, they have identified two ideas for considering the design work: the idea *with* the product, i.e. a need/market-based idea and the idea *in* the product, i.e. a design/realisation-based idea. This is exemplified by the Walkman. The fact that the user can walk and listen to his/her own music is the idea *with* the product, while using known technology but miniaturising it and introducing a robust playing mechanism is the idea *in* the product. Hansen & Andreasen state that *a new product concept should be understood in both the use context and the design context, and show conceptually new features in at least one of these dimensions.*

2.1.3 Ways of Describing the Artefact

There are theories and models which describe the artefact from a technical perspective, based on its structure or functions, e.g. theory of technical systems [Hubka & Eder, 1988]. The artefact may also be described from a user perspective, in a way it is intended that the user should apprehend it, e.g. semantics [Monö, 1997].

Theory of Technical Systems

The *theory of technical systems* (TTS) is a descriptive theory of the machine system or artefact, [Hubka & Eder, 1988]. The technical system provides effects (actions of a material, energy and information related character) through different types of functions, these effects being essential in order to produce transformations which should convert an operand from an existing state (input) to a desired state (output) in a technical process (Figure 2.4). Beyond the technical system, humans and an active environment affect the technical process. The technical process may be divided into three phases owing to the time-sequence of the work flow, namely the preparing, executing and finishing phases [Hubka & Eder, 1992].

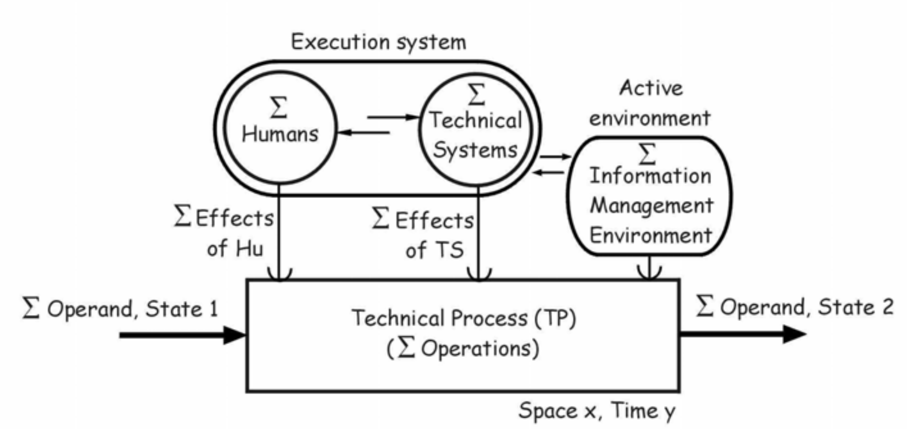


Figure 2.4 *A general model of a transformation system [Hubka & Eder, 1992]*

Theory of Domains

Andreasen [1980] advances the theory of technical systems, described in Hubka & Eder [1988], and identifies four different levels of systems structure in the design of a complex machine system, namely the domains of process, function, organ[4] and part, see Figure 2.5. Each domain has different abstraction levels and complexity levels.

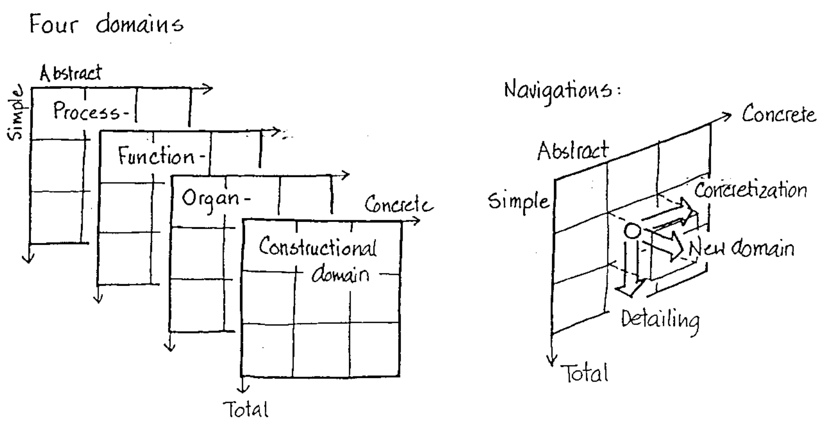


Figure 2.5 *The four domains of design with gradual change in abstraction and complexity [Andreasen, 1992]*

The process describes the transformations of the technical system, the functions describe the effects which are performed by the technical system, the organs create the necessary effects through their way of working and interacting, and the system of machine parts realises the organs [Andreasen, 1991].

There are alternative structural models for the machine system, e.g. the functions and organs in a hierarchical structure, as shown below.

[4] An organ is a material element or an interaction between several material elements based on a physical regularity, which create the desired effect [Andreasen, 1992].

Function Structure

A function is *what an element (system, part, component, module, organ, feature, etc.) of a product or human actively or passively does in order to contribute to a certain purpose* [Hubka & Eder, 1988].

A mechanical system may be broken down into functions, with each function being realised by a means. The decomposition reduces the complexity of the solutions space and the decomposed functions describe the functionality of the mechanical system [Hansen, 1995]. A similar theory for disintegration of the mechanical systems to functions is FAST – Function Analysis System Technique [Fowler, 1990]. As in the previous decomposition method, the technique ideally expresses the functions by two-word combinations, a verb and a noun.

The decomposition may be described as a function-means tree [Tjalve, 1979; Andreasen, 1980], which sets out functions and means in a hierarchical structure, as in Figure 2.6. The lines between the functions and means describe their causal relationship. The tree may also show alternative solutions for solving the functions. The search for the means to realise the functions is a synthesis activity.

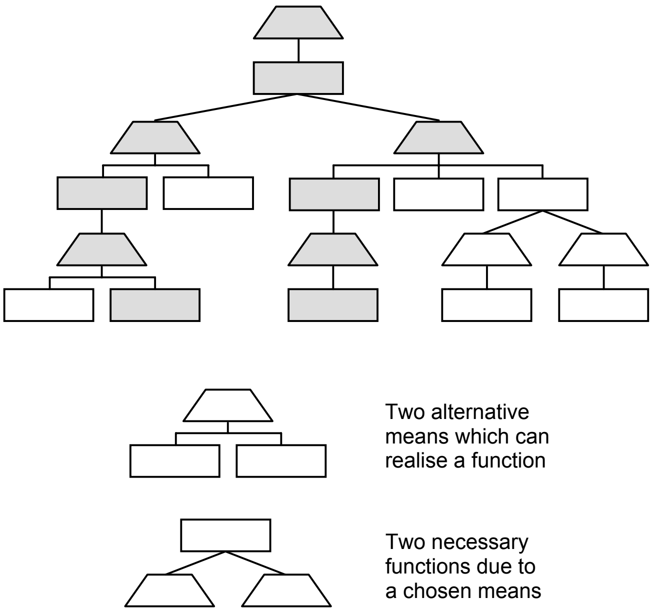


Figure 2.6 *Function–means tree, after Svendsen & Hansen [1993]; the shaded boxes show a possible solution*

Warell [2001] has excluded the human activities from Hubka & Eder's definition of function and narrowed it to comprise only what the product or an element of a product does in order to contribute to a purpose. This definition forms the foundation for his classification of the functions of the human-product system that has two main classes: *technical functions* (internal product functions) and *interactive functions* (human-product interaction functions), see Table 2.1. The technical functions are divided into operative functions, which enable the transformation of the operand, and structural functions, which are necessary for ensuring the structural stability and solidity of the product. The interactive functions are divided into ergonomic functions and communicative functions. The ergonomic functions are essential for the product’s adaptation to the physical and physiological requirements of the human body and the effect of the environment, and the communicative functions are needed for the “communication” between product and human.

Table 2.1 *Function classes of a human-product system, including technical and interactive functions [Warell, 2001]*

Function class	Function type		
Technical functions (internal product functions)	Operative	Primary	*Transforming*
		Secondary	*Communication* *Interface* *Power* *Control* *Protection*
	Structural		
Interactive functions (human-product interaction functions)	Ergonomic		
	Communicative		*Semantic*[5]
			Syntactic[6]

Examples of communicative functions are the semantic functions (Table 2.1). In the field of Industrial Design, Monö [1997] has investigated the product’s message to the receiver, i.e. the user. He presents four semantic functions; *describing* (facts), *expressing* (properties), *exhorting* (to reactions) and *identifying* (e.g. origin). Figure 2.7 illustrates the humans who perceive the semantic functions through the product and the notion that they are influenced by factors such as their experiences and feelings. The semantic functions may be used to analyse and define requirements for products in a perspective of the user [Wikström, 1996].

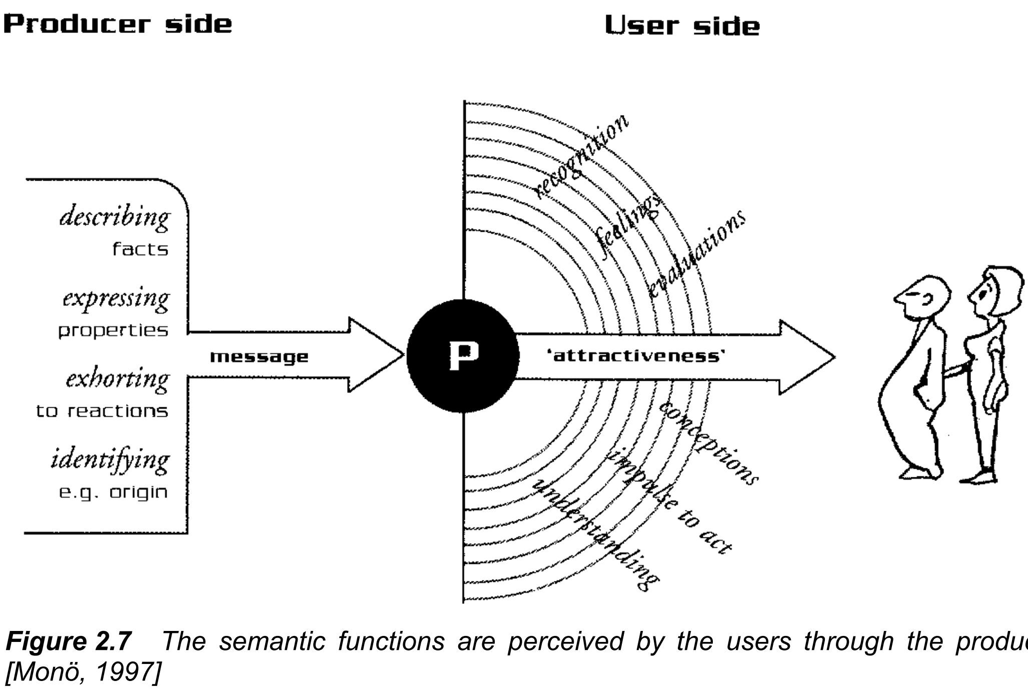


Figure 2.7 *The semantic functions are perceived by the users through the product [Monö, 1997]*

[5] Semantics is the study of the signs’ messages, i.e. the meaning of the signs [Monö, 1997]. Krippendorff & Butter [1984] describe product semantics as the study of the symbolic qualities of man-made forms in the context of their use and the application of this knowledge to industrial design.
[6] Warell [2001] defines form syntactics as visual structure and content of form language.

2.1.4 Formal Design Methods

Design methods may be intended to bring rational procedures into the design process. Some of these are adaptations from areas such as decision theory or management science*,* and some are expansions or formalisations of informal techniques that designers already apply. According to Cross [1994], design methods correspond to various activities that designers may use and unite to obtain an overall design process. They may be procedures, techniques, aids, or tools for designing. However, other authors [e.g. Martin, 1997] separate aids and tools from methods.

Process, Methods, Tools and Environment

There may be confusion in the meanings and distinctions of the concepts of process, methods and tools. Hence, Martin [1997] presents a model: the *PMTE Paradigm*, which explains their relations (Figure 2.8). The process utilises appropriate methods for each process stage, whereas the methods may be applied with support from one or more tools and the tools need to be supported within the environment where they are applied.

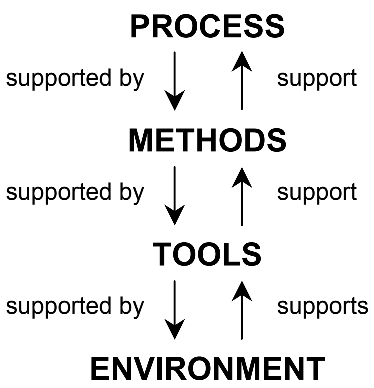


Figure 2.8 *The PMTE Paradigm [Martin, 1997]*

Martin defines process as *a logical sequences of tasks performed to achieve a particular objective*. He states that a process describes *what* is to be done, without detailing *how* the tasks should be carried out, whereas a method *consists of techniques for performing a task*[7], i.e. it describes the *how* of each task. A tool is an instrument (e.g. computer and software) applied to a method, which may make a task more efficient. The surroundings, the external objects, conditions, or factors that affect the actions of an object, a person or a group constitute the environment.

Benefits from Design Methods

Design methods *formalise* certain procedures of design. They tend to widen the approach taken to a design problem and encourage the designers to think of other solutions than the first one that appeared. Moreover, they *externalise* design thinking, i.e. they support the designers in transferring the thinking onto paper, e.g. by using diagrams and charts, which release the thinking from systematic work for intuitive and imaginative thinking [Cross, 1994].

[7] Since a method consists of a sequence of tasks that describes *what* to do in each step, it is also a process, i.e. *how* becomes a *what* in the lower level of abstraction [Martin, 1997].

According to Ulrich & Eppinger [2003], structured design methods:

- Assure that important issues are remembered, since they may work as checklists for the steps and activities in the product development process.
- Document decisions for future references and education of new product developers.
- Make the grounds of the decisions clear and available for all those involved in the design process and reduce the likelihood that they will carry out work based on unconfirmed decisions.

It is also noted by e.g. Norell [1992] and Wright [1998] that many design methods encourage the integration and communication between different competencies in product development.

Criteria for Rewarding Design Methods

The methods should be easy and uncomplicated to use, and should not require any expertise to be utilised by the designers [Smith & Dunckley, 2001]. This statement meets approval from the research of Norell [1992], which is also supplemented with other criteria concerning support methods for product development. Rewarding methods should:

- Utilise accepted, non-trivial knowledge within the current area.
- Provide support in finding weak points.
- Be fruitful for different competencies and contribute to the building of common references.
- Support cooperation and have a learning effect for the users of the method.
- Contribute to a systematic way of working.
- Provide valuable and, if possible, measurable effects on the project work within the product development process for the current area.

Classes of Design Methods

There is an extensive assortment of rational methods covering every phase in the product development process. Cross [1994] classifies[8] the design methods into two broad groups: creative methods, which are intended to encourage the stimulation of creative thinking, and rational methods, which support a systematic approach to design activities. The two groups of methods may have the same purpose, such as expanding the search area for alternative solutions or facilitating teamwork activities.

Jones [1992] classifies design methods as either being divergent, transformational or convergent. The divergent methods imply exploring design situations and searching for ideas. Methods for exploring the problem structure may belong to the transformational methods, since the purpose of such methods is to find patterns in order to stabilise the divergent process for future convergence, i.e. transforming a complex problem into a simple one by modifying its form and deciding what is to be investigated further. Convergent methods, such as ranking and weighting methods, involve the process of reducing the uncertainties in order to obtain one final solution.

[8] Authors suggest different types of classification for the formal design methods. However, all categories of methods can be found in the same product development assignment.

López-Mesa et al. [2002a; b] have classified design methods that are based on their suitability for developing revolutionary or evolutionary products. The different types of method are defined as:

- *Innovative divergent methods,* which assist the generating of new ideas and novel concepts, such as brainstorming. Their fields of application are radical change or product renewal.
- *Adaptive divergent methods,* which support searching for solutions to problems that have been detected in a concept through successive improvements, such as value engineering. Their area of use lies in the improvement of existing solutions.
- *Innovative convergent methods,* which support the evaluation of approximate soft data. They are applicable to the evaluation of new, vague ideas.
- *Adaptive convergent methods,* which support the evaluation of precise numerical data, such as rating and weighting methods. They are suitable for the evaluation of matured concepts with precisely known performance.

López-Mesa & Thompson [2002a] state that this classification provides a good understanding of the methods and also supports the choice of method depending on the required novelty of the solution. A guideline for identification of the characteristics of the methods is presented in Figure 2.9.

INNOVATIVE METHODS		ADAPTIVE METHODS
DIVERGENT METHODS		
Highly innovative	**Highly adaptive**	
• Facilitate the detachment of the problem from the way it is customarily perceived • Stimulate the generation of a large amount of ideas • Tend to produce imprecise ideas	• Useful for further development of already known solutions • Develop further a single idea • Tend to produce concrete solutions within a focused solution space	
CONVERGENT METHODS		
Highly innovative	**Highly adaptive**	
• Require approximate or soft information about concepts • Evaluation of a large amount of diverse ideas • Gather together information that helps to take a decision	• Require hard and precise information about concepts • Evaluation of a single concept • Give a numerical solution	

Figure 2.9 *Guideline for identification of innovative and adaptive characteristics of methods [López-Mesa et al., 2002a; b]*

Implementation of Methods

The implementation and use of new methods and tools is limited [Araujo, 2001]. Causes and consequences of this are discussed by authors such as Gill [1990], Hein [1994] and Frost [1999]. Many companies are unaware of the benefits they may acquire from using formal product development methods [Araujo et al., 1996]. Araujo [2001] presents a number of aspects negatively affecting the implementation of the new methods, e.g.:

- Negative attitudes of people in the organisation towards the new method.
- Insufficient support from top management.
- Deficient information on the method; the method was too complex or too theoretical.
- Shortage of clear instructions on the implementation and use of the method.
- Lack of careful analysis of the methods' potential value and adaptability to the organisation.
- Lack of essential competencies for using the methods.

Norell [1992] has studied the implementation of formal product development methods in Swedish manufacturing companies and found that, after the initial introduction of the method, its usage will decline unless special efforts are made and a breakpoint is reached instead, see Figure 2.10. Additional resources or anchoring activities may increase the usage of the method (upper curve in Figure 2.10) and there is a tendency for utilisation to stabilise.

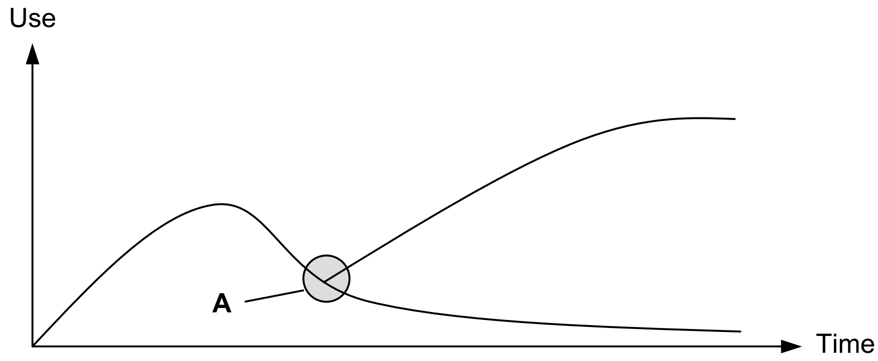


Figure 2.10 *The method implication model in which the implementation progress is described. The graph shows usage of a new method over time [Norell, 1992], where A is the breakpoint.*

2.2 Users in Relation to Product

> *A user is any individual who, for a certain purpose, interacts with the product or any realised element (system, part, component, module, feature, etc., manifested in software or as concrete objects) of the product, at any phase of the product life cycle [Warell, 2001].*

Karlsson [1996] has a narrower definition of the user. She proposes that the user is the *end user*. This does not include persons such as the repair man as a user of the object (e.g. the car) he is repairing. The repair man has his user relation to the tool he is using in order to repair the car. This approach is based on the view that use implies the activities that are carried out with an object (e.g. a product) in order to attain a specific goal. The aim of the artefact is not inherent in the artefact itself, but is a mediating object.

2.2.1 Classes of Users

Buur & Windum [1994] declare that the primary users embrace those who use the product for its primary purpose, e.g. the driver who drives a truck. However, they also state that there are users in every phase of the product life cycle, who need to operate the product in various ways (Figure 2.11). A seller needs to demonstrate the product in a sales situation and the repair man has to repair the product in order to get it working and intact.

Development	Manufacture	Sale	Use	Destruction
Technical writer Designer Etc.	Function tester Quality inspector Etc.	Salesperson Technician Etc.	Installer Primary users Repairperson Maintenance worker Etc.	Garbage sorter Recycling technician Etc.

Figure 2.11 *Division of users, according to Buur & Windum [1994]*

In a similar way to Buur & Windum, Monö [1974] has classified persons who interact with the product and named them *target groups* and *filter groups*. The subjects in the target groups, which are in accordance with the primary users described above, are the persons towards whom the developed product is targeted. The subjects in the filter groups sift the product characteristics and products from the assortment passing them on the way to the target group. They may also influence and decide the target group's choice of product. Examples of such subjects are distributor and purchaser.

Researchers at the HUSAT (Human Science and Advanced Technology) Research Centre at Loughborough University of Technology, UK [Eason, 1988], have defined three user groups for technical systems. These groups comprise *primary users* and *secondary users,* where the difference is that the primary users are the "hands on" and perhaps full-time users of the products and the secondary users the occasional users or those who have to work with the output from the products. The third group is the *tertiary users,* who are likely to be influenced by the use of the products but are not direct users of them. Purchasers and suppliers are examples of tertiary users.

Apart from categorising the users according to their aim in using the product, there are other methods of classification. Since the nature of the user population is diverse, it may be worthwhile to identify or investigate the users according to their use experience [Faulkner, 2000; Preece, 2002], and their involvement in the acquirement of the product they are using [Grudin, 1995].

2.2.2 Human-Machine System

A human-machine system may be a very simple system, such as a carpenter using a hammer, or a more complex system, such as an aircrew flying an aeroplane. Sanders & McCormick [1993] define the human–machine system as *a combination of one or more human beings and one or more physical components interacting to bring about, from given inputs, some desired output.*

The theory of technical systems describes machines with the help of transformations. The technical system receives input, transforms it through a function and outputs a result, see Section 2.1.3. Simply by changing terms, human behaviour can be described in a parallel way [Chapanis, 1996]. Human beings receive stimuli, process the information and deliver an output in the form of responses, according to Figure 2.12.

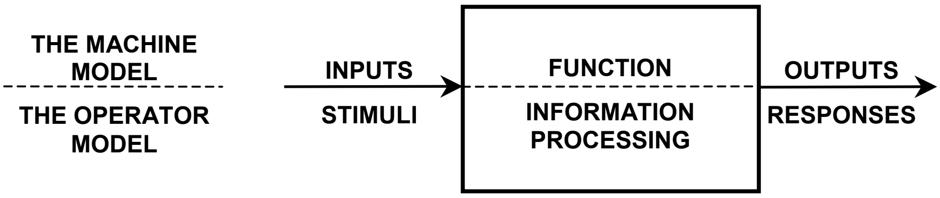


Figure 2.12 *A machine model (technical system model) and the corresponding operator model [Chapanis, 1996]*

Drawing parallels between the technical system and the human being makes it possible to regard the human operator as a system component. The metaphor has to be used with caution, since human activities are influenced by variables. Some are related to the technical system and the interaction with it, e.g. machine interfaces and work environments, and others are individual, such as fatigue, boredom, stress, attitude, motivation and personality.

Chapanis [1976; 1996] presents also a more complete model of the human–machine system. The model, shown in Figure 2.13, schematises the interaction between human and machine as a loop of signals. The display gives the operator a signal from the operation, which triggers the information processing, allowing decisions to be made. This results in an action from the operator, who uses the controls to send signals to the operation. All these activities are carried out under influence from the environment.

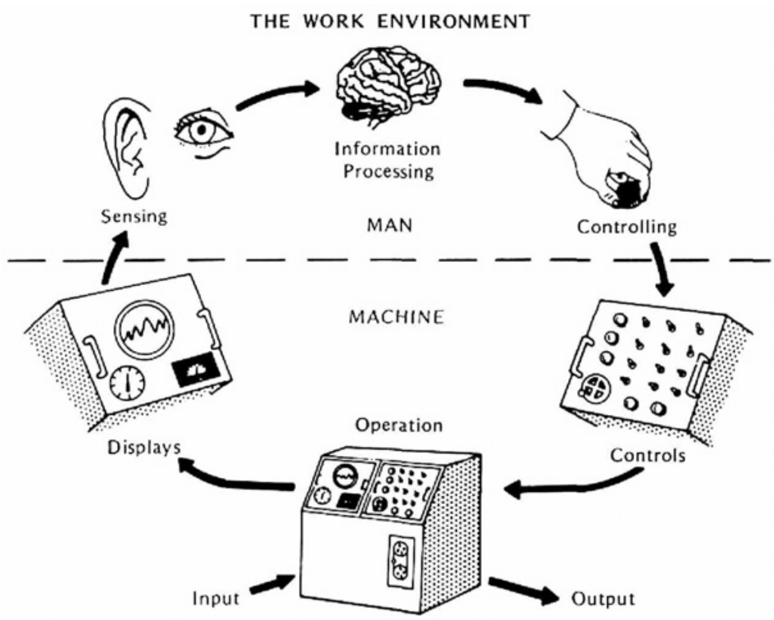


Figure 2.13 *A model of interaction between man and machine [Chapanis, 1976]*

2.2.3 The Human Activity Theory

The human activity theory has been developed for universal purposeful human activity and was, like cognitive psychology, a reaction against behaviourism's fundamental view that the human is a passive, reactive being. Leont´ev [1978], among others, developed the theory of human activity in the 1930s. The following theory is based on the interpretations of his work by Bødker [1991] and Nielsen [2001].

The human activity is a process *through which the human being produces some kind of relations to the physical and social world around her* [Bødker, 1991]. The activities are bound to a goal, which may be to solve a task and/or a problem, directed towards a physical object. Behind the goals there is also a motive. "Shop for a dress" is an example of an activity, which is directed towards the object "dress". The goal could be to look nice for a party in the evening, to get something to wear in the office or just to have a nice dress ready for upcoming events.

The activity is accomplished by several *actions*[9], i.e. performing what ought to be done, which are related to a conscious purpose. To obtain the activity "shop for a dress", actions such as "try dress on" and "pay for dress" may need to be performed.

Actions are realised by one or a chain of *operations*. For example, the action "pay for dress" may consist of the operation "open purse", "take out credit card from purse", "give shop assistant credit card" and so on. Contrary to the actions, operations are in general carried out subconsciously; in other words, they may be performed automatically. Machines may also carry out the operations. Figure 2.14 shows the structure of the relations between the activities, actions and operations.

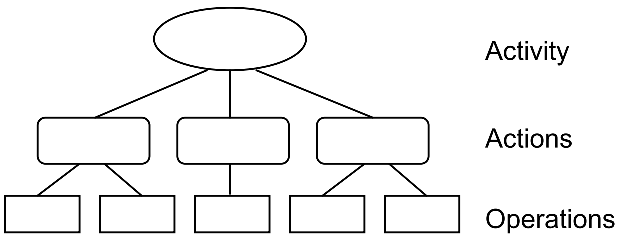


Figure 2.14 *The general structure of an activity: The activity is realised through one or more actions and the actions only exist through one or a chain of operations [Bødker, 1991]*

2.3 Design for User-Product Interaction

Users are individuals and each individual is unique. This implies that designing a product to suit many individuals is a challenging task. To simplify this work, it is necessary for the designers to understand the users and the use situation, and also to grasp the distinctions between their own and the users' way of perceiving the product. An available form of support is the assortment of design methods which consider the user aspects.

[9] An action is a goal-directed process, which is subordinate to the representation of the result that must be attained. An action is subordinated to a conscious purpose [Nielsen, 2001].

2.3.1 Designer's Relation to and Perception of the User

There may be both physical separations and distinctions in class, culture and language between the product developers and the users. These barriers are often critical for design work [Grudin, 1995]. Therefore, it is necessary for the product developers to have contact with the users and learn about their needs through methods such as interviews, observations and discussion groups [Gould, 1995; Stanton, 1998; Ulrich & Eppinger, 2003]. It is stated by González & Palacios [2002] that products are given a more significant value for the market, in other words they become more successful, if the designers have a comprehensive picture of the users and their needs. Holt [1989] is of the opinion that all those engaged in product development activities should be concerned with the users.

Designer - User

Other differences between the designers and users are to be found in their knowledge about the product, an aspect that is discussed by Teeravarunyou & Sato [2001a]. They have identified two types of knowledge: *user knowledge*, which is acquired in the learning and problem solving process with the product in the context of use, and *design knowledge*, which is the knowledge of building artefacts. These are included in the *knowledge life cycle* and the artefact is a carrier of knowledge in this life cycle (Figure 2.15).

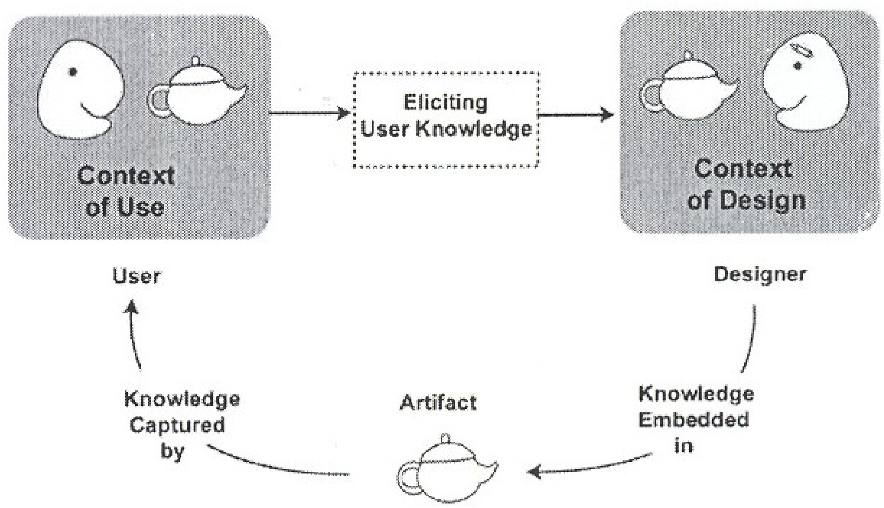


Figure 2.15 *Knowledge life cycle between users and designers [Teeravarunyou & Sato, 2001a]*

The distinction in the knowledge could be compared to the differences between the *user work model* and the *system work model*. The user work model refers to the logical way, for a user, in which the product should be used, which is connected to the user's mental model, whereas the system work model, i.e. the actual use sequence, is connected to the function of a technical system (driven by the technology) and its need for support [Beyer & Holtzblatt, 1998].

When the designer wants to achieve user friendliness of a product, he/she tries to think in the same way as a user. According to Buur & Windum [1994], there are five different ways in which the designer may perceive the user; *technical*, *ergonomic*, *psychological*, *pedagogical* and *social perception* (Figure 2.16). None of these perceptions alone can bring about a user-friendly product.

Markussen [1995] has expanded the model and stated further relevant perceptions that the designer may have. These include *system technical perception,* which means that use can be described as an interchange of information, energy and material between user and product, and *functional technical perception,* which means that the user could be described in a similar way to a machine.

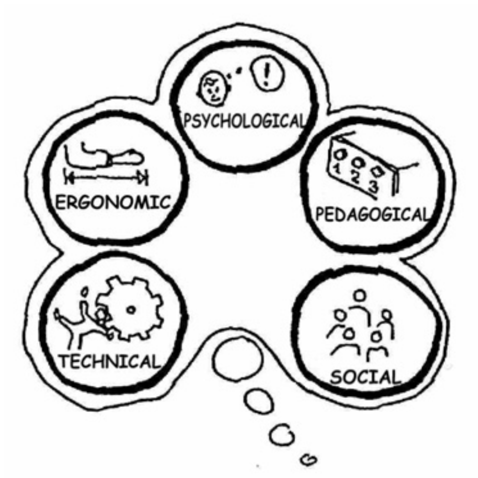


Figure 2.16 *Five different perceptions of the user [Markussen, 1995]*

2.3.2 Human Factors/Ergonomics

Sanders & McCormick [1993] define human factors by their focus, objectives and approach. They state that human factors focus on human beings and their interaction with the products, equipment, facilities, procedures, and environments found in work and everyday living. The two major objectives are to enhance the effectiveness and the efficiency of work and other activities, and to enhance certain desirable human valuables, such as improved safety, reduced fatigue, and improved quality of life. The third element of the definition of human factors (i.e. the approach) is the systematic application of relevant information about human capabilities, limitations, characteristics, behaviour, and motivation to the design of things and procedures, and the environment in which people use them.

The International Ergonomics Association (IEA) defines ergonomics (or human factors) as *the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance* [IEA, 2005]. IEA divides ergonomics into three domains of specialisation: *physical ergonomics*, which deals with human anatomical, anthropometric, physiological and biomechanical characteristics, *cognitive ergonomics*, which is concerned with aspects such as perception, memory, reasoning, and motor response, and *organizational ergonomics*, which includes organizational structures, policies, and processes.

Generally, the term "human factors" is used in the USA and a number of other countries, while "ergonomics" is more widespread in Europe and the rest of the world [Sanders & McCormick, 1993]. The existence of the two dissimilar terms is more the result of historical occurrence than the purpose of separating the signification of them [Chapanis, 1976]. Human factors and ergonomics may be considered as synonyms.

> *"Human factors" discovers and applies information about human abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable and effective human use [Chapanis, 1985].*

Many disciplines contribute to the area of human factors, e.g. *psychology*, *anthropometry*, *applied physiology*, *environmental medicine*, *engineering, statistics*, *operations research* and *industrial design* [Capanis, 1996], Figure 2.17.

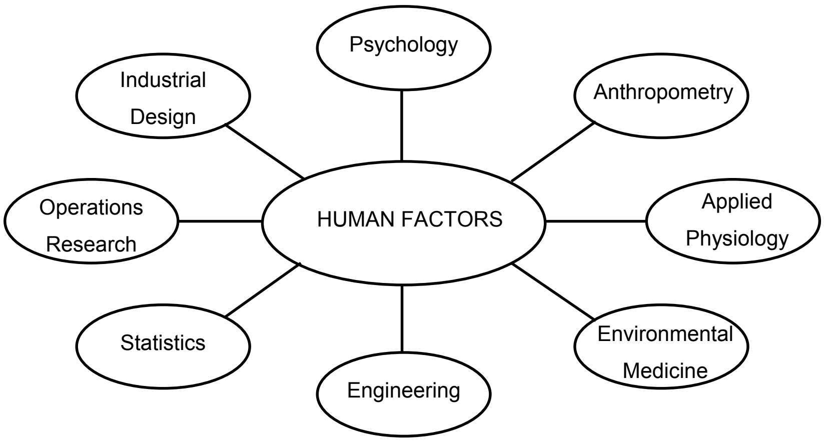


Figure 2.17 *Technical disciplines contributing to human factors [Chapanis, 1996]*

The discipline of ergonomics has been active for more than 50 years. The Ergonomics Society in the UK celebrated its 50th anniversary in 1999 [Wilson, 2000].

2.3.3 Formal Methods and Procedures for User-Product Interactions

Numerous methods and procedures have been developed in the field of ergonomics, primarily for purposes of analysis. They include *heuristics*, *observations*, *questionnaires*, *layout analysis*, *link analysis* and *hierarchical task analysis* (HTA) [Stanton, 1998]. A presentation of methods relevant to this research work follows below. Further methods for user-product interaction are described in Paper A.

User-Centred Design

A user-centred design approach will, not unlike other formal design processes, start with an analysis of the user needs. According to Stanton [1998], these needs, together with the functional specification and technical requirements, constitute the system specification. From these data, a prototype is built, tested and evaluated, according to Figure 2.18. The result of the analysis may lead back to a new analysis of user needs, a modification of the prototype or a refinement of the design, and a new prototype. There may be many loops in the process before the final product is developed.

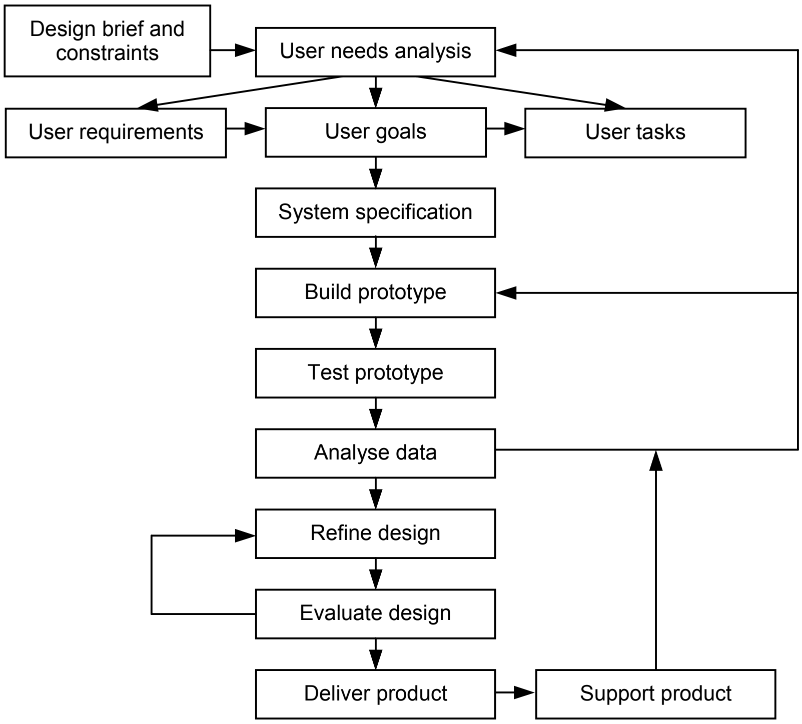


Figure 2.18 *A model of a user-centred design approach [Stanton, 1998]*

In his book about the psychology of everyday things (POET), Norman [1990] defines user-centred design as a philosophy based on the needs and interests of the user. He approaches the area of user-centred design by formulating certain essential items that the designer is required to think about when designing a comprehensible and usable product. The main principle for user-centred design of POET is to make clear that the user can reason out what to do with the product and furthermore assume what is going on with the product.

Inclusive Design

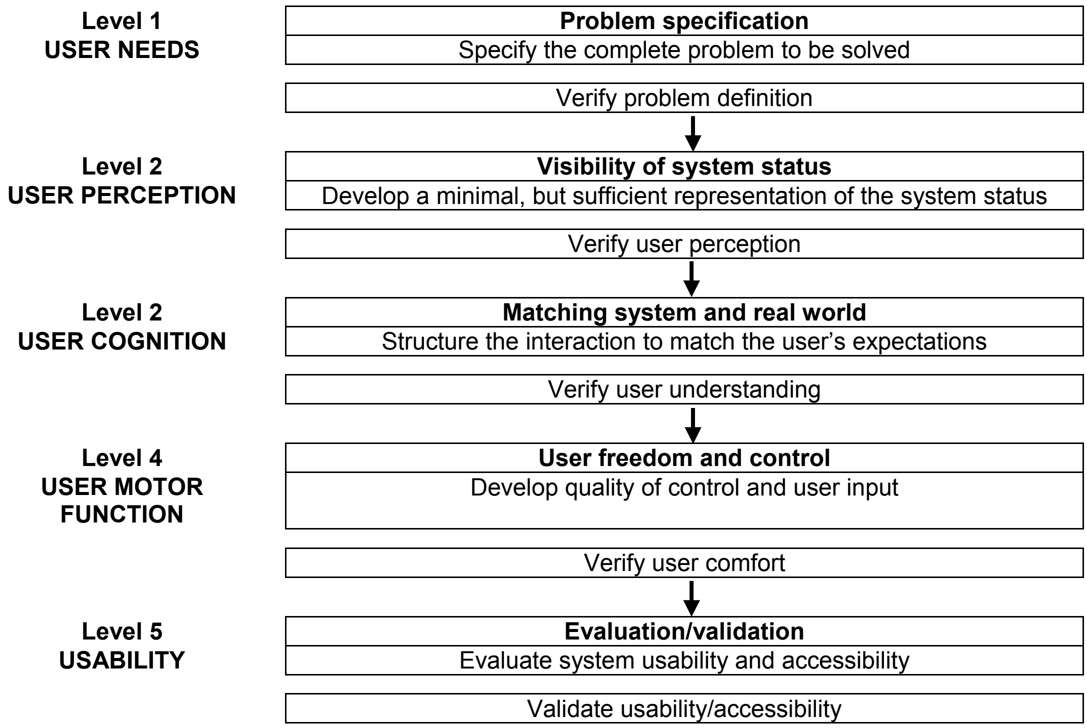


Figure 2.19 *The 5-level design approach [Clarkson & Keates, 2001]*

Earlier, arguments have been presented for the importance of defining the intended users [Gould, 1995] instead of designing for an average user [Friedman, 1971; Buur & Nielsen, 1995]. However, there are occasions when it is important to try to design for as many different individuals as possible. This may be relevant when designing products to be used in public environments, such as buses and cash dispensers. Keates et al. [2000] and Clarkson & Keates [2001] present an approach whose objective is to make the products accessible for a large section of the population where all types of users are expected, including elderly and disabled people. The inclusive design approach embraces a 5-level approach (Figure 2.19) and an Inclusive Design Cube (IDC) (Figure 2.20). The former constitutes the framework for development and the latter illustrates the needs of different sections of the population and how different methods of inclusive design are complementary. The axes on the cube represent sensory, motion and cognitive capability, a representation that is intended to indicate the population coverage attained by different design choices.

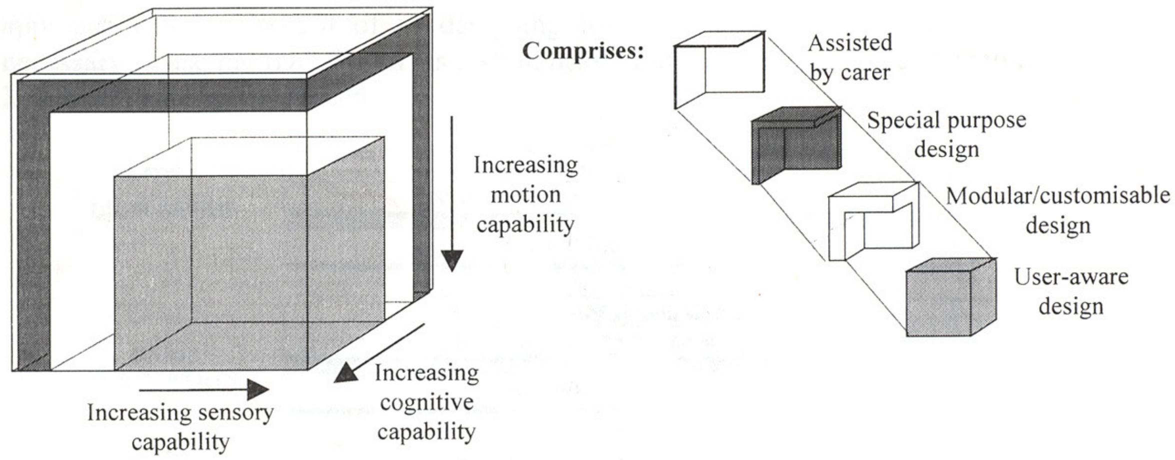


Figure 2.20 *Inclusive Design Cube [Clarkson & Keates, 2001]*

Hierarchical Task Analysis

Hierarchical task analysis [Kirwan & Ainsworth, 1992] breaks down tasks into operations and plans in a hierarchical structure. Figure 2.21 shows an example of tasks when listening to in-car entertainment.

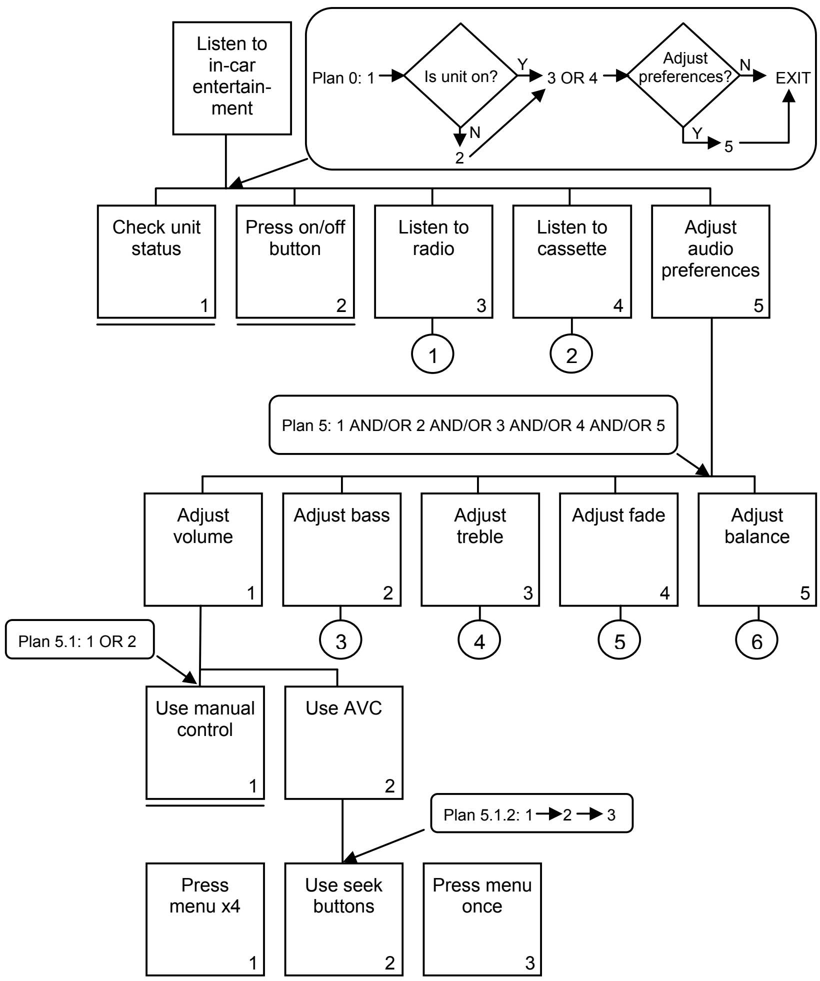


Figure 2.21 *An example of a hierarchical task analysis [Stanton, 1998]*

The process starts with defining a goal which the user of the system is intended to achieve. The goal is attained with the help of the user operations. HTA may, for example, be used for collecting information and proposing system modifications. One application deals with specific concerns regarding aspects such as interface design, work organisation, and the development of operator manuals and job aids. The method provides basically descriptive information. HTA is also used as input for other task analyses. Some practice in the utilisation of the methods is required before they can be used with assurance [Stanton, 1998].

Scenarios

Scenarios are described as narrative descriptions, i.e. stories, of people and their activities [Nardi 1992; Carroll, 2000]. Every scenario consists of at least one user/actor, who has particular goals, a work context and a sequence of actions and events. There are many definitions of scenarios, see Rolland et al. [1998] and in order to demonstrate the user activities they can take many different forms, such as textual narratives, annotated cartoon panels, video sequences and play-acting [Buur & Nielsen, 1995; Carroll, 1995]. Fulton Suri & Marsh [2000] have narrowed the definition of scenarios and adapted it for user-product interaction. They define scenarios as *descriptions of natural, constructed, or imagined contexts for user-product interactions*.

Scenarios have many different roles in product development. Among other purposes, they can be used for envisionment, implementation, documentation and training, and evaluation [Carroll, 1995]. Scenarios are also useful for analysing, acquiring and validating requirements [Potts et al., 1994].

According to Holt [1989] and Carroll [1995] scenarios could help the design team to focus on the future use and needs of the product. Since a scenario deals with use in a very concrete way, it becomes easier both to talk about use and design for use. Moreover, the discussions are more easily focused on the user activities [Carroll, 2002]. Many authors, such as Erickson [1995], Bødker [1998] and Carroll [2002], state that scenarios support communication and help to mediate thinking between people in the design team as well as to stakeholders outside the group.

Scenarios are useful in the synthesis part of the design work, since they not only provide retrospective analyses of an existing product [Hasdoğan, 1996]. Building a scenario may stimulate the imagination and support the design team in being creative. By using extreme or distinctive scenarios, or characters in the scenarios, the designer is encouraged to see things in another perspective, which may lead to new ways of designing [Bødker, 2000; Djajadiningrat, 2000 et al.; Alexander, 2002].

The limited accuracy of scenarios makes them easy to create and expand, but their use is also easily rejected [Carroll, 2002]. Their vagueness stimulates discussion and triggers people to be critical, as it is easier to express opinions on matters that are not finalised. At the same time, stories are specific, since they are directed towards a particular situation. This can cause the design team to loose control of the general design issues if the scenarios trigger them to focus on unnecessary details in a design [Sutcliffe, 2003]. Another consequence could be that scenarios are used to support weak solutions, since people tend to look for positive evidence to support their decisions, beliefs and hypotheses [Ashcraft, 1994].

User Characters

Although user characters may be an ingredient in scenarios, they can also be used alone. Design proposals can be tried out for various user characters. As stated by Buur & Nielsen [1995] and Kaulio et al. [1999], user character technique may have a twofold purpose; it may be used for innovation [e.g. Djajadiningrat et al., 2000] and for evaluation [e.g. Högberg, 2003]. It supports the focus on the users' problems and attitudes, and make it easier to communicate the user's needs and feelings [Buur & Nielsen, 1995; Högberg, 2003].

Apart from general information, such as name, family situation, age and hobbies, the user characters' personalities, skills, experiences and attitudes also have to be described [Buur & Nielsen, 1995; Fulton Suri & Marsh, 2000]. They should be described in a way that makes them personal. Pictures and drawings may facilitate communicating the personality of the users.

Djajadiningrat et al. [2000] maintain that extreme characters help the designers to highlight particular aspects for the design issues and expose traits of an intended user, which may be concealed if they are incorrect or embarrassing. *The extremes make one realise that the way things are is not necessarily the only way*. Also Buur & Nielsen [1995] and Fulton Suri & Marsh [2000] agree that the user characters should be distinct and that the designers should avoid designing for the prototypical users in a target group. However, they consider that the user characters need to be realistic and built on facts, since the value of personalisation will otherwise be lost.

More than One Method is Needed

In order to avoid biased information from one single method, Sanders [1992] suggests an approach, the *Converging perspective method*, where different methods such as observation, classification, conversation, description and participation are to be used to find overlapping information about user needs.

2.3.4 User Involvement

Techniques for learning about the users, understanding who they really are and how they work are necessary for developing products suited for the users [Beyer & Holtzblatt, 1998]. Macaulay [1995] suggests that cooperation and an increase in shared understanding between target users, potential buyers and other stakeholders early in product development, i.e. at the requirements stage, may lead to products that are more likely to be accepted and meet these peoples' needs. It is stated by Eason [1988] that users have to be involved in establishing their needs. However, the product developers should be aware that users do not have the same insight into the design issue. The users do not know what can be provided and what the consequences may be.

A greater user involvement in systems design was the subject of experiments in Europe during the 1970s and 1980s [Grudin, 1995].

Macaulay [1995] presents three degrees of cooperation between user and designer in the design activities:

1. *Analysts "elicit" requirements from users:* The approaches in this category are mainly based on interviews, questionnaires or observations. The users play a relatively passive role and the methods within this category rely heavily on the analyst's experience.
2. *Users and design teams participate:* An active involvement from users and designers is encouraged and the contribution from the users is believed to increase the possibilities of success. There are many forms of user participation, such as assisting in analysing problems at work and setting future objectives for efficiency.
3. *Involving stakeholders in understanding user needs:* More recent approaches request the product developers to involve not only the users and designers but also the stakeholders in identifying user needs.

There are different methods for user involvement in product development, see Kaulio [1998]. Kaulio categorises these methods according to the users' degree of involvement in design: design *for* users, design *with* users and design *by* users, and also how the methods support user involvement in different phases. It is found that the methods support user involvement mainly in the stages of specification, concept development and prototyping.

Holt [1989] categorises the approaches of user involvement according to whether the user has an active or passive role and whether the information is provided through coincidence or systematic involvement of the users.

2.4 Concluding the Theoretical Framework

Since the aim of the research is to develop formal design methods for user-product interaction, it is relevant to consider theories of relations between designers and users, the nature of rewarding design methods and an overview of existing design methods which take user aspects into account.

The purpose was also to investigate whether the design methods for user-product interactions could be based on existing theories and methods for design. Therefore, the theories of technical systems, domains and the design process are of great importance. User aspects should be combined with engineering design theories and therefore a good approach is to investigate whether the user can be described in a similar way to the technical system. The theory of human-machine systems shows that the human operator may be illustrated as a system component; hierarchical task analysis is an example showing that it is possible to describe the user operations and goals in a hierarchical structure. One question is whether it is possible to parallel the user actions to the functions in the function-means tree.

3 Research Approach

Initially, the chapter gives a short presentation of design science in general, where the nature and types of design research are treated. This is followed by a presentation of two methods that have affected the final research method of this work and a description of the various studies that were performed in order to develop and evaluate the new theories and methods.

3.1 Design Science

Even though this research work has an interdisciplinary character, it has its primary base and perspectives in the scientific area of engineering design. The final outcomes of the research are intended to support product developers, in particular design engineers, when introducing the user perspective into design activities.

Engineering design did not become a research area until the second half of the 20th century. Thus, it is a relatively new research area and one of the fastest growing [Blessing, 2002]. Successful design research should have some consequence in practice, since the objective of the research is to improve design. Blessing [2002] suggests that engineering design research should involve:

- *the formulation and validation of models and theories about the phenomenon of design, and*
- *the development and validation of knowledge, methods and tools – founded on these models and theories – in order to improve the design process (i.e. support industry in producing successful products).*

There are many aspects that have to be investigated, or at least considered, in research within this field. These aspects and the aim of engineering design research are illustrated in Figure 3.1.

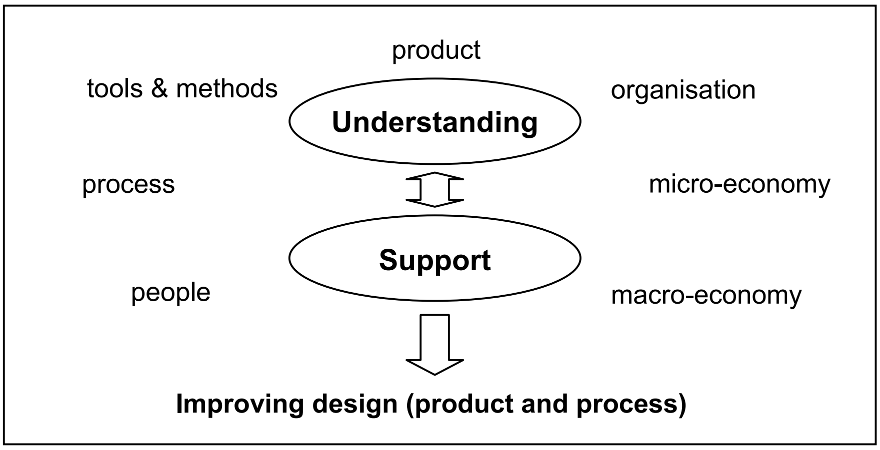


Figure 3.1 *The aim of design research is to build an understanding of the design phenomenon with its influencing aspects in order to create support for improving design [Blessing, 2002]*

The differences and similarities between design and research are frequently discussed. However, a major difference is that, while the aim of research is to build knowledge [Owen, 1997], the aim of design is to develop successful products. There are also distinctions between engineering science and natural science (e.g. physics, chemistry and biology). The aim and methodology of design science are mostly concerned with “synthesis”, whereas natural science deals mainly with “analysis”.

Design science embraces a broad area and may be carried out in various ways. Cross [1995] has structured design research into three areas:

- Research *into* design, such as empirical studies of design activities
- Research *for* design, such as creating tools and methods for different phases in the design process
- Research *through* design, such as abstractions from experience of designing and testing

All three areas of research are represented in this work.

Another way of dividing up engineering design is to use three knowledge categories, suggested by Horváth [2001]. These are the *source categories,* which embrace the fundamental mental capacity of engineering design, e.g. aesthetics, ergonomics and psychology, the *pipeline categories,* which establish the connections between the scientific/theoretical and the pragmatic/technical knowledge categories, e.g. design methods and conceptualisation, and the *sink categories,* which comprise the knowledge that is essential for the ultimate use of the entirety of engineering design knowledge, e.g. management and sustainability. Horváth presents nine contextual research categories in a reasoning model based on the three knowledge categories, see Horváth [2001]. Since the research carried out in this work belongs to the pipeline categories, it therefore needs support from the source categories and should sustain the sink categories.

3.2 The Research Method

Even though there are differences between engineering design and design science, the methods for carrying out research and design could be comparable, as Jørgensen [2002] points out in his model of development research and projects (Figure 3.2). He states it is generally established that development and research projects should comprise at least one synthesis operation as a major part of the project.

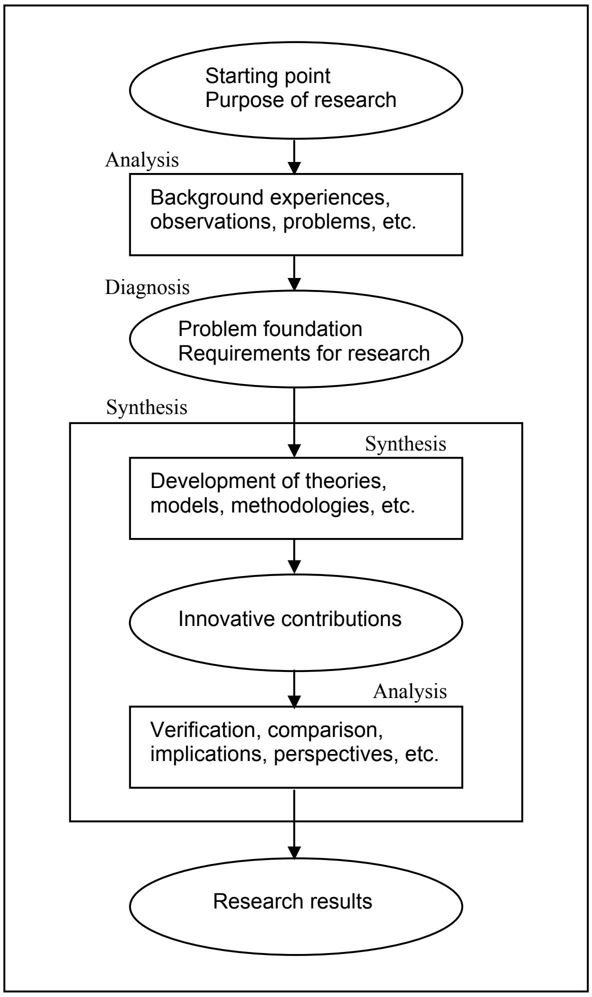


Figure 3.2 *A commonly used structure for development and research projects [Jørgensen, 2002]*

Together with the research method of Blessing et al. [1995] for developing product development methods intended to lead to more successful products (Figure 3.3), this model has influenced the research method within this work.

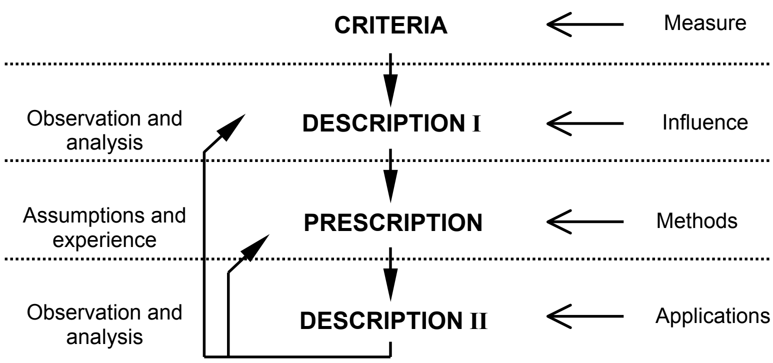


Figure 3.3 *Design research methodology, after Blessing et al. [1995]*

Accordingly, the first step in the research method of Blessing et al. [1995] is to decide which *criteria* should be used to judge success. To achieve a better understanding of the design process and the problems to be solved, a descriptive study is made (*Description I*). The outcome from the descriptive study indicates where support is useful and necessary, and thus provides an essential foundation for improving the design process. Guidelines, examples, methods and tools can be developed with the help of the results from the study (*Prescription*). Finally, the developed method should be validated. By performing a descriptive study (*Description II*), it is possible to investigate whether the method has had the expected effects on the criteria for success.

The research method for this work has four discernible phases: the initiation of the research problem (*Criteria*), investigating background information on the research problem (*Description I*), developing theories and methods (*Prescription*) and finally evaluating the theories and methods (*Description II*), see Figure 3.4. These are described in more detail below.

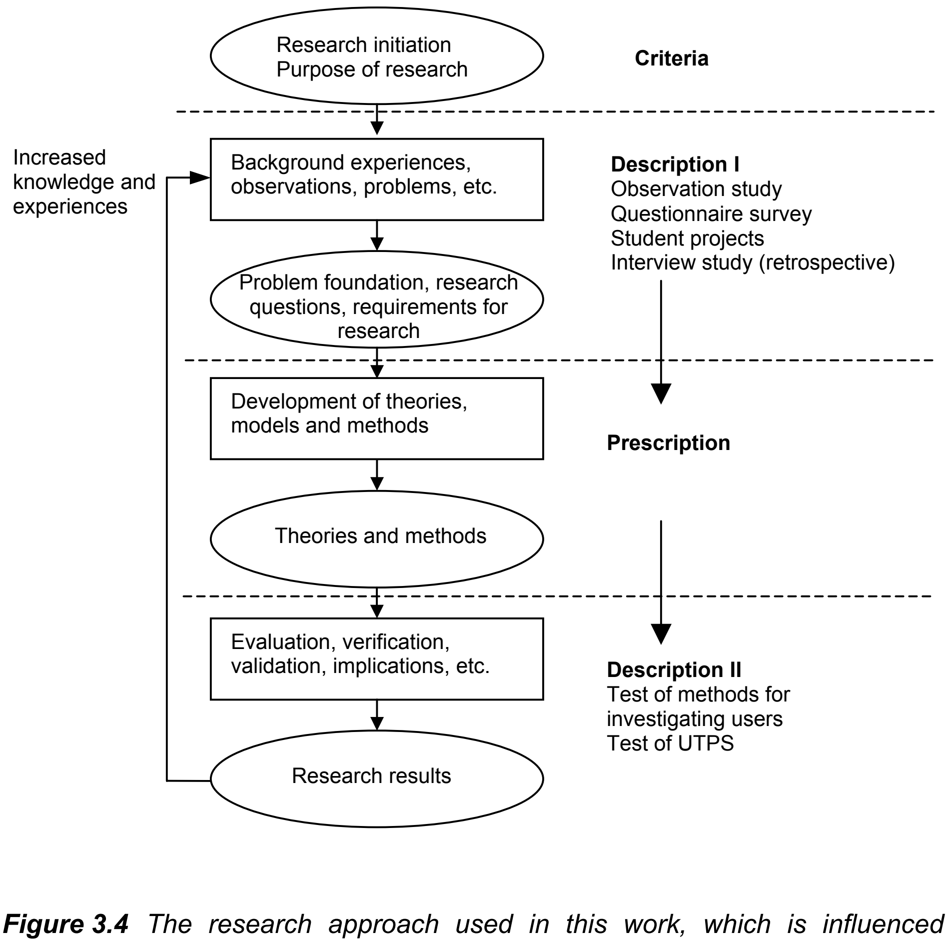


Figure 3.4 *The research approach used in this work, which is influenced by the methods of Blessing et al. [1995] and Jørgensen [2002]. For a description of the studies in Descriptions I and II, see Table 3.3.*

3.2.1 Criteria

The principal aim of the research work is to develop methods that support product developers in working with user aspects. In accordance with the research method of

Blessing et al. [1995], the natural starting point was to form a number of conditions, i.e. *criteria*, important for the design methods to fulfil in order to be valuable and usable for the product developers.

Obviously, there are numerous aspects determining the success of the product. The most common criteria are success in the market (sales, profit, return on investment) and fulfilment of technical requirements (good design). However, this research work has focused on the adaptation of the product to the user, and user aspects are therefore of the greatest priority in this research work. A more attractive and adapted product holds its own in the face of competition and is therefore a more successful product. The problem is to find appropriate criteria to measure. It is, for example, difficult to show that a change in sales is connected to the use of the developed methods. Since it was not possible within the scope of the test work to follow products from concept development to the time in the market when their profit could be estimated, the criteria for success have been limited to the work of the product development teams. Criteria that earlier have been shown to be important success factors during design work are chosen for the criteria of success, namely the product developers' awareness of and focus on the product users [e.g. Cooper & Kleinschmidt, 1987; Griffin & Hauser, 1993; Gould, 1995; Margolin, 1997] and the product developers' common agreement and knowledge of who the intended users are [Cooper & Kleinschmidt, 1990; Gould, 1995]. Since the developed methods are aimed at supporting the product developers in their synthesis work, the ability of the methods to support the generation of new ideas and requirements on the product is also investigated. Moreover, since a method needs to be simple and uncomplicated in order to be utilised [Norell, 1992; Smith & Dunckley, 2002], it is relevant to investigate the product developers' understanding of how the method should be used, as well as the ease of application of the methods.

In summary, the criteria for evaluating the methods consist of their capability to:

- Stimulate and support discussion about the users and the design issue within the design team
- Be rewarding for the product developers' understanding of the design issue, the users and the use situation
- Elicit new ideas, problems or requirements of the product to be developed
- Be understood and received by the product developers, i.e. indicate whether they are easy to apply

In addition to these criteria, the author has been open to identifying other positive and negative effects from the use of the developed methods.

3.2.2 Description I

The initial descriptive studies in this work are based on supervision of student projects, an observation study and a questionnaire survey (Table 3.3). Relevant factors influencing the product developers' (or students') work with design methods and user aspects were identified and investigated in order to obtain relevant background information for developing the theories and methods. After the methods were developed and tested, another descriptive study, a retrospective interview study, was carried out in order to investigate the product developers' work with and relation to the users. The outcomes from the studies are presented in Section 4.2.

- *Student projects:* During the supervision of industrial product development projects carried out by students, concrete examples from the projects have been studied. An abstraction was made of the students' work approaches, in particular their use of design methods, experienced through the supervision they were given.

- *Observation study:* At the outset, an observation study in a Swedish company which develops consumer products was performed. A product development project was followed for six months, where project meetings were observed. The observations focused on the way in which the company deals with user aspects in the product development process.

  The observation survey was of an open and passive nature [Holme & Solvang, 1997]; in other words, the test participants knew that they were being observed and the author's participation in the meetings was only for observing the work, not participating actively in it.

- *Questionnaire survey:* A survey was carried out on companies in Sweden who carry out product development [Janhager et al., 2002]. This comprises studies of the use of tools and methods in product development and design work, the use of different types of disciplinary knowledge in design work, and the collaboration between professional categories focusing specifically on the area of industrial design - engineering design interaction.

- *Interview study:* A retrospective study was carried out at the end of the research work (i.e. after description II) to confirm the relevance of and the need for the methods. Since the aim of the study was not to investigate the developed methods, but to give rise to new methods or modifications of the developed methods, it has the character of *Description I*. The study investigated how developers involved in early stages of product development communicate and work with the users. Four companies were investigated - two companies developing hand tools for professional use and two companies developing durable consumer products. Three people from each company were interviewed, a design engineer, a marketing representative or a marketing manager and a product development manager. The interviews were of semi-structured character [Lantz, 1993]. The study investigated how the various product development participants work with user aspects and whether their contacts, considerations and views of their users differ between them. Moreover, the study explored which methods the companies use for introducing user aspects in their design work. The results from the study are presented in Paper G.

The outcome from the descriptive studies indicated where support is useful and necessary, and thus provides an essential foundation for improving the design process.

3.2.3 Prescription

Based on the outcome of these studies (in *Description I*) and existing design theories, new theories and methods were developed, as described in Sections 4.3 and 4.4. This is the most important work in this research project and in the main it was performed in two steps. Firstly, the theories and models were established and then, based on these, the methods were created. Various approaches have been applied to a large number of products and different cases in the evolution of the final theories and methods. Even though the developed theories and methods are based on existing theories, the empirical work has provided the greatest impetus to progress.

A total of six methods have been developed. Four *Methods for investigating users* are identified, involving three ways of classifying users and their relations to their product and other users, together with an analysis of the motives behind the use of the product. Moreover, the technical process is expanded with the user process and theories about the interaction between user and product are established. Based on these theories, methods for introducing user aspects into the design issue in early design stages are developed; namely a scenario technique named the *User-technical process scenario (UTPS) technique* and a decomposition of functions and actions to a *Function-action tree (FAT)*.

3.2.4 Description II

Finally, the developed methods, apart from the *FAT*, were tested. The tests were divided into two descriptive studies in order to investigate whether the methods have the expected effects on the previously determined criteria. Unexpected side effects of the methods were also registered. It is important to ensure that the side effects do not have a negative influence on the success of the product [Blessing et al., 1995]. The methods were tested in industrial design teams. The tests were tried out with preliminary tests on students before they were actually carried out at the companies.

- *Test of methods for investigating users:* Three design teams, with four or five test persons in each, from the companies ITT Flygt, DeLaval and ESAB tried out four methods on products with which they are working. The methods are *User identification*, *User relations, Use profile* and *Activities, goals and motives*. The aim of the test study was to investigate whether the developed methods fulfilled the four criteria described above. Table 3.1 presents the products whose users were investigated in the companies, the number of test persons and the competencies represented in each group.

Table 3.1 *The test groups and the products to which they applied the four methods for investigating users*

Company	Product/concept	Number of test participants	Competencies in test group
ITT Flygt	Drainage pump, READY	4	Engineering design
DeLaval	Management system for milking	4	Engineering design System testing
ESAB	Remote control for welding machine	5	Engineering design Marketing Testing and development

The methods were evaluated by means of:

- *Observations* of the test sessions, which were videotaped. Afterwards, the product developers' work with the methods was analysed.
- *Questionnaires* dealing with the benefits and shortcomings of the methods.
- *Group discussions* with the test participants as a complement to the questionnaire.

- *Follow-up questionnaires* about the newness and importance of the requirements and ideas elicited during the test sessions.

The results of these tests can be found in Sections 5.2 and 5.3, and Paper E.

□ *Test of User-technical process scenario:* A developed scenario technique, named the *User-technical process Scenario* (*UTPS*) *technique* was tested by four design teams from companies carrying out product development: BT Industries AB, Husqvarna, Electrolux and Volvo Construction Equipment. Each test group consisted of four to seven persons with different competencies, which are presented in Table 3.2 together with the investigated products.

Table 3.2 *The participating companies and the investigated products*

Company	Tested products/concepts	Number of test participants	Competencies in test group
BT Industries AB	Counterbalanced trucks	4	Engineering design Marketing
Husqvarna	Petrol powered chainsaw	7	Engineering design Marketing Service
Electrolux	Air cleaner	6	Engineering design Marketing Service
Volvo Construction Equipment	Access to cabin	6	Engineering design A customer and an internal contact person for the customer Three students

Analogous to the test of the four methods for investigating users described above, the purpose of this test study was to investigate whether the *UTPS technique* fulfilled the previously presented criteria. Moreover, the study investigated whether the *UTPS technique* can be used for comparing different design solutions.

Observations, questionnaires and group discussions were performed similarly to the tests on the four methods, described above.

The result from the study is shown in Sections 5.2 and 5.3, and in Paper F.

During the two test studies of the developed methods, the author acted as instructor and guide, i.e. test leader, for the methods and was also observer of the investigations. There are a number of difficulties with observation studies and they become even more complicated to handle with these multiple roles. Influence and interpretation problems have been found to occur [Hansson, 2003].

The Influence Problem

By simply being present, the author/observer has an uncontrolled influence on the objects (the test participants and their use of the methods) being observed. For example, when the subjects know that they are being observed (as in these cases) it may happen, whether the observer is passive or active, that the subjects act in a way they think the researcher wants them to, which does not have to correspond to the researcher's wishes and is not necessarily part of their normal manner. Passivity by the observer may inhibit the participants' activity or irritate the participants. The opposite case is also possible, i.e. that an active observer dispels the participants' power of initiative. The best way to function in the group is to be adaptable and to try to act as the group expects, although this is not easy to judge. The observer's influence on the situation is thereby reduced [Holme & Solvang, 1997].

In this case, the test leader has tried, as far as possible, not to interfere in the process of implementing the methods, since one purpose of the tests was to investigate whether the group could manage to apply the methods by themselves. Furthermore, the test participants' opinions about the usability of the methods seemed to be more valid in this way. However, in all test sessions, the test leader introduced each method and supported the test participants in carrying out the methods by asking questions and guiding them carefully, for example if they did not know how to proceed.

An observer is also affected by the observation situation, which is particularly problematic when it comes to interpreting the observations.

The interpretation problem

The interpretation problem implies that the observer interprets the observations in a way that makes them less reliable, e.g. that the observer becomes subconsciously affected by his/her expectations about the outcome. Apart from being observer and test leader, the author is also the developer of the methods. This particular relation to the phenomena being observed may enhance the likelihood of subconscious expectation effects. Therefore, another person, not involved in the development of the methods, has supported the observations in order to reduce the risks of subconscious expectation effects and misinterpretations.

3.2.5 Summarising the Studies

The studies or research method phases carried out in this work can be compared with the classification made by Cross [1995] (Section 3.1). In Description I, the research is performed *into* design. The Prescription composes research *for* design. Moreover, even though the author, during the tests, has tried to avoid excessive involvement in the performance of the methods, the evaluation of the methods is somewhat self-experienced. Description II comprises research *through* design.

A summary of the studies in Descriptions I and II is shown in Table 3.3.

Table 3.3 *Overview of the empirical studies performed during the research work (see Figure 3.4). The student projects are not presented in the table, since they were followed informally.*

	Study	Objective	Study type	Data collection methods	Number of subjects	Presentation of the result
Description I	**Observation study**	Investigation of a consumer product developing company's work with the user aspects	Observation study: open, passive (explorative, descriptive)	Observations, informal interviews	7 to 15 (different team sizes)	Unofficial, unpublished research report
Description I	**Questionnaire study**	Study of the use of product development methods, design competencies, and communication aspects in Swedish industry	Questionnaire survey (explorative, descriptive)	Questionnaire (mail)	99	Conference paper [Janhager, Persson & Warell, 2002]
Description I	**Interview study**	Investigation of industrial hand tool developers' and consumer product developers' work with the users	Interview study (explorative, descriptive)	Interviews	12 (in 4 companies)	Conference paper (Paper G)
Description II	**Test of methods for investigating users**	Evaluation of four developed design methods, that take the user into account in actual industrial projects	Observation study: open, partly active (explorative, explanatory)	Observations, questionnaires, group interviews and follow-up questionnaires	13 (in 3 teams)	Conference paper (Paper E)
Description II	**Test of User-Technical-Process Scenario (UTPS)**	Evaluation of a developed scenario technique (UTPS technique) in actual industrial projects	Observation study: open, partly active (explorative, explanatory)	Observations, questionnaires and group interviews	23 (in 4 teams)	Submitted to journal (Paper F)

4 Results

The results acquired during the research work are initially presented in an outline and placed in a model of design science by Hubka & Eder [1988]. This is followed by an extraction of the descriptive results from the introductory studies and the retrospective interview study, after which there is a discussion of these with certain respect to the product developers' relation to and work with the users and need for design methods considering the user aspects. Finally, this chapter presents the developed theories and methods, which are demonstrated with examples, together with a proposal for a procedure in which the methods are introduced.

4.1 Outline of the Results

The results acquired during this research work consist of findings from the introductory studies (the student projects, the observations study and the questionnaire survey) and the retrospective interview study (1). Further contributions include theories and models of the user classifications and the user-technical systems (2), as well as methods for user consideration (3) which are mainly based on the theories developed (in 2). All results are summarised in Figure 4.1.

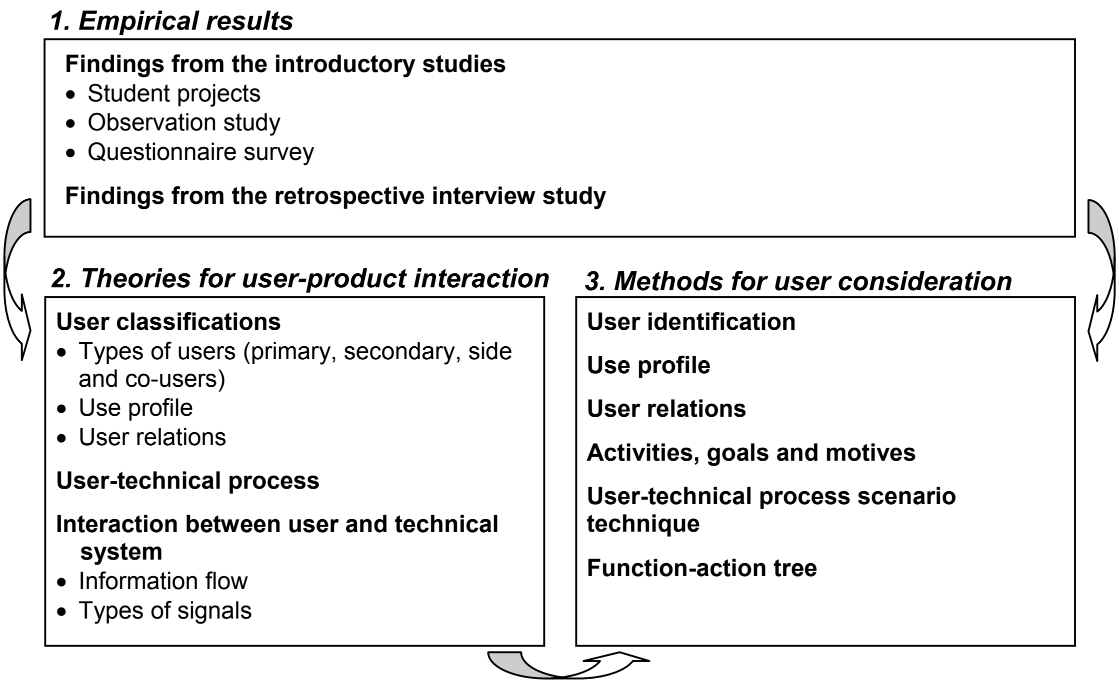


Figure 4.1 *A summary of the results contributed by this research work; the arrows show how the results have influenced one another*

4.1.1 Dimensions of Design Science

Hubka & Eder [1988] divide design science into two dimensions. One dimension consists of the descriptive and prescriptive statements and the other of the aspects of the technical system and the studies of the design process, as shown in Figure 4.2. The results from this research concern three quadrants in the model. The findings from the introductory studies and the retrospective study (1) belong primarily to the lower right quadrant. The results that involve supplementation of the user process to the theory of technical systems (2) fit into the lower left field, where the classifications of the users and their relation to the product (2) may also be suitably placed, even if they are focused more on the user than the technical system. However, the classifications are based upon the users' relation to the technical system. The design methods, which consider the users and are developed for supporting synthesis and creativity work (3), correspond to the upper right quadrant.

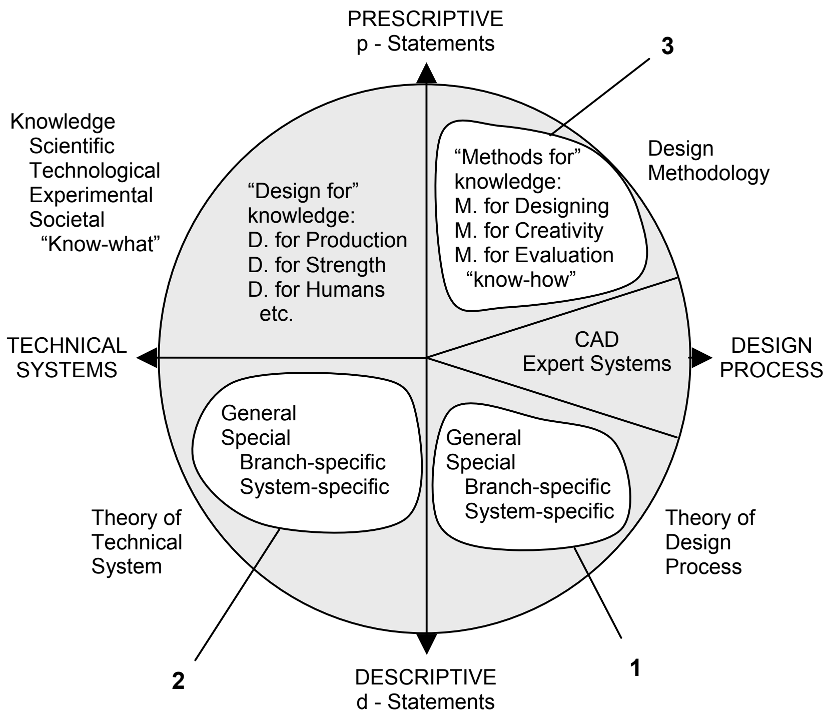


Figure 4.2 *The dimensions of design science [Hubka & Eder, 1988]; the numbers indicate how the results developed in this research work fit into this model and are in accordance with the numbers in Figure 4.1*

4.2 Empirical Results

The findings from the introductory studies embrace the outcomes from the student projects, the observation study and the questionnaire study. Outcomes from the retrospective interview study carried out at the end of this research work are also presented in this section. Finally, the empirical results are discussed.

4.2.1 Findings from the Introductory Studies

The outcomes from the introductory studies have provided essential background information for the theories and methods developed in this work. They confirm the need for a suitable content of methods for user-product interactions and suggest ideas for such content.

Student Projects

By supervising and observing student projects for several years, it has been obvious that there is a need for support to introduce user aspects into design. There is a lack of synthesis methods which take the interaction between user and product into consideration. The supervised students have worked with methods based on the Technical Process [Hubka & Eder, 1988] and the function-means tree [Andreasen, 1980] (Section 2.1.3) and it is clear that these theories are insufficient for products with intensive user interactions. Exploration of these theories in order to find supplementations was found to be a relevant approach.

Observation Study

An observation study was conducted in a Swedish company which develops consumer products. The survey continued for six months and focused on the company's treatment of user aspects in the design process. Among other things, the following outcomes were found:

- The observed company had no clear description of the intended users of the product to be developed, which implied that the product developers were uncertain about what the users might wish to have. It also caused conflicts in a number of stated requirements.
- The product developers focused more on the customer than the user. They discussed more in terms of how they should make the product sellable than how it should suit the intended users.
- Industrial designers were not involved in the project during the initiation phase, i.e. not during the six months while the project was being followed. A usability representative participated in one meeting at the end of the study. However, there seemed to be good cooperation between the various competencies.
- The company utilised user studies. For example, the user interface was tested with the help of a computer program which simulates the interface. Moreover, market research was carried out and the product developers seemed to have a high level of confidence in the results from this. In other words, they struggled to fulfil the user wishes derived from these investigations. Even though their defined product development procedure declared that they should use QFD in product development projects, they did not use it. They had tried the method once, but considered that it required too much time in relation to the benefit obtained.
- The most valuable outcomes from the study were the identified areas where support may be needed. The study showed that the product developers need support for focusing their discussions and that it is important to make a careful definition of the product idea, the users who are expected to use the product and their use situation. The result also emphasises the importance of making a

thorough product definition as early as possible in the mission statement, so that the whole design team is in agreement with the object in view.

Questionnaire Survey

The questionnaire survey was carried out among a number of Swedish companies who carry out product development. The study dealt with the use of tools and methods in product development and design, the use of different disciplinary knowledge in design work, and the collaboration between such professional categories, focusing on the area of industrial design - engineering design interaction. For further information about the survey, see Janhager et al. [2002]. Additional outcomes of the survey, concerning the industry's use of product representations, can be found in Johansson et al. [2001].

In the questionnaire survey, it was found that industrial designers and ergonomists are infrequently involved in the product development process. In many cases, they are called in occasionally to work on a project and therefore they may not belong naturally to the design team. In industry, aspects regarding consideration to the user are more frequently dealt with by the design engineer than the industrial designer or the ergonomist. Almost half of the companies use design engineers for aesthetic design purposes. The result also showed that the use of formal methods was rather limited. It was indicated that a frequent discussion of the design problem correlated to the use of formal methods. Moreover, the size of the company correlated to the experienced contact with the end users. The smaller companies considered that they had good contact with the users to a greater extent than the larger companies. However, it was more likely for the larger companies to have a defined procedure for product development work than the smaller companies. The respondents thought that there was a lack of time for reflection and consideration in the design process.

Based on these results, it is concluded that there is a need for formal design methods that are aimed at supporting the design engineer in introducing user aspects in design activities. The methods should also integrate industrial designers, ergonomists and other relevant competencies with the design team in a natural way.

4.2.2 Findings from the Retrospective Interview Study

Four companies that carry out product development were investigated with regard to their communication and work with users. The companies were chosen from two branches of industry. Two of them develop hand tools for professional use and the other two develop durable consumer products. Three persons from each company were interviewed: a design engineer, a marketing representative or marketing manager, and a product development manager.

It was found that none of the investigated companies have a defined and documented procedure for describing their intended end users. One of the developers of the consumer products creates a picture of the users based on a questionnaire, which accompanies the product bought by the user. The questionnaires provide the product developers with information on aspects such as the consumers' living situation, income and education. Furthermore, they get an idea of what the users think about the product and the motivation for their purchase. The central marketing division of the other consumer product developing company has defined market segments, which describe aspects such as the user's way of life, age and beliefs. However, none of the interviewed product developers take these into consideration when developing the products.

Under the assumption that the investigated companies correspond to a general picture of other companies in similar branches, there seemed to be a difference in the two branches' contact and work with the end users. The interviewees, including both the marketing representative/manager and the design engineers from the companies that develop tools, met users of their product regularly. Their attitude was also that these meetings were important for understanding the use situation and design problem, since they were not users of the products by themselves. On the other hand, the consumer product developers relied on the information from the sellers and their contact with the users, together with the product developers' own experience of the use of the products they were developing.

It was also noted that the knowledge and use of formal product development methods which consider user aspects are rather limited. None of the companies use formal methods regularly to analyse or generate new ideas about the user or use situation. One of the companies that develop hand tools had recently tested a structured interview form that the design engineer used when he visited the users of the tools. The interview form dealt with ergonomic issues such as working posture and experienced comfort. The interviewees from the companies that develop durable consumer products were satisfied without using methods for investigating the users and the use of the product, whereas interviewees, in particular the design engineers, from the tool companies asked for methods that deal with user aspects.

A summary of the outcomes from the interview study is found in Table 4.1. For details and further readings, see Paper G.

Table 4.1 *Results from the retrospective interview study*

	Company A	**Company B**	**Company C**	**Company D**
Developing	Hand tools	Hand tools	Consumer products	Consumer products
User group	Homogeneous	Varying	Varying	Varying
Procedure for defining the users	No	No	No	No
Description of the market segment	No	No	Defined intended market segment	User profile, based on questionnaires
Primary target groups	Users	Users	Users and sales companies	Users, sales companies and distributors
Market research with external support	Yes, but the design engineer and marketing representative did not know about it	No	Yes	Yes
Formal contact with users	Yes (all of the subjects)	Yes (all of the subjects)	No (none of the subjects)	No (none of the subjects)
Videotaping use sequences	No	Yes	? (Contradictory statements)	No (not initiated by the company)
QFD	No	No	Yes (version of)	No
Other types of formal methods considering the use/user, such as scenario techniques or user characters	No	No	No	No

4.2.3 Discussion of the Empirical Results

This discussion is primarily concentrated on the results from the retrospective interview study. However, results from the observation study and questionnaire study are also treated, especially to highlight results that are in accordance with each other.

The Use and Need of Methods Treating the User Aspects

Despite the fact that many authors, such as Cross [1994], Wright [1998] and Ulrich & Eppinger [2003], maintain that formal design methods are valuable for various purposes, e.g. integration and communication between different product development competencies and structuring of design work, the utilisation and implementation of methods is rather limited [Araujo, 2001], particularly in the concept stage [Araujo et al., 1996]. This is confirmed by the observation study, questionnaire study [Janhager et al., 2002] and interview study (Paper G), and also concerns methods that deal with user aspects. Noted reasons included insufficient knowledge of suitable design methods and negative experiences that have created a suspicious attitude towards them. Research has been carried out of the use and implementation of methods, e.g. Norell [1992]; Araujo [2001] and Lindahl [2005]. However, it appears that further investigations of the poor usage of the methods are needed. Even though many methods fulfil the identified criteria for being valuable, they are not applied in industry. Is it due to the company organisation or the character of the methods, is the information about the methods and their benefits simply communicated unsuccessfully to the industry, or are the statements of their benefits totally wrong? These are relevant questions to which answers are needed by researchers and others working with development of product development methods and tools in order to find better methods.

Product developers, in particular the design engineers, in the tool developing companies asked for methods supporting them in their work with the users. The reason why the tool developing companies and not the consumer product developing companies had realised this need may be that the former have more demanding user related problems to handle, for which they have realised they need support. The high workload on the operators using the tools means that the products' ergonomic properties are crucial. Poorly designed tools strongly influence the users' performance negatively and may lead to injuries. This calls for thoughtful consideration of ergonomics in the hand tool design process. For consumer products, poor ergonomics may cause annoyance and disappointment, but other values such as aesthetics may be more important for the choice of product.

Another reason for the difference in the attitude towards design methods for working with the user aspects may be found in the difference in contact with the users. Since the consumer product developers had already received filtered information from the sellers and distributors, it may appear quite uncomplicated for them to handle it, while the tool developers become aware of more problems and design mistakes during their contact with the users and realise that they need support in the work of finding the key concerns, sorting the information from the users and evaluating product concepts.

A motivation for the methods developed in this work is that the product developers within the companies talk about users and formulate user requirements mainly from a technical perspective and not a user perspective. For example, they specify the minimum and maximum size of the handle instead of specifying what hand sizes the tool should fit. This approach entails that the designers become bound to a particular type of handle. Moreover, the user group can change, making it difficult to ensure that the products are suited to the intended users. User characters and scenarios help the product developers to personalise the users and elevate the discussions about the design problem.

As already argued by many authors, e.g. Buur & Nielsen [1995], Carroll [1995] and Clarkson & Keates [2001], there is a need for design methods that take account of the users and the use of the product. The studies performed within this work strengthen this statement.

Defining the Users

It is found that neither the observed company in the observation study nor the investigated companies in the retrospective interview study have a procedure for defining their intended users. The central marketing division in one of the investigated durable consumer product development companies has defined user segments, but the product developers do not consider them when designing the products. However, for this type of product it is better to identify an intended user group and work together to position the product to this user group than to leave the design open for many type of user. Otherwise, there is a risk that the product's features will diverge and not suit any users at all. This was observed in the observation study, where conflicts between requirements on the product to be developed occurred. For example, the product developers argued on one occasion that the product should suit people in a stressful environment who need to save time, and on another occasion they said that the users would enjoy spending some time in finding and learning the user interface and all the functions of the product.

A well-defined user group that is known to the product developers is stated by many authors [e.g. Gould, 1995; Margolin, 1997; Preece, 2002] as being important for designing successful products. Utilising methods such as the user classification methods and identifying *Activities, goals and motives* (Section 4.4) may provide a more homogeneous picture of the intended users and the use situations for the product development team. Product developers need to be informed about the importance of acquiring a clear description of their intended users.

Product Developers' Contact with the Users

A correlation is shown in the questionnaire study which indicates that smaller companies have better contact with the users than larger companies. The tendency was also discerned in the interview study. This connection is probably an effect of looser organisations and more flexibility in smaller companies that encourage product developers to take the initiative in adopting what seem to be more unusual working approaches, such as the structured interview form concerning the tool operators' use of the products. Another explanation may be that the users or the customers, who sometimes form the link to the users, feel that contact with smaller companies is smoother and more personal, and such companies therefore have more natural access to the users. This implies that large companies need to work more actively than today with user relations.

The product developers' contact with the users differed in the two investigated branches "hand tools for professional use" and "durable consumer products". The reason for the developers of the hand tools being more particular about investigating the users than the consumer product developers may be that they are not users by themselves. While they do not know what it is like to operate the products for many hours daily and therefore need the operators' guidance, the developers of the consumer products have the opportunity to use the product in their everyday lives. However, the product developers should be careful in regarding themselves as users of the products they are developing. Since they know the reasons for, and solutions of, particular functions and applications, they are not going to experience the same problems with, or expectations on, the products as general users. According to Grudin [1995], it has become less trustworthy to rely on intuition in product development, and the value of using intuition instead of communicating with the users ought to be investigated. Hence, it is vital to have contact with the users and to learn about their needs through, for example, interviews, observations and discussion groups [Gould, 1995; Stanton, 1998].

Even though the thesis argues that it is important for product developers to meet users, it is also necessary to have access to methods that can be used without user participation, such as the methods developed in this work. The reason for this is that the designers also need time for creation by themselves. It is valuable to let the users become involved in establishing their needs, but, as pointed out by Eason [1988], they do not have the same insight or knowledge of the prospects or the consequences of product design as the designers may have. Furthermore, in new product development, there do not always exist users with experience of the product to be developed. However, in those cases where users exist, it is relevant to introduce them occasionally when practising these methods.

Directing the User, the Customer or the Seller?

Grudin [1995] states that, particularly in less mature markets, the products in general are designed to attract the customers, i.e. the person who decides about the purchase, not the users. The observed consumer product development company in the observation study was more directed towards the customers than the users. The interviewed developers of the durable consumer products were also more focused on the customers than the users. They approach the sellers and the distributors, as their support is needed to reach the customers and users. Unlike these companies, the companies that develop hand tools thought it is crucial to meet and consult the operators of the tools, since they have a great influence on the choice of the purchase. Another reason for the durable consumer product developers approaching the sellers instead of the users may be that they think that the sellers' knowledge about the users that they obtain through daily contact with them in selling situations is sufficient. The confidence these product developers have in the information on the users communicated to them from the sellers can be questioned. Apart from the fact that second-hand information is always slightly distorted, a problem is that the sellers and the users do not always have the same demands on the products. The sellers want products that are easily sold or give a good profit, while the users probably want products they are going to enjoy using or possessing. For example, a large number of functions in a cellular phone may be a selling argument, even though they may not be used by the prospective user, while the user is probably disappointed with a product containing functions that he/she has paid for but which are either unnecessary or too complicated to apply. Holt [1989] maintains that the designers have a mission:

> *"The challenge to the design engineer is to provide the users with what they want, rather than persuade them to buy what he thinks they want".*

Another problem with relying on the sellers' information about the users is that the sellers are assumed simply to deliver retrospective proposals, such as problems and complaints, which may lead to minor changes. They do not come up with new suggestions for completely new functions or technical advances. Another related problem might be that the type of information about the users the product developers obtain from the distributors or the sellers is not suited for product development. For example, according to Griffin & Hauser [1993], traditional market studies are appropriate for strategic decisions, but deliver almost no suitable information for product design.

Consequently, it is insufficient just to meet the sellers. The designers must also occasionally meet the users, not simply to obtain correct information of the right type, but also to become inspired.

4.3 Theories for User-Product Interaction

This section offers theories for classifying and investigating users. Moreover, a new model - a *User-technical process*, which is a supplement of the user process to the technical process (Section 2.1.3), and additional theories to this are presented. All introduced theories, except for *Interaction between user and technical system*, are integrated in the final methods described in Section 4.4.

4.3.1 User Classifications

Users may be classified according to their relation to the products or other users. Below, three ways of classifying the users are proposed.

Types of User

Certain products, such as trains, have numerous different users. A classification of four user types is identified. The motorman and the passenger are *primary users*, since they use the product for its primary purpose [Buur & Windum, 1994]. Other persons interact with the product actively without using it for its particular purpose, such as the cleaner and the repair man. They are named *secondary users*. The *side users* are the people who live in the vicinity of the railway, and are affected by the noise from the trains and the hazardous environment. These individuals have no certain purpose for interacting with the railway. *Co-users* are those who cooperate with a person who uses a product, see Figure 4.3 and Table 4.2.

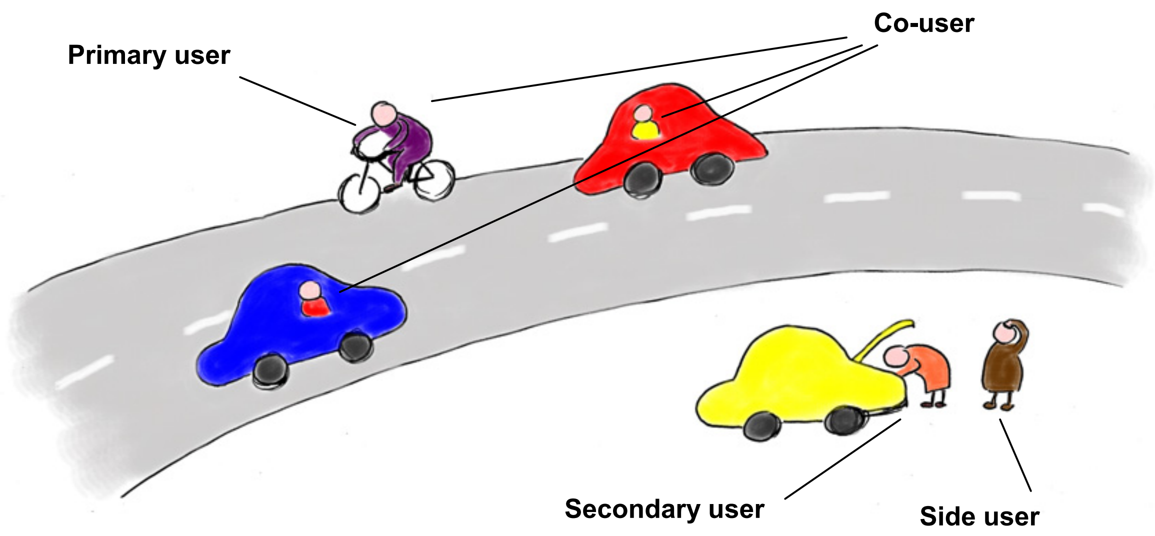


Figure 4.3 *An illustration of primary user, secondary user, side user and co-user*

During product development, it is essential to consider all these groups of individuals, since they may have requirements on the product.

Table 4.2 *Four types of user; the examples are adapted to a car*

User type	Definition	Example	Examples of requirements on a car
Primary user	A person who uses the product for its primary purpose [Buur & Windum, 1994]	Driver or passenger in a car	Low petrol consumption Spacious boot
Secondary user	A person who uses the product, but not for its primary purpose	Motor mechanic Car salesman	Easily used gearbox Readily sold
Side user	A person who is affected by the product, either negatively or positively, in daily life but without having decided to use the product	People living near a motorway become side users of the cars passing by	Minimise noise from the engine Minimise toxic pollution
Co-user	A person who co-operates with a primary or secondary user in some way without using his or her product *(Co-users may each have a technical system of their own which they use on the same level. They may often be seen as co-operating primary users vis-à-vis the ordinary primary users, but for a higher level of the system.)*	Driver in a traffic situation *(He/she is a co-user of another driver's car. The two drivers may also be regarded as primary users of the traffic system)*	Clear hazard warning light Clear flashing direction indicator

It is possible for a person to have more than one of these use roles at the same time and they could be directed either towards different products or towards the same product. For instance, a person could be a primary user and secondary user of a radio he is listening to if he is cleaning it at the same time. Therefore, it could be convenient to talk about primary use, secondary use, side use and co-use instead of giving the persons different roles. This classification is also presented in Paper B.

However, when the word "user" appears alone in this thesis, it refers mainly to the primary user.

Use Profile

The importance of considering users' experience of the product is emphasised by authors such as Faulkner [2000] and Preece [2002]. However, apart from use experience, there are other conditions in the relation between user and product that differ between various users. A classification based on the users' relation to their products or the use of the product is made. The various users could be investigated under the categories use experience, influence on and responsibility of the use, emotional relationship to the product and degree of interaction with the product.

Use Experience

Users' experience of the product depends on their:

- *Length of use and education* concerning the products. Users may be categorised as newcomers, experienced users or specialists.
- *Frequency of use,* i.e. how often the users use the product. Requirements on the product change if a user uses a product rarely, occasionally or often.

Influence on and Responsibility of Use

It is also relevant to categorise the users according to their:

- *Influence on the choice* of product they are going to use, which differs since other people may have the power to decide what kinds of product to order, for example in a working place.
- *Influence on the use situation*. Another user or the technical system may have control over the use situation. Compare the situations for a pilot and a passenger of an aircraft.
- *Responsibility in use* of a product, which may be essential for a designer to consider, e.g. a surgeon handling his instruments.

Emotional Relationship to the Product

The special feelings users may have for a product, from very strong to inconsiderable, vary between different types of products as well as between users and may depend on:

- *Ownership* of the product, i.e. whether the user owns the product or not. The product could, for example, be a general product located in public places where anyone can use it.
- *Social aspects*, i.e. the user may wish to give a particular signal, such as exclusiveness or group affiliation, to other persons in the surroundings.
- *Mental influence* that the product may have on the user, such as feelings, impressions and opinions regarding the product.

Degree of Interaction with the product

Users could also be categorised according to their mental and physical interaction with the product, namely the user's:

- *Cognitive interaction* with the product, whose intensity differs for various products. High cognitive interaction sets demands on the product's semantic functions.
- *Physical contact* with the product, which affects the demands on the physical ergonomics of the product.

Within each of these categories, a user can be studied to determine the conditions to which he/she is subject. The different categories are collected in Table 4.3. The table also shows various aspects which are important to consider in designing products for these types of user. For more comprehensive explanations of the categories and examples of how these can influence the requirements on the design, see Paper B.

Table 4.3 *The use categories, users' degree of performance of the categories and examples of extent of importance of aspects possibly relevant for the product, due to the categories*

High extent

Low extent

	Categories	Degree of performance	Extent of importance of the product
Use experience	Length of use and education	Newcomer Experienced Specialist	Easy to understand and use
	Frequency of use	Rare Occasional Frequent	Ergonomics; Stress factors
Influence on and responsibility of use	Influence on the choice of product	No influence Some influence Great influence	Adaptability
	Influence on the use situation	No influence Some influence Great influence	Physical ergonomics; Confidence
	Responsibility in use	No responsibility Some responsibility Great responsibility	Reliability; Confidence
Emotional relationship to the product	Ownership	Use of general product Use of rented product Use of owned product	Easy to use; Characteristic; Adaptability
	Social aspects	Of little importance Of some importance Of great importance	Aesthetics/sense; Characteristic
	Mental influence of product	User with no mental influence User with some mental influence User with great mental influence	Semantics; Aesthetics/sense
Degree of interaction with the product	Cognitive interaction	No cognitive interaction Some cognitive interaction Great cognitive interaction	Semantics
	Physical interaction	No physical interaction Some physical interaction Great physical interaction	Physical ergonomics

User Relations

A product may have more than one user (e.g. primary users, secondary users, side users and co-users) and there are different kinds of relations between these users. A user can, for example, control, collaborate with, perform/demonstrate for, meet, influence or prevent another user through the product (Figure 4.4). In the case where these relations exist, they may affect the conditions and requirements for the design. Table 4.4 and Table 4.5 present various classes of user relations and applications of these.

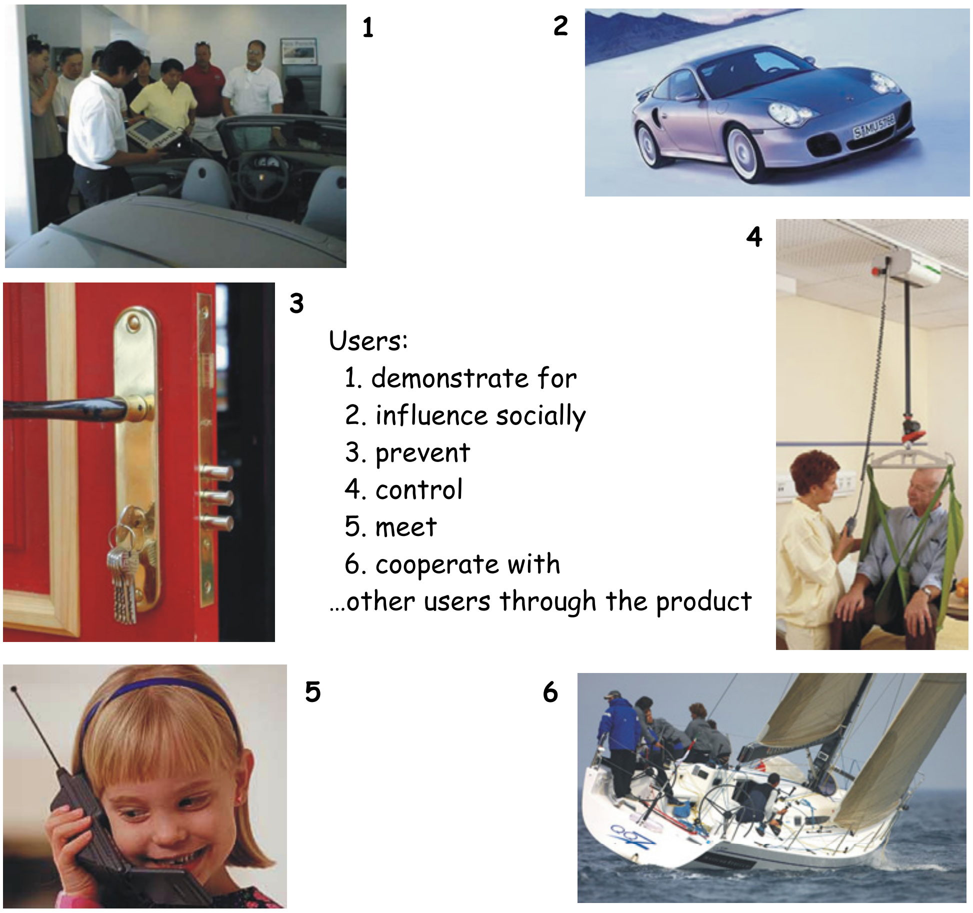


Figure 4.4 *Users may have different relations to other users*

Table 4.4 *Primary users', secondary users', side users' and co-users' relations through the product may be based on control, collaboration, performance/demonstration, meeting, prevention and social relationships*

Relation	***Explanation/Comment***	***Importance***	***Examples***
Control			
User with responsibility and dependent user	The user who operates the product and is responsible for it has a responsibility towards another user who is dependent on him/her and the product.	The users, both the responsible and the dependent, should trust the product.	*Carer/doctor – patient* *Driver – passenger*
User who affects another person	The affected user may not use the product for its primary purpose and he/she may not have chosen to be in this relation with the product and the other user.	The product needs to be designed for creating a good relation between the users.	*Motorist – pedestrian* *A person using a chainsaw – a person who is near the chainsaw*
Collaboration			
Collaborating users of the same product	Some products need more than one user in collaboration in order to be used in a proper way.	The product needs to have an apparent user interface and the allocation of the tasks should be clear.	*Crew on a sailing boat* *Children playing with a seesaw*
Collaborating users with one user controlling the product	A user of the product may need to collaborate with a person who is not primarily using the product but may use another product.	This kind of collaboration is often based on rules and regulations.	*Two motorists in a traffic situation* *Two helmsmen meeting in different boats.*
Compromised users	Users who need to agree with each other when using the product may need to compromise.	These products need to be designed to facilitate the compromise in such situations.	*People sharing the space around a cash desk* *Passengers in a plane who are taking their seats*
Performance and Demonstration			
User with spectators	A user may need to handle the product while others are watching.	The product ought to have a clear, simple user interface and be quick and simple to use.	*Person showing OH slides to an audience* *Person taking photos of another person*
Expert and amateur/novice	A person could be at a disadvantage to another user since there may be differences in their knowledge about the product.	It is important that the two parties can conduct a discussion about the product and understand each other.	*Repair man – customer*
Instructor and learner	Sometimes, a person needs to demonstrate and explain to another user how a product works.	The design of products may support and facilitate demonstration and learning.	*Computer technician – primary user of the computer*

Table 4.5 Continuation of Table 4.4

Relation	Explanation/Comment	Importance	Examples
Meeting			
Users meeting via the product	Users may not interact physically but could meet through the product.	The product should be easy to adjust/readjust and to leave tidy.	*Users of rented products (e.g. cars) Shift workers sharing their workplace with others*
Prevention			
User who inhibits another user with the aid of the product	This type of relation occurs when a user prevents another user from doing something with the product or with the aid of the product.	Especially relevant for crime prevention and safety issues.	*Parents prevent children from opening the oven door by fitting a safety catch*
Social Relationships			
Person who wishes to influence other persons	A user may want to use the product to give those around him/her the impression of being a particular person or to show group affiliation.	It is necessary to consider what impression the product should give, whether it should symbolise something special and in that case how the design could support this.	*A person with an exclusive wristwatch - the person he/she wants to impress*

More detailed explanations and additional examples are shown in Paper B.

4.3.2 User-Technical Process

In traditional design theories, such as Andreasen [1980] and Hubka & Eder [1992], the user is not particularly considered in the synthesis part of the design work, i.e. when the product concepts are created. The product is investigated as an isolated system, despite the fact that many products do not attain their whole functionality or do not function at all without the involvement of human beings. Instead, the user and the technical system, in interplay with each other, together constitute a unified system - a *user-technical system*. Whether the user or the product carries out a particular task may affect product design and performance. This is illustrated with different designs of a saw. The user and the technical system should together perform the tasks:

- Cut wood fibres
- Create movement of saw organ
- Create driving force
- Operate and handle saw
- Keep saw in position

The *User-technical processes* in Figure 4.5 show:

1. A foxtail saw - the user has to perform all the tasks, apart from cutting wood fibres.
2. A manual mitre saw - the technical system supports the steering of the saw's movement and the cutting of wood fibres.

3. A chainsaw - the user only needs to operate and handle the saw, and to keep the saw in the right position.
4. A circular saw – the technical system executes all the tasks apart from operating and handling the saw.

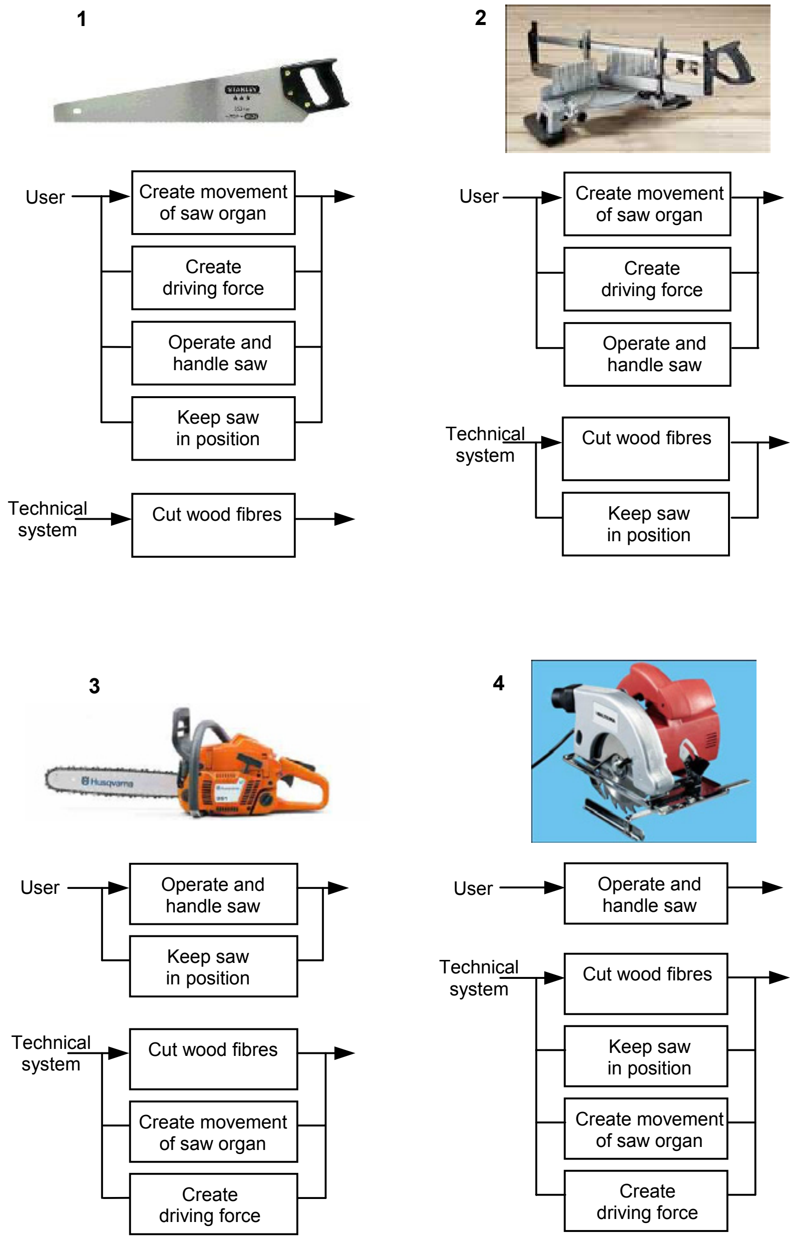


Figure 4.5 *Four different types of saw, depending on whether the user or the technical system is going to perform the functions and actions*

The *user actions* and the *technical functions* have been placed in parallel in a model – a *User-technical process* (Figure 4.6) in order to illustrate the interactions between the two parts and their flow. The users' feelings and thoughts, in other words the *mental activities,* are also introduced in the model. The user actions and the mental activities constitute the *user process*, while the technical process consists of the technical functions and the *interface functions*. A time axis extends along the processes, parallel to the actions, activities and functions.

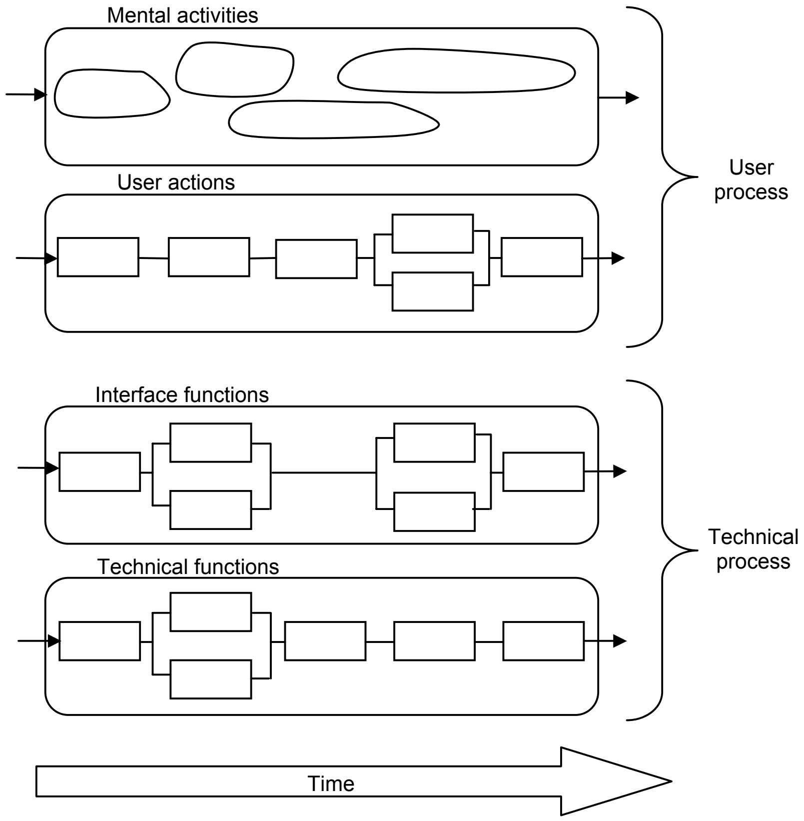


Figure 4.6 *The User-technical process, which consists of the user process with its mental activities and user actions, and the technical process with interface functions and technical functions*

The Components of a User-Technical Process

□ *Mental activities:* In the mental activities, the user's feelings and thoughts are illustrated. It is impossible to predict what kind of emotions or attitudes the user will have in the relation to the product, but it is possible to imagine the worst feelings or the most pleasant thoughts. A sequence of feelings may also be difficult to schematise, because the user experiences them more or less all the time and thoughts come and go. However, it is feasible to illustrate when the designer wants the feelings or thoughts to be initiated or when he/she believes they are going to occur.

□ *User actions:* An action is a process directed towards a conscious purpose and is subordinated to the representation of the result that must be achieved. An action is subordinated to a specific goal [Nielsen, 2001]. The user's intended actions are described here in the user process. In a more detailed user process, the user's actions may consist of user operations[10].

□ *Interface functions:* The interface function is an integral part of the technical functions and consists of what an element of a technical system actively or

[10] One or a chain of operations realises the actions. The operations are in general carried out unconsciously (automatically).

passively does in order to contribute to the interaction between user and product. It deals with sending and receiving signals with the aid of the product's performance and appearance. The semantic functions [Monö, 1997] are a type of interface function, see Section 2.1.3.

- *Technical functions:* A technical function is what an element (system, part, component, module, organ, feature, etc.) of a technical system actively or passively does in order to contribute to a certain purpose [Hubka & Eder, 1988].

A *User-technical process* for an oven may be arranged as the process in Figure 4.7.

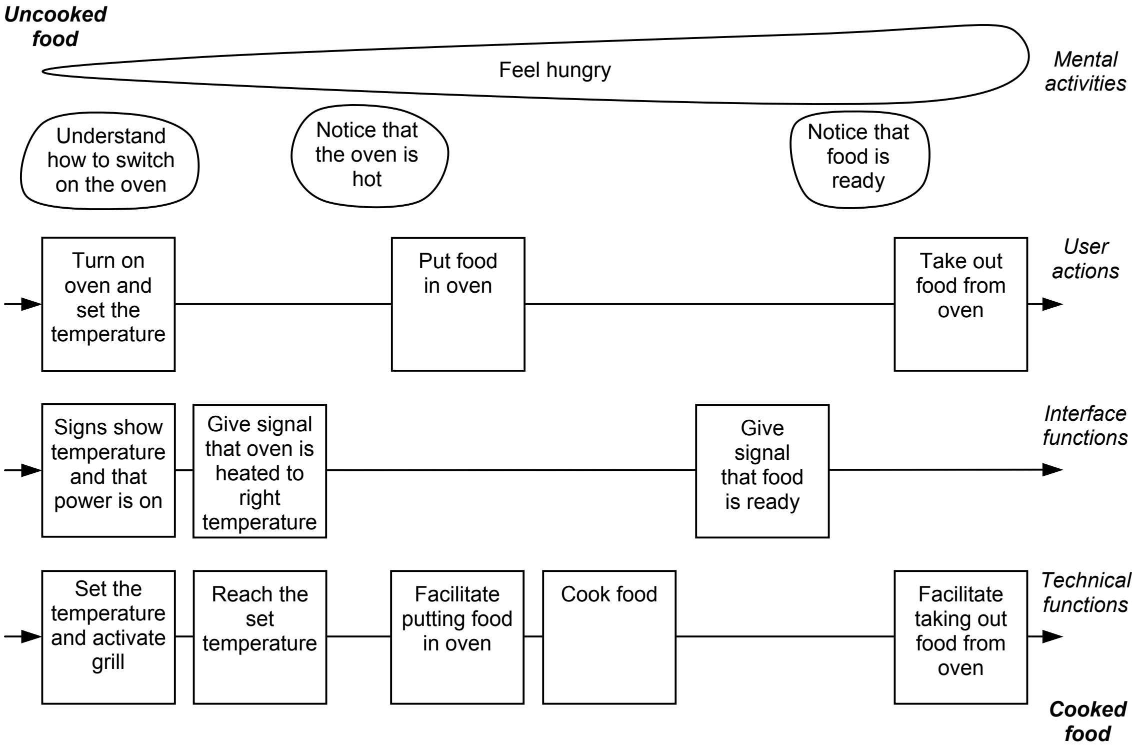


Figure 4.7 *The beginning of a User-technical process for an oven. The process may be made more or less specific, depending on which stage in the product development process the design is in, i.e. how much is known about the design. For example, the opening and closing of the oven door is omitted here.*

If the user interface is not particularly complex, a suggestion is to let the interface functions be included in the technical functions and perhaps omit most of them from the process. It is more appropriate to deal with the interface functions separately when working with products having an advanced user interface, such as remote controls and cellular telephones. In most of the following applications and examples of the *User-technical process*, the interface functions are either not treated or are included in the technical functions.

Since the user and the technical system collaborate to attain a particular goal, such as performing a task, it is practicable and necessary that the two systems' processes have the same operand with the same input and output, see Section 2.1.3, despite the fact that the user actions may not immediately be directed towards the operand. While the technical functions may be focused on the operand's transformations, the user actions may be directed towards the technical system or another user. However, the operand is transformed with the user and the technical system in cooperation with each other. Some of the following examples are too detailed for the technical functions to be immediately directed towards the operand.

Non-transforming Products

Another benefit of introducing the user actions to the technical process is that this model can also treat products that have no transformation but an interaction with a user, for example a chair. Even if a chair is a static product and may be experienced in somewhat artificial terms as a technical process, the process becomes more natural and the chair is given a meaningful assignment by introducing the user actions, see Figure 4.8.

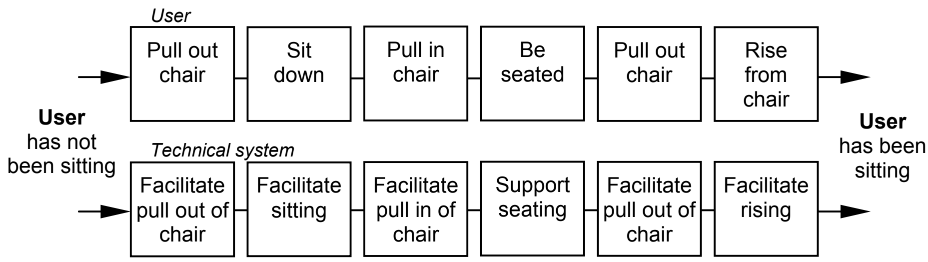


Figure 4.8 *User-technical process for a chair; the user is operand*

More than One User of a Product

If it is difficult to decide which technical principle is to be used or in what order the tasks should be performed, it may be necessary to create more than one *User-technical process*. Sometimes, it is also relevant to include more than one user, as in the example of a cash desk with a cashier and a customer as users (Figure 4.9).

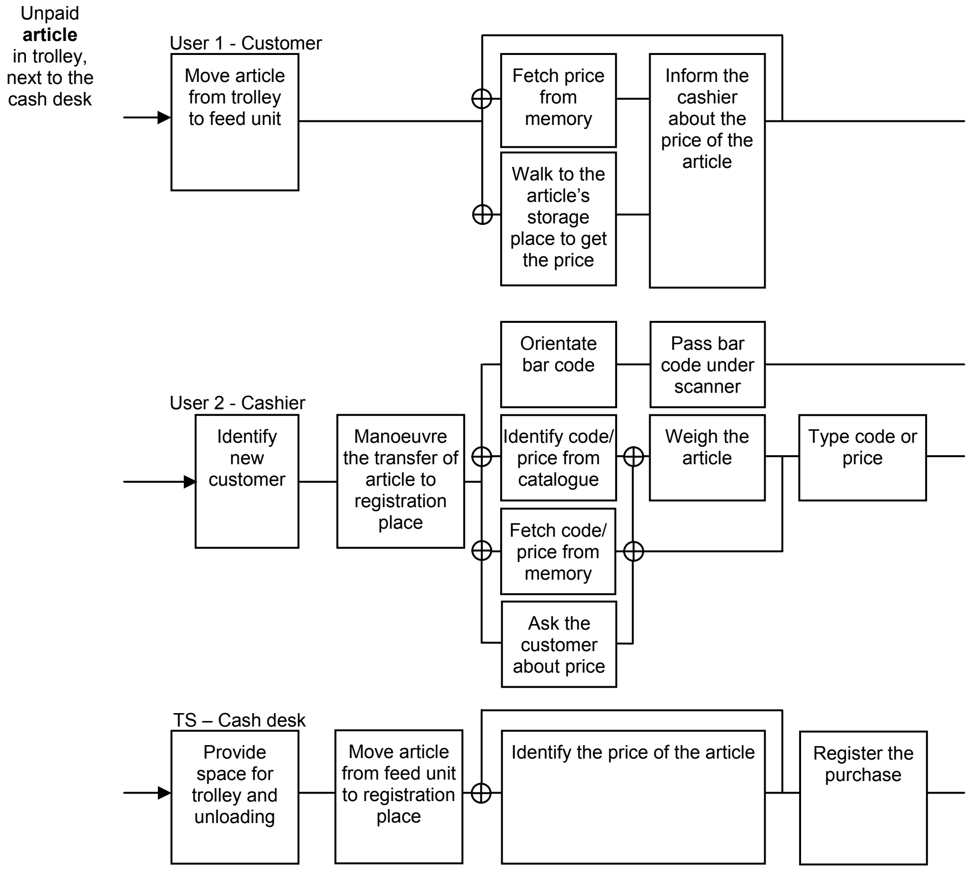


Figure 4.9 *Example of the beginning of a User-technical process for a cash desk. The process includes two users; the customer and the cashier. The sign ⊕ indicates "or".*

Marking Options and Uncertainties

Before the concepts are generated, there may be uncertainties about whether the user or a product should perform a specific task; alternatively, they may both be involved in the assignment. It is relevant to indicate these different circumstances in the *User-technical process* and later to transfer them into the *Function-action tree*, see Section 4.4.6.

□ *Undecided tasks*: When it is not decided whether the user or the technical system is to perform a particular task, it is convenient to mark the technical function and the user action with a symbol for "or": ⊕. In the example of a fork lift truck in Figure 4.10, it has not yet been decided whether the machine or the user is to drive the truck forwards, i.e. whether it is going to be motor-driven or not.

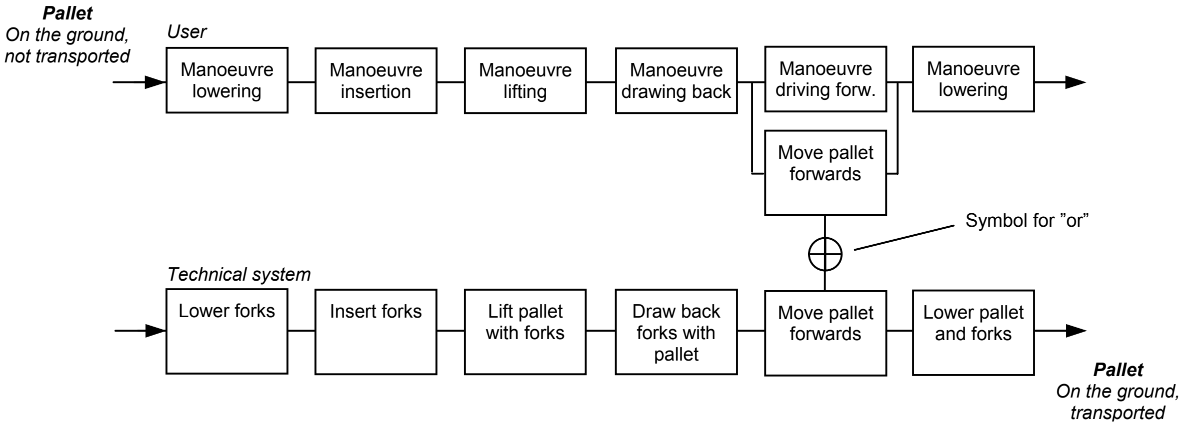


***Figure 4.10** Example of a fork lift truck; it has not yet been decided whether the user or the technical system is to drive the truck forwards*

- *Coupled tasks*: When it should be stressed that both the user and the technical system are needed to handle a task, the function and action can be marked with a summating junction: ⊗. The example of a chainsaw in Figure 4.11 illustrates how a summating junction may be used. This information is necessary when the means are to be chosen for the function and action (see Section 4.4.6), since they are connected to each other.

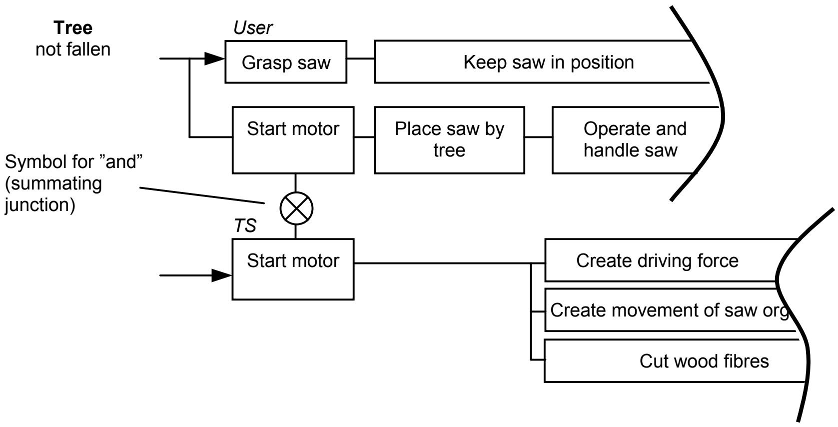


***Figure 4.11** Example of a chainsaw; both the technical system (TS) and the user need to be involved in the function/action “Start motor”*

Different Phases of User Processes

The examples of the *User-technical process* illustrated above are adapted to users in the primary use phase. Use in other phases in the product life cycle, such as assembly phase, installation phase, service phase and recycling phase (Section 2.2.1), may also be modelled by the *User-technical process*.

In an assembly phase for a cellular telephone, it is possible to think of different solutions. For example, the screws may be assembled manually or they may already be attached to the front shell, which would perhaps make it easier to put the two shell parts together. The screws could also be assembled with the aid of a power screwdriver or manually. This type of discussion illustrates one of the benefits of establishing a *User-technical process* for the assembly of the product. In this case, a second technical system (the power screwdriver) with an additional technical process may be introduced in the model.

More about the *User-technical process* and its applications is presented in Paper A and C and Janhager [2002].

4.3.3 Interaction between User and Technical System

A new model of the user-technical system is shown above. The model could also be utilised for describing interactions between user and product. In this thesis, an interaction between user and product refers to all the physical and mental interplay that may occur between the two. It may, for example, be the user who physically handles the product or is influenced by its performance, function, messages or expression. The user may perceive a signal from the technical system in the form of a sound, a tactile feeling, a smell or appearance. A user hearing a warning signal from the system is an example of a perceived signal from the product and expressing something with the aid of the shape of a product is another example of information the product may give to the user. A problem is that different users may interpret the signals in different ways.

Information Flow

Chapain's man-machine model, (Figure 2.13), describes how the signal flows go from the technical system to the user and back again. This man-machine model could be compared with and applied to the representation of the *User-technical process*, which furthermore describes a process flow, see Figure 4.12.

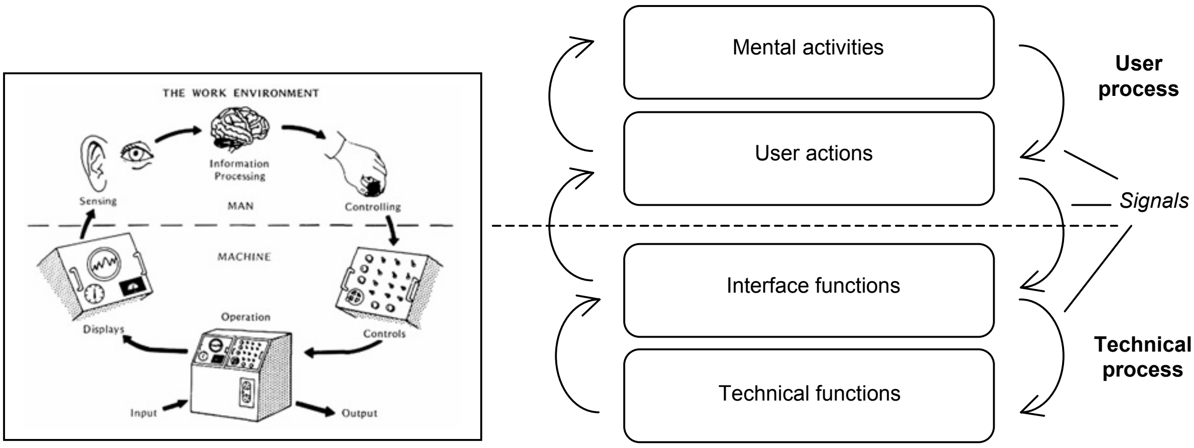
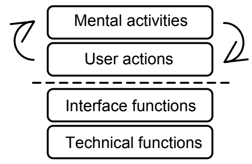
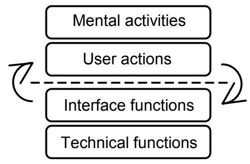


***Figure 4.12** The User-technical process compared with the man-machine model of Chapanis [1976]*

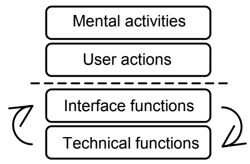
Information flows are identified between actors as below:



- *Mental activities and user actions*: In the mental activities, the user's intended feeling and thoughts are described. This includes the user's information processing and decision-making. The user actions are directed towards the technical system and perhaps to another user. According to the definition, an action is a goal directed process[11], but in order to adapt this process model to the man-machine model, see Figure 4.12, it may be appropriate to think of the action as a physical handling or operation. Perceiving different signals from the technical system, the environment or another user with the sense organ is also symbolised by the user actions. The mental activities are triggered by the sense organs and after processing they send information back to the body movements, i.e. the actions.



- *User actions and interface functions*: Information is sent with the aid of the user actions (operations) to the user interface and its interface functions, e.g. by pressing a button or giving a voice command. Users also receive information from the interface functions, such as a flashing signal to warn of something or an expression given by the shape of the product.

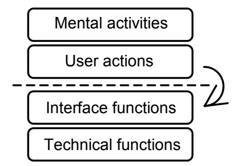


- *Interface functions and technical functions*: The interface functions inform the technical system what it should do. For example, if a button is pressed, the interface functions give the technical system a code which describes how the system should respond. The interface functions are carried out by the user interface, which is a part of the technical system. The technical functions also inform the interface functions about what they should communicate to the users.

Types of Signals

Different types of signals are transmitted between the user and the technical system. Signals from the technical system could be intentionally designed into the product or carried out by the system on its own without any intention on the part of the designers. The user sends signals to the technical system both passively and actively. Different types of signals are presented below.

Signals from User to Technical System



1.1 *Active signal:* When a user sends an active signal to a technical system, he/she takes the initiative in performing the sending and also does something actively in order to send the signal, e.g. pushes a button.

[11] An action is a goal-directed process, which is subordinate to the representation of the result that must be attained. An action is subordinated to a conscious purpose [Nielsen, 2001].

1.2 *Passive signal:* A passive signal from the user occurs when the technical system takes the initiative to read the signal. The user may be conscious that the signal is being transmitted, but may be focused on something else. Thus, a passive signal from the user to the product does not mean that the user is totally passive, but he/she is passive in regard to the specific signal that is transmitted. A system registering that a person is sitting in the driver's seat (in order to send a signal to notify the person that he/she should use the seat belt) is an example of a technical system receiving a passive signal from the user.

2.1 *Conscious signal:* The user is aware that he/she is sending the signal, although he/she may be passive or active while it is being sent. There may be differences in the degree of consciousness about the signal being sent, since it is firmly connected to the feedback given to the transmitter, i.e. the person who sent the signal. For instance, if a chain saw has a dead man's hand-grip and this function is known by the user, he/she sends a passive conscious signal. However, the operator may feel uncertain that it really works, since feedback is only given if he/she drops the saw.

2.2 *Unconscious signal:* A movement detector that notices that a person is still in the building and therefore does not turn off the light may be an example of a receiver of an unconscious signal (sent by the person). The person may become aware of the signal if he/she stands still for a fairly long time and the light goes out.

3.1 *Intended signal:* An intended signal is conscious and has the purpose of being sent, even though the result does not correspond to the intended aim.

3.2 *Unintended signal:* When a user sends an unintended signal, he/she has no purpose in doing so. The user may also be unconscious that the system interprets the signals. A person leaving a clothes shop with a recently purchased sweater in a bag sends an unintended signal to the alarm system if the shop assistant has forgotten to inactivate the shoplifting alarm[12].

It may be difficult to grasp the difference between passive, unconscious and unintended signals. For example, a signal from a dead man's hand-grip is a passive but mainly conscious and

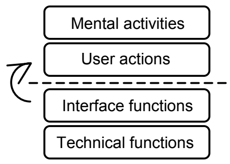
[12] It may appear that a *user* who sends unconscious or unintended signals is not in accordance with the definition of a user, since a user should interact with the product for a *certain purpose*. However, a user can interact with the product with a *certain purpose*, without being conscious or directed towards all elements or functions in the product, or he/she can interact with the product on a higher level. For example, a user of a cellular telephone with functions inherent in the product but unknown to the user is still a user of these functions if he/she happens to come across them during use. In this particular case, the user may use the clothes shop for its ability to provide opportunities for purchasing clothes.

intended signal, since the user is passive in the transfer of the signal (as long the hand stays on the grip), but nevertheless the signal is sent on purpose and is known by the user, who feels confident about its existence.

4.1 *Continuous signal:* A continuous signal sent by the user is an unbroken signal to the technical system. For example, it may consist of the movement applied to a steering wheel while driving.

4.2 *Intermittent signal:* An intermittent signal is a signal given now and then as required, e.g. to give a command to the technical system by pressing a button.

Signals from Technical System to User



1.1 *Active signal:* Like the user, the technical system may send active signals. Active signals occur when the system has to do something actively to send them and furthermore has to take the initiative to do so, e.g. the system starts to make a sound in order to warn about something.

1.2 *Passive signal:* A passive signal sent by the technical system requires the user to take the initiative in interpreting it. An example of a passive signal is the appearance of a product. The user can read the symbols on the product and thereby understand how it should be used or who its producer is.

2.1 *Intended signal:* An intended signal is deliberately placed on the product with the aid of the design in order to give the user a message.

2.2 *Spontaneous signal:* A spontaneous signal is due to the components in the product or the components' structure. The signal is not placed in the design intentionally. It is inherent in the product. A spontaneous signal could, for example, be rust on a car, which indicates that it is beginning to age, or vibrations from an engine, which indicate that the structure cannot withstand speeds above a certain rpm.

3.1 *Continuous signal:* A continuous signal is an unbroken signal as for the user above. The appearance of a product which gives the user information about the product, and the feedback from a steering wheel, are examples of continuous signals.

3.2 *Intermittent signal:* The opposite to the continuous signal is the intermittent signal. The technical system might, for example, use this type of signal to attract the user's attention to something by suddenly making a sound. An intermittent signal could also be regular, for instance an alarm that reminds the user about something at the same time every day.

3.3 *Gradually changing signal:* A gradually changing signal is a signal that changes little by little. The signal could, for instance, be a colour which has faded and thereby informs the user that the product is ageing. Another example is a drilling machine that becomes warmer and warmer. When the tool becomes too warm, it tells the user that the motor is overheated and should be switched off.

The signals transmitted between the user and the technical system are combinations of the above signals. The ringing of a telephone is a combination of an active, intermittent and intended signal from the technical system to the user.

4.4 Methods for User Consideration

All three classifications of the users presented in Section 4.3.1 and Paper B are adopted as methods for identifying and investigating the users of the product to be developed. They are named *User identification*, *Use profile* and *User relations*. By classifying the intended users, a deeper understanding of the users and the design issue is acquired. Moreover, the classification may support the elicitation of requirements, important aspects and new ideas for the product.

In addition to the three methods developed from the classifications, three further methods: *Activities, goals and motives*, *User-technical process Scenario (UTPS)* and *Function-action tree (FAT)* are presented below. The tests of these methods are described in Chapter 5.

4.4.1 User Identification

The performance of the method starts with the product developers identifying the primary users, secondary users, side users and co-users. Thereafter, these various individuals' requirements on the product are elicited. The same person may have more than one of these user roles.

4.4.2 Use Profile

The categories of relations between user and product are investigated and estimated for each user, and important aspects due to these relations are identified (Table 4.6).

Table 4.6 *A driver of a private car is investigated with the Use profile*

	Categories	Degree of performance	Examples of aspects of the product to consider
Use experience	Length of use and education	Newcomer Experienced Specialist	Many functions Standards
	Frequency of use	Seldom Occasional Frequent	Satisfactory ergonomics Durability
Influence on and responsibility of use	Influence on the choice of product	No influence Some influence Great influence	Attractive design (Appeal) Character Good ergonomics
	Influence on the use situation	No influence Some influence Great influence	Inspire confidence
	Responsibility in use	No responsibility Some responsibility Great responsibility	Safety Reliability Inspire confidence

4.4.3 User Relations

Various relations between users and the roles they play in the use situation are investigated. The demands on the product affected by these interactions are identified.

4.4.4 Activities, Goals and Motives

Users may have various aims in using the product depending on different situations. For example, a hammer can be used for different purposes; to drive in a nail or to pull out a nail, as well as for purposes for which it is not designed, such as breaking an object into pieces (Section 2.2.3). The design team should speculate on what the different aims might be, since these may cause the product to be used in different ways.

Behind the activities are the goals and motives, the major aspect that distinguishes one activity from another being their aims [Nielsen, 2001]. Even if the user is not always conscious of the motives, it is possible to predict some of them. A more comprehensive picture of the user and the use situation may be acquired if the product developers analyse the users' activities, goals and motives for utilising the product. This is expected to stimulate the acquisition of new ideas and requirements on the product. It is impossible to identify every activity, but by conducting an idea generation exercise with the whole design team it is possible to find many of them. Examples of goals and motives behind the activities and possible requirements on the product when using a fishing rod and a microwave oven are shown in Table 4.7 and Table 4.8.

Table 4.7 *Feasible activities using a fishing rod*

Activity	**Goal**	**Motive**	**Example of requirements**
Fishing for fish	Achieve amusement	Boredom, desire for amusement	Offer many functions and challenges
Fishing for fish	Achieve relaxation	Desire for relaxation	Not complicated and easy to handle
Fishing for fish	Obtain food	Hunger	Catch a large quantity of fish
Fishing for fish	Compete (participate in a competition)	Desire to win Desire for amusement	Catch special type of fish Catch a large quantity of fish
Measure the depth in a container for bulk material	Know how much bulk material it is in the container	Perform prognosis of need for recharging or delivering the material	Easy to connect measuring equipment Durable
Fishing for a key with a magnet	Retrieving the key	Loss of key in a well	Provide precision

Table 4.8 *Activities using a microwave oven*

Activities	**Goals**	**Motives**	**Example of requirements**
Cook food	Cook food quickly	The children are hungry	Cook food quickly
Cook food	Make delicious and attractive food	The user is expecting dinner guests	Cook well-cooked, attractive food
Investigate microwave oven	Find out how it works	Wonder how it works (newly purchased microwave oven)	Clear user interface

The examples show that there may be different motives behind the activities of fishing and cooking food, and that the users may have other goals than those for which the product is intended, e.g. using the fishing rod as a tool for retrieving a key which has been lost in a well. It is relevant to identify the different activities, since they cause the user to use the product in different ways. Even though the aim of this method is not to adapt the product to unusual applications, such as retrieving a key with a fishing rod, it is still worthwhile since it stimulates the product developers' imagination and makes them think of the product development problem in other perspectives. Occasionally, the method may also lead to new and unexpected applications for the product.

4.4.5 User-Technical Process Scenario (UTPS)

By implementing the format of the *User-technical process*, a structured scenario[13], *a User-technical process scenario (UTPS)*, can be built.

A set of individual users with characters, issues, tasks and use situations is established. Stories are created with these individuals using a product or concept by applying the structured format according to the *User-technical process* (Figure 4.13).

[13] A scenario is a narrative description, i.e. a story, of people and their activities, which consists of at least one user/actor (who has particular goals), a work context and a sequence of actions and events [Carroll, 2000; Nardi, 1992].

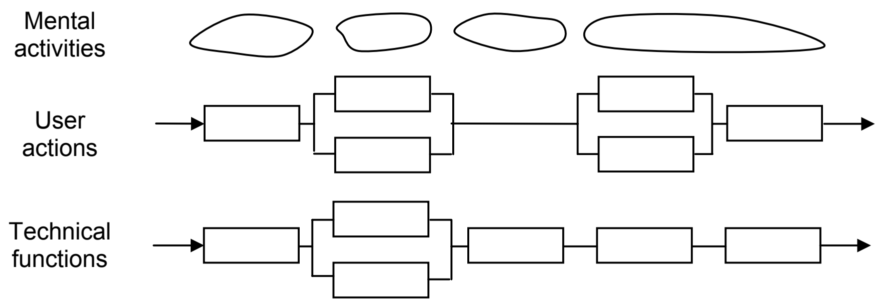


Figure 4.13 *The User-technical process can be used for scenario building. The illustration excludes the interface functions.*

This type of model for a scenario clearly shows the concurrence between a user action and the corresponding technical function, i.e. the *UTPS* illustrates visibly what the user and the technical system perform simultaneously. The distinctions in the users' actions and mental activity are also visibly separated. It is feasible to lift out a process and investigate it in isolation to see what either the user or the technical system does. Whole combinations of actions or functions can also be exchanged from the scenario. This is believed to be useful for comparing different product solutions. For examples of such scenarios, see Papers C and F.

4.4.6 Function-Action Tree (FAT)

In the function-means tree, which could be used as a synthesis method, functions are broken down in a hierarchical structure and means (concrete solutions) are found for solving the functions [Andreasen, 1980], see Section 2.1.3.

The function-means tree is a hierarchical representation of the technical system. Utilisation of the method has proved to work well. However, as the user is not represented in the model, the applications of this theory and method to products with an intensive user interaction have been found to be incomplete. To obtain a better configuration of the user-technical system, the user actions, interface functions and mental activities have been supplemented to the function-means tree. This expanded model is named the *Function-action tree (FAT)*, see Figure 4.14. The interface functions are not further treated in this thesis because the work and the examples have concentrated on mechanical products without a particularly complex user interface.

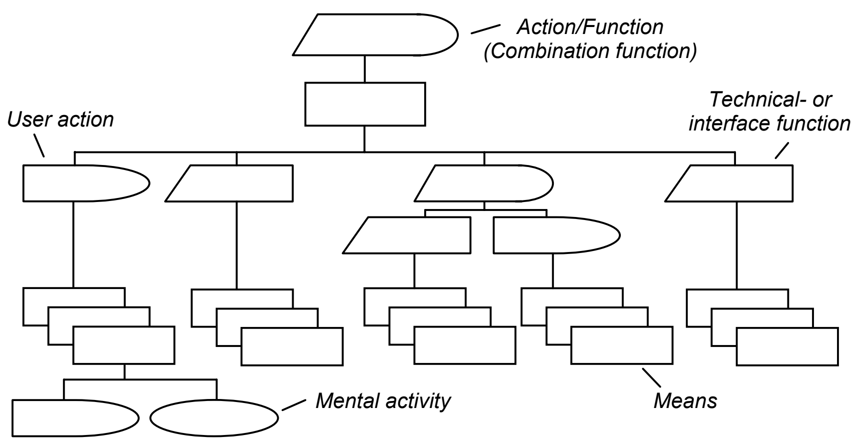


Figure 4.14 *A schematic picture of a Function-action tree (FAT)*

There are two cases when it may be advantageous to use a combination of a user action and a technical function - a *combination function* during the building of the hierarchical tree:

1. When it is not decided whether the technical system or the user is to perform a specific task - *undecided combination*
2. When both the user and the technical system are involved in the same task, i.e. they perform the task in collaboration - *coupled combination*

The combination functions can be split up into actions and functions on a lower level.

Figure 4.15 demonstrates a part of a *Function-action tree* for a chain saw. User actions may lead to technical functions which need to be fulfilled by technical means (area 1). The figure also shows how a combination of a user action and a technical function is split up into a user action and a technical function (area 2).

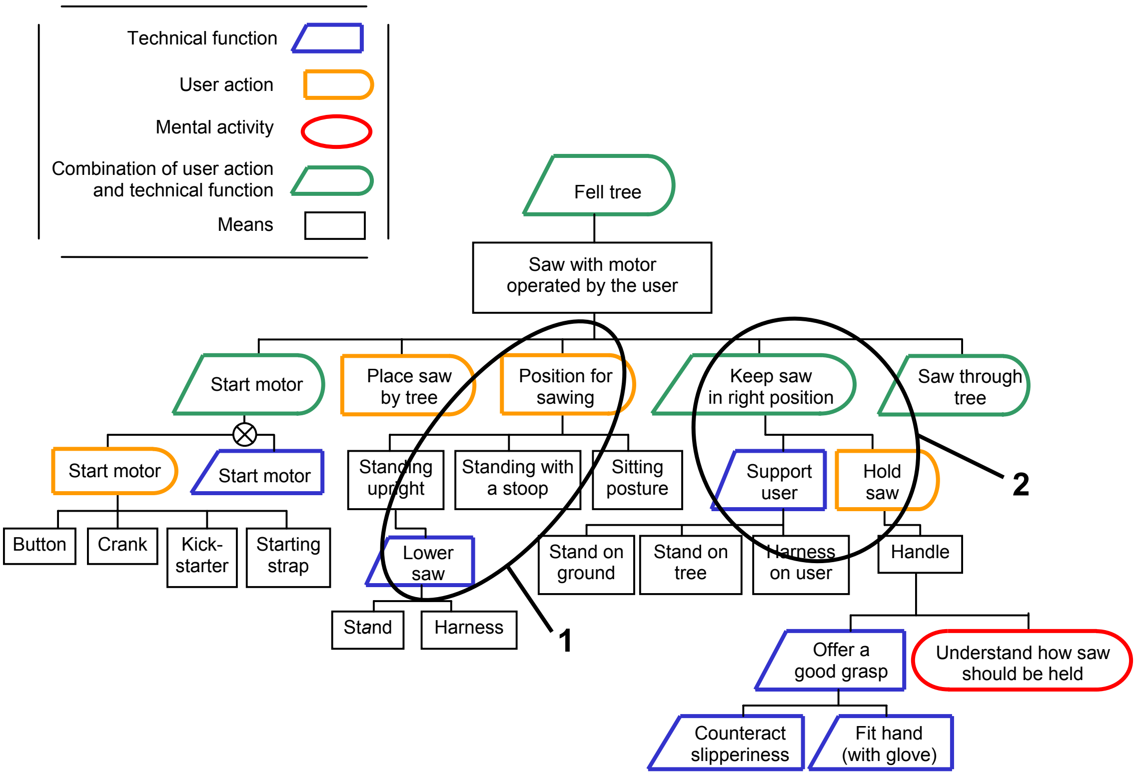


Figure 4.15 *An example of a Function-action tree for a chain saw. It demonstrates a user action, which leads to a technical function with technical means (1), and a combination function split up into a user action and a technical function (2).*

Further examples and applications of the *FAT* can be found in Paper D and Janhager [2002].

4.4.7 The Methods Placed in a Procedure

In order to place the methods in a context and describe their relations to each other, a proposal for a concept development procedure in which the methods are included is presented here. The methods can also be used individually as well as in another order. The emphasis in the phases and the suggested methods for each phase are related to this research work. In other words, they are focused on the intended users of the product and investigations concerning aspects such as estimation of technical and economic prerequisites are not considered in the procedure. Additional methods may naturally be introduced in each phase.

1. *Delimit the design task.* In order to delimit the product development assignment, a specification of the product idea, intended users and use situation should be composed.
Method: *User identification*, i.e. primary users, secondary users, side users and co-users.

2. *Investigate the design task.* The users and the product development problem need to be investigated in order to create a common picture of the intended users and use situation within the design team.
Methods: *Use profile*, *User relations*, *Activities, goals and motives*
(For each user type, i.e. primary user, secondary user, side user and co-user, it is possible to create *Use profiles*. Each user may have various activities, goals and motives behind their use of the product. Between the users, within and between the user types, there are relations.)

3. *Specify the problem.* A requirements specification should be created. The requirements acquired during the performance of the methods in the earlier stages need to be evaluated and prioritised in order to be rejected or introduced in the specification.

4. *Outline the design context.* The aims of the product and user should be described schematically before the concepts are created.
Method: Create a *User-technical process* (which constitutes the base for both the *Function-action tree* and the *User-technical process scenarios*)

5. *Generate concepts.* Numerous concepts should be created.
Method: *Function-action tree*

6. *Evaluate and select concepts.* The generated concepts have to be evaluated and one or more concepts chosen for further development.
Methods: Diverse methods for evaluation, e.g. the concept comparison and evaluation matrix of Pugh [1990]

7. *Investigate and compare concepts.* Investigate the concepts with various users in different use situations and compare concepts with each other (before mock-ups are built).
Method: *User-technical process scenario*

8. *Further investigate the selected concept/concepts and their users.* Since there may be changes in the assumptions when the concept is established, the concept and its users may need to be further investigated.
Methods: *User identification*, *Use profile*, *User relations*, *Activities, goals and motives*

9. *Update the requirements specification.* The requirements acquired during the investigations and the use of the above methods need to be added to the requirements specification.

In Table 4.9, the proposed procedure for the concept development phase is compared to the concept phase described by Ulrich & Eppinger [2003] (see Section 2.1.2).

Table 4.9 *The suggested procedure compared to the concept phase by Ulrich & Eppinger [2003].*

Process focused on the users	Ulrich & Eppinger [2003]
1. Delimit the design task	Identify customer needs
2. Investigate the design task	
3. Specify the problem	Establish target specifications
4. Outline the design context	
5. Generate concepts	Generate product concepts
6. Evaluate and select concepts	Select product concept(s)
7. Investigate and compare concepts	Test product concept(s)
8. Further investigate the selected concept/concepts and its users	
9. Update the requirements specification	Set final specifications

5 Evaluation of the Developed Theories and Methods

In order to evaluate the theories and methods developed in this work, logical and acceptance verifications are applied to the theories and methods. All the methods, apart from the Function-action tree, are also validated with tests in product development teams. This chapter presents the results from these verification and validation methods. Moreover, further outcomes and learning from the tests of the developed methods are presented and discussed.

5.1 Verification of Theories and Methods

The scientific results in engineering design are seldom verified [Blessing, 2003] and, as pointed out by Buur [1990] and Blessing et al. [1995], they are very difficult to verify and validate empirically. One reason is that the nature of the design process is stochastic. A new design method may increase the likelihood of product success, but cannot ensure it, since a design situation is affected by an extremely large number of factors. Moreover, the existence of these factors makes it impossible to perform exact repetitions of an experiment in order to validate a method. In addition to the factors that may fluctuate from day to day, the outcomes from the tests may be affected by the test participants' skills, background and attitude to formal methods, the design problem, and the working atmosphere that is due not only to the people in the organisation but also to aspects controlled by the management, such as equipment, roles, time and independence [Ekvall, 1987].

5.1.1 Logical and Acceptance Verification

One way to approach this is to verify the result by *logical and acceptance verification* [Buur, 1990]. To verify the result logically, it is necessary to ensure that it is:

- *Consistent*, i.e. there are no internal inconsistencies between elements
- *Complete,* all relevant occurrences can be explained or rejected by the theory
- *Well established*, i.e. the methods concur with the theory, and cases and specific design problems can be explained by means of the theory.

This means of verification is better suited to analysis than synthesis activities, since the design theories are mainly evaluated by analysis of cases and observations. To verify the result by acceptance implies that the statement of the theory and methods derived from the theory is acceptable to experienced product developers. However, many aspects may affect the product developers' judgement of a statement or a method, such as their need, knowledge and experience, and the complexity or presentation of the information.

The developed theories and models that constitute the various ways of classifying the users, the *User-technical process* and the *Interaction between user and technical* *system*, have proved to be consistent within the frame of this work. Naturally, it is probably possible to supplement the theories and models. For example, further classes of user or types of interaction between the user and technical system may be identified.

Regarding the theories' establishment in existing theory, the classifications are in one way an extension of existing classifications. The *User-technical process* is developed in concurrence with established theory. Moreover, the three ways of classifying the users and the *User-technical process* constitute the basis for the developed methods *User identification*, *Use profile*, *User relations*, *UTPS* and *FAT*.

Each developed method, apart from the *Function-action tree*, has been tested in groups from industry comprising product developers with different competencies. The four methods for investigating users *User identification*, *Use profile*, *User relations* and *Activities, goals and motives* were all tested together in three different test teams (Paper E). The *User-technical process scenario (UTPS) technique* was tested by four test groups focusing only on that method (Paper F). The majority of the test participants were positive concerning the methods' usability. In this way, the methods, and indirectly the involved theories, are verified by acceptance. The *FAT* is not verified by acceptance; however, it builds on existing theories.

5.2 Validation and Evaluation of the Methods

Apart from providing a means of acceptance verification, the aim of testing the methods was to validate them; in other words, the methods were investigated to determine whether they fulfil the previously determined criteria. The methods were also evaluated by unprejudiced observations, where benefits and disadvantages of the methods were identified.

Below are presented the results from the observations, the questionnaires handed out after the test sessions and the group discussions also carried out directly after the tests in the two studies.

5.2.1 Test Results for User Identification

The test groups were encouraged to identify the primary users, secondary users, side users and co-users of the product with which they were working. They had no problems in finding these users.

The result from the questionnaire handed out after the test session showed that all test participants thought it was easy to understand how the method was to be applied. Some test participants had difficulties in comprehending the difference between side users and co-users, but after further explanation from the test leader the test groups had no problems in finding such users.

Many subjects agreed that communication of the design issue between the group members was stimulated and it was observed that there were fruitful discussions in all the test teams during *user identification*.

The test participants thought that the method was valuable for understanding the design issue. The participants were asked whether the method gave them new ideas about the design problem and the answers were quite widely scattered. Not surprisingly, it was possible to see a correlation in the answers and the novelty of the product they were investigating in the tests. The test groups working with a product in the preliminary stage of development thought that the methods generated new ideas. The other two groups, who investigated products already introduced on the market, did so to a lesser degree.

One test participant came up with a suggestion to identify the type of use instead of the type of user, for example side-using and co-using a product, since an individual can be both side user and co-user of the same product in different use situations. Another suggestion was to apply this classification in prioritising the importance of requirements. For example, requirements directed towards the primary users should be valued higher than requirements directed towards the side users.

5.2.2 Test Results for Use Profile

The test persons were asked to create a *Use profile* for one of the primary users. The user was investigated on the basis of ten categories within the areas Use experience, Influence on and responsibility of use, Emotional relationship to the product and Degree of interaction with the product. The level of fulfilment of each category was determined. Moreover, important aspects due to these categories were identified. For an example, see Table 4.6.

More than half of the subjects considered the *Use profile* simple to understand, although it was relatively difficult to apply.

Many of the test persons agreed that the method contributed to communication and almost half of the test persons agreed that new ideas were elicited.

The categories were verbally explained during the test session and a small number of the aspects proved difficult to understand for some of the subjects, for example *cognitive interaction* and *influence on the use situation*. It was also particularly commented during a test session that the categories must be clearly explained in the completed and delivered description of the method.

5.2.3 Test Results for User Relations

Different relations between the users (i.e. controlling, collaborating, demonstrating, meeting, preventing, influencing) and requirements on the products due to these relations were identified when applying this method.

The opinions of the ease of comprehension were scattered. However, no-one thought that this method was very difficult to understand. Half the subjects considered that the method was easy to use and the other half found it difficult to use.

Most of the test persons agreed that communication was stimulated and that they were inspired to new ideas.

The adaptability of the method varied for the different products, depending on the number of involved users of the tested products. One group, which was working with a product with many users, found users for all relation types and the participants in this group were also more positive to analysing *user relations* than the other groups. They considered the method easier to understand and use, as well as more productive for communication and insight than the members in the other two test groups thought.

5.2.4 Test Results for Activities, Goals and Motives

In this method, the test participants were intended to identify *activities, goals and motives* behind the identified users' use of the product they were investigating. The requirements on the product due to these various activities were also identified.

The method was considered easy to understand and the opinion was that it was simple to find activities, goals and motives for the users of their product. The method worked well. In some cases, the tendency was that the test leader had to push the test groups to make them find more unusual activities, goals or motives.

The results from the questionnaire also showed that most of the subjects agreed that fruitful communication was facilitated. More than half of the test persons were able to perceive a value for the design teams' enhanced understanding of the design problem.

Even though the test participants did not consider to a very great extent that the method generated new ideas, the observations showed that a number of interesting design proposals and requirements were elicited. Compared to the other test groups, more test persons from the group that worked with the product in its preliminary stage considered that new ideas were stimulated.

5.2.5 Results of Group Discussions about the Methods for Investigating Users

In the group discussions following the tests of the four methods *User identification*, *Use profile*, *User relations* and *Activities, goals and motives*, the comments about them and this particular way of working were mainly positive. Many of the subjects thought that it is important to discuss the users, their relations to the product and the use situation at the beginning of a product development project and that these methods should support such discussions. Consequently, they believed that the methods would have been more useful if they had investigated products in earlier product development stages. Every test group also emphasised the benefit of including different competencies in the groups when applying these types of method.

One test participant maintained that the methods generated too many users. He believed that it is impossible to consider all these people and fulfil all their wishes in a design project. However, other persons in his group were of the opinion that analysing other individuals influenced by the product than the primary users alone broadens the designers' view and gives them other perspectives which could lead to other design ideas.

The members of one of the test groups declared that they had never held discussions in such an organised way before and considered these methods more structured than the procedures they had tried earlier. It was also stated that the common feature of the four methods was that they all led to stimulating discussions.

5.2.6 Test Results for the UTPS Technique

Four test groups tested the *UTPS technique* on products with which they are working. Each group performed three scenarios. All groups needed support at the beginning in creating the user characters, who were going to be the actors in the scenarios. However, when building the first scenario, the test participants' ability to perform the scenario by themselves varied. Two groups were self-governing, whereas the other two groups had difficulties and needed the test leader's support. They were guided with questions such as "What happens in the next step?" in order to drive the scenario forwards. After a while, in one of these groups, the participants were able to carry on the discussion by themselves. The other team needed support throughout the first scenario.

However, the questionnaire and the group discussion, each carried out directly after the test session, showed that none of the test participants thought it was difficult to understand how the *UTPS technique* should be used. In particular, test persons in the two groups that needed most support in building the scenarios stated that the method was useful and easily learnt, and that everyone in the group was able to participate.

The *UTPS technique* was also adapted for comparing two product variations or concepts. The observations and the questionnaire showed that the comparisons worked out well.

It was noticed that the scenarios, especially at the beginning, were not especially unexpected or accidental, and that the user character could in many cases have had a greater influence on the scenarios. In most of the groups, the first scenario resembled a detailed description of an intended use sequence. They had to be encouraged to find unusual or accidental sequences. Many problems that were never included in the scenarios were discussed. It was also possible to see a tendency for detailed questions to be investigated while the major issues were neglected.

Most of the participants thought that it was rewarding to use the technique. The greater part thought that the scenarios stimulated new thoughts and supported communication between the team members, and that the scenario technique is valuable for understanding the design issue and predicting problems the user might encounter during use. The opportunity to really analyse the whole use sequence and study what might happen with the product was stated as being very useful. They thought that the method would be valuable at the beginning of a project in order to form a common picture of the design issue and for a newcomer to the design group to learn about the product. This was also confirmed by the observations. It was discerned that the technique was used for learning and knowledge transfer between the members in the group concerning the product and the intended use situation. Questions and problems were highlighted and given concrete form with the help of the technique.

The test participants who had previously tried out other scenario techniques commented that the *UTPS* had certain advantages compared with other techniques, such as separating actions from technical functions and paying attention to mental activities. Moreover, they thought that this presentation was lucid and more detailed than other scenario techniques they had tried. None of the test participants had previously worked in this structured and detailed way with use sequences. It was also remarked that the technique is fast and that the focus on a narrow part of the use deepens the understanding.

They also stated that the technique is useful for detecting problems and defects early in product development work, which provides better products faster and may save money since unnecessary prototype building can be avoided. It was observed that the technique supported the detection of problems, gaps and possibilities in early product concepts, as well as further development of these concepts by identifying new solutions and ideas. The use situation was made clearer and different alternatives of use situations were investigated depending on users' lifestyle, personality and experiences. Furthermore, with the support of the *UTPS technique* a concrete form was given to user needs and new product requirements were found. The technique seemed to be most valuable in early design stages when trying out a new product idea or concept.

Moreover, the feasibility of using the technique to find ways of marketing and selling the product was discussed. The test participants also emphasised the need for a facilitator to lead performance of the methods.

5.2.7 Function-Action Tree

There was no room within the scope of this work to test the *Function-action tree* (*FAT*) in industrial product development projects, since this requires a relatively long learning time. However, students who are already familiar with the function-means tree, on which the *FAT* is built, have tried using the method informally and have demonstrated its merits.

5.2.8 Summarising the Validation of the Methods

The developed methods are investigated in relation to the *Criteria* determined in Section 3.2.1. In most of the tests, the results from the questionnaires, interviews and the observations have pointed in the same direction. It is found that all five tested methods *User identification*, *Use profile, User relations*, *Activities, goals and motives* and *UTPS* stimulate communication between the members in the design group and that different competencies could be united through the methods. Moreover, it was found that *User identification*, *Use profile*, *Activities, goals and motives* and *UTPS* are fruitful for understanding the design issue. The benefit from *User relations* is dependent on the product. It requires many involved users in order to be rewarding. The test persons thought that *User identification*, *Activities, goals and motives* and *UTPS* are easy to work with. *User relations* and to an even greater extent *Use profile* caused some difficulties. The *UTPS* generated new ideas about the design task. More than half of the subjects considered that *User relations* inspired new ideas about the design issue. However, the other methods did not generate many new ideas. One reason may be that the design problem was not new to the test groups. The *UTPS technique* is also useful for comparing products or concepts for a particular use sequence.

In Table 5.1, fulfilment of the criteria for validation of all five methods is summarised.

***Table 5.1** The validation methods and fulfilment of the validation criteria*

Result - methods	***Validation method***	***Fulfilled criteria***
User identification (Primary users, secondary users, side users and co-users)	Tested in three industrial product development teams	• Stimulate and support communication • Rewarding for understanding the design problem • Elicited few new ideas* • Easy to apply
Use profile	Tested in three industrial product development teams	• Stimulate and support communication • Rewarding for understanding the design problem • Elicited few new ideas* • Relatively difficult to apply
User relations	Tested in three industrial product development teams	• Stimulate and support communication • Depending on product: rewarding for understanding the design problem • Elicit new ideas about the design problem • Neither easy nor difficult to apply
Activities, goals and motives	Tested in three industrial product development teams	• Stimulate and support communication • Rewarding for understanding the design problem • Elicited few new ideas* • Easy to apply
User-technical process Scenario	Tested in four industrial product development teams	• Stimulate and support communication • Rewarding for understanding the design problem and use situation • Elicit new ideas about the design problem • Relatively easy to apply • Useful for comparing products or concepts
Function-action tree (FAT)	Tested by students	

**The design problems were not new to product developers, which may have influenced the result.*

5.3 Findings and Discussion of the Methods

Many experiences were gained during the tests of the methods. Expected effects as well as side effects (most of them also expected) of using the methods were identified.

The results are also compared with the criteria for a rewarding method identified by Norell [1992] as presented in Section 2.1.4. The final methods fulfil these criteria. The methods enable knowledge about the product, its users and use situations to be raised, discussed and shared within the group. They support collaboration and learning for different competencies in the design team. The methods, in particular *UTPS*, also provide support for identifying weak points in the design and the use situation.

However, it is difficult to find measurable effects of the application of the methods, since the crucial point of the methods is to generate new ideas and acquire a better understanding of the design problem and the use situation. The number of ideas and new requirements gathered during the sessions may be a measure of how well the session turned out. This was measured in the tests of the four methods for investigating users (Paper E). The test groups worked mainly with products already established on the market and therefore not many requirements were new to everyone in the groups. However, the tests showed that one third to almost one half of the requirements discussed during the sessions were unknown to at least one person in the groups and that the test participants set different priorities on the requirements.

More rewarding outcomes from performing the methods would probably have been obtained if all the test groups had worked with new product development in the concept stage. However, these projects are unusual (most product development projects concern redesign) and if they are encountered they are mostly classified as secret, which either complicates or prohibits testing of the methods.

5.3.1 Becoming Submerged in Detail or Focusing on Broader Issues

One unexpected effect of the *UTPS technique* is that the participants occasionally worked “outside the box”, i.e. they dealt with treated encountered matters and problems on the periphery of the specific scenario, and with broader issues on a higher level than expected. For example, the participants in one test group started to discuss how they should sell and market their products, and how they should inform the users concerning use of the product and accessibility of necessary expendable supplies. However, the test of the *UTPS technique* showed that it predominantly led the participants to adopt a detailed approach concerning the design task, which is in accordance with Sutcliffe’s [2003] statement that scenarios mainly make the practicians concentrating on details. Nevertheless, it was commented when testing the *UTPS technique* that the detailed work was valuable. The impression is that design engineers and other product developers seldom investigate use in a detailed way and that there was a need for this. In such a case, this effect of the method may be rewarding. This shows a need for the *UTPS technique*.

The other tested methods (*User identification*, *Use profile*, *User relations* and *Activities, goals and motives*) produced discussions on both a detailed and a more general level, but with a predominance of the latter.

5.3.2 Demonstrating with Support from the Methods

Another unexpected effect was that the test participants used the *UTPS technique* to learn and agree about the current intended use sequences. Surprisingly, even for products established on the market, the participants needed to go through the intended use sequence in order to reach a consensus before the scenarios could be built. This demonstrates a new application for the *UTPS technique*: to illustrate the intended use sequence of a product for new product developers in the team or people outside the groups, such as customers or the steering committee. Various authors, e.g. Erickson [1995], Bødker [1998] and Carroll [2002], have also declared this benefit of scenarios.

The value of using the methods for communicating thoughts and ideas outside the group was also commented when testing the four methods for investigating users.

5.3.3 Defending Solutions

An expected effect is that the *UTPS technique* may be used to defend deficient design solutions, since people tend to search for facts to confirm their decisions, beliefs and hypotheses [Ashcraft, 1994]. The tendency was observed. The scenario is not a suitable method for confirming design solutions, since it is impossible to cover all possible cases. Hence, scenarios are a better method for finding new ideas, detecting problems or rejecting product proposals than for verifying new product ideas. Also the opposite case occurred in some test groups, who tended mainly to search for the problems and weaknesses in the design solutions. However, when this occurred, it sometimes entailed that the creators of the investigated products/concepts adopted a defensive position and advocated the product. This may have inhibited the other group members' activity of continuing to look for problems in the products. This type of incident is tricky to handle, since it is difficult for the creator not to take a defensive position regarding his/her product solution. On the other hand, the defects and problems need to be detected before the product reaches the market.

5.3.4 Encouraging the Acquisition of Ideas

Since all the developed methods, apart from the *FAT*, are based on the users' way of acting or their expectations on or relations to the product, there may be a risk of the designers developing fixed ideas about stereotypes or their prejudices of people. The effect may be that they become restricted instead of broad-minded and open to new ideas, which is the purpose of the methods. Openness requires a great deal of the participants' confidence in raising unconventional propositions and suppositions. They may be afraid or cautious about suggesting unorthodox ideas or extreme characters, since they may fear that the other participants think they are naïve or unprofessional. It appears that this anxiety occurred in a number of test groups. The participants were quite restrained, i.e. they did not let their imagination run away with them in the way that these types of methods may encourage, in particular the *UTPS technique* and *Activities, goals and motives*. The product developers should preferably feel confidence in the group. It is argued in theories about brainstorming [e.g. Wright, 1998] that this is supported by avoiding people in managing positions in the group, since they may inhibit the group participants' activity. Moreover, criticism of suggestions generated during performance of the methods should be avoided, as it may restrain the criticised person from making further suggestions. To counter this problem, a facilitator may be needed to conduct the group activities during performance of the methods. However, as soon as the extreme characters are created for the scenarios, they may encourage free rein to be given to the product developers' imagination, since it is the characters who, for example, do not understand the product or who behave strangely, and not themselves. According to Djajadiningrat et al. [2000], this is one of the benefits of employing user characters.

5.3.5 Need for a Facilitator

As already mentioned, it is believed that a facilitator is of great importance in future use of the methods, even though the practitioners may already be familiar with them. This is also recognised as important from theories about brainstorming, e.g. Wright [1998]. The facilitator should lead and guide the group in applying the methods, and support and encourage the participants to come up with new and unconventional ideas. Wright furthermore states that the facilitator should be familiar with the problem. This is relevant also for the developed methods. However, it may be an advantage if the facilitator is not an expert on the design problem, since he/she should have a mediating role. If he/she knows the problem well and is part of the design team, it is more difficult to avoid bias of particular ideas or interests. A slightly novice facilitator may also be beneficial in the way that this authorises him/her to ask any type of question about the design problem or use of the product, and force the group members to carefully think through the design task.

5.3.6 Group Size and Composition

Wright [1998] suggests a number of five to twelve participants in a group of idea generation activities, such as brainstorming. This is probably appropriate for the methods for classifying the users and identifying the *Activities, goals and motives*, since they have resemblances to brainstorming. However, during the tests it was shown that it was difficult to get more than six participants actively involved in working with the *UTPS technique*. This method, as well as the *FAT,* involves more processes of structuring and decision-making, which affect the execution of the work and demands agreement between the members in the groups. Therefore, no more than seven persons in the group are recommended for performing *FAT* and *UTPS*.

The recommendation is to mix various competencies in the groups, since this type of method is most rewarding if different views are elicited. This was also stated as being valuable by the test participants.

5.3.7 Collecting and Reflecting over the Outcomes from the Methods

Even though a facilitator is employed to handle the documentation, each team member is recommended to keep their own notebook, in which they could write down their reflections, ideas that are not further treated during the session and issues to clear up after the session. This may appear trivial, but many test participants did not work in this way during the tests. Probably, they relied on the notes taken by the person who was documenting the session or they believed that they would remember every important aspect that emerged during the session. However, each team member has his/her own interests and many areas are covered and many ideas emerge during the performance of the methods. For example, the consideration and discussions about the relation between seller and customer may be more interesting for a marketing representative than a production representative. Moreover, the *UTPS* requires that choices be made continuously, in every step, in order to proceed with building the scenario. This means that many possible outcomes are never investigated further. One way of encouraging note-taking is to reserve time for reflection and own writing regularly during performance of the methods, for example after each completed scenario or investigated user. Preferably, the whole session should be concluded with a short recapitulation from each member concerning the most important findings from the method.

6 Outline of Appended Papers

This chapter provides a short presentation of the contents of each appended paper.

Paper A: An Approach to Design for Use

The aim is to provide a presentation and insight regarding existing formal methods that consider user-product interaction and to offer a proposal for a new design approach. A selection of methods that deal with both user performance, user's feelings and thinking about design elements is described. When it comes to traditional mechanical design theories, these are mainly focused on the product's structure or its technical function and omit its relation to the users. An alternative to these theories and models is to describe the product from the user's viewpoint. Hence, the approach that is proposed in this paper is to parallel the user actions with the technical process and develop a user process. The approach may offer a way of determining what the user and technical system respectively ought to do. In conclusion, a proposal for a specification of a new method that would consider the user aspects is presented and further research within the area is suggested.

Paper B: Classification of Users - due to their Relation to the Product

Three ways of classifying the users and their relation to the products and other users are presented. Two new groups of individuals, side-user and co-users, who are affected by the product, are defined. It is important to consider these individuals when designing a product. The different types of user could also be investigated by a number of categories and a *Use profile* could be set up. Furthermore, a number of relations between these different users were identified and it was stated that it is important to consider these relations in the design phase. In summary, the paper shows that it is possible to classify the users in various relevant ways and that different demands could be applied to the products on the basis of their users' group affiliation.

Paper C: Utilization of Scenario Building in the Technical Process

The research showed that the technical process can be supplemented with the user process, together constituting a *User-technical process*. The *User-technical process* can be used for building structured scenarios, which is illustrated with an example in the paper. The benefit of using this type of technique for building scenarios is that the user's and the technical system's mutual and own actions and functions are clearly schematised. The different activities are clearly described at each point in time. For example, it is possible to change combinations of actions or functions from the scenario, exchange one of the users for another individual or compare different design solutions with each other by keeping the same user sequence.

Paper D: Hierarchical Decomposition of Technical Functions and User Actions

A method is presented for introducing user aspects in the synthesis stage of the product development process. The user actions and the mental activities are added to the hierarchical decomposition of the functions of a product. This decomposition constitutes a *Function-action tree (FAT)* intended as a support in the creation of new product concepts. The *Function-action tree* could also be used to analyse relations between functions and actions, and to investigate whether the relations lead to new conditions for the product. Examples for demonstrating the method are included in the paper.

Paper E: Approaches for the Identification of Users and their Relations to the Product

The three ways of classifying the users (presented in Paper B) were utilised to investigate the product and its users. These, together with a method for investigating the *activities, goals and motives* behind the use of the product, were tested and investigated in three groups of four or five test persons from the companies ITT Flygt, DeLaval and ESAB. This paper presents the results from this study. It was concluded that most of the test persons thought that all four methods stimulate communication between the members of the design group. Furthermore, it was shown that the test persons considered most of the methods to be fruitful for understanding the design problem and that they were easy to apply. However, only a few new ideas were created. One reason may be that the design problems were not new to the test groups.

Paper F: User-Technical Process Supporting Scenario Building

Tests and investigation of the developed scenario technique based on the *User-technical process* (Paper C) are presented. Four product development teams from the companies BT Industries AB, Husqvarna, Electrolux and Volvo Construction Equipment tested the *User technical process scenario (UTPS) technique* on products with which they are working. The results from the tests show that the technique is useful for understanding design problems, stimulates discussion in the group, is relatively easy to work with, elicits new thoughts about the design problem and is useful for comparing different product concepts with each other. It is indicated that the scenario technique is most valuable for investigating product ideas or concepts at an early stage.

Paper G: Product Developers' Relations to their Users - an Interview Study

A retrospective interview study was performed in order to investigate how people involved in product development communicate and work with the users. Four companies from two different branches were studied in order to investigate differences. Two of the companies develop hand tools for professional use and the other two develop durable consumer products. Three people from each company were interviewed: a design engineer, a marketing representative or marketing manager, and a product development manager. The result shows that none of the investigated companies have a defined and documented procedure for describing their intended end users. The two companies that develop consumer products have produced descriptions of their market segment. The product developers from the companies that develop hand tools for professional use are directed to a greater extent towards the end users and have closer direct contact with the users than the developers of the consumer products. For the developers of the consumer products, it is instead more important that they also consider the distributors and sellers. The knowledge and use of product development methods for taking account of user aspects are rather limited. None of the companies use formal methods to analyse and generate new ideas about the user or the use situation.

7 Summary

This chapter summarises the contribution of this research, which takes the form of new theories and methods that consider the users in early design stages and findings about product developers' work with the users.

7.1 Theories and Methods Based on the Theory of Technical Systems

The function-means tree is supplemented with interaction functions, user actions and mental activities. The extension composes a *Function-action tree – FAT* (Paper D). The function-means tree breaks down functions of a product in a hierarchical structure, which can be used for finding solutions to each function. These solutions may be combined in order to create new product concepts. *FAT* involves the user handlings in this hierarchical structure. This is relevant when creating product concepts since the user actions may affect the performance of the concepts. A technical function and a user action can work in collaboration or they can compete with each other, which will lead to different product solutions.

Supplemented theory consisting of interaction functions, user actions and mental activities is added to the technical process constituted of the technical functions. Together, they compose a *User-technical process* (Paper C). Categories of interactions between the user and product are identified. The model is used in a structured scenario technique (Paper C), the *User technical process scenario (UTPS) technique*, which is tested in four product development projects. The *UTPS technique* proved to be valuable for understanding the design issue, as well as being relatively easy to work with and supporting discussion between the group members. Moreover, it is useful for comparing product concepts and eliciting new thoughts about the design task, such as problems, requirements and design solutions. The technique is most valuable in early design stages when trying out a product idea or a concept (Paper F).

The *UTPS technique* and the *FAT* elicit synthesis activities.

7.2 Methods for Investigating the User and Use Situation

Three ways of classifying the users depending on their relation to the product and other users have been identified (Paper B). The classifications have been adopted and used as design methods to investigate the product development problem and the users of the product. A method for investigating the users' *activities, goals and motives* behind the use of the product was tested at the same time as the methods for user classification. All four methods, *User identification*, *Use profile*, *User relations* and *Activities, goals and motives,* stimulate communication between the members, who may be of different competencies, in the design group. The methods are also fruitful for understanding the design problem. The benefit from *User relations* depends on the product. It appears to require many closely involved users in order to be rewarding. *User identification*, and *Activities, goals and motives* are easy to work with. *User relations* and to an even greater extent *Use profile* caused certain difficulties. It is uncertain to say whether the methods generate new ideas, since they were tested on established products (Paper E).

7.3 Product Developers' Work and Relation to the User

Further contributions to this thesis include findings from product developers' work with and relation to the users and use of formal methods. It is found that companies use very few formal methods and almost none of them are directed towards the users. Another finding is that companies seldom have procedures for identifying or defining their users. It is also indicated that the product developers' contact with the users and their attitude to the importance of close contact with the users differs between different branches (Paper G). The interviewed design engineers and marketing representatives from companies that develop professional hand tools have contact with users at least a couple of times per year. None of the interviewees from the durable consumer product companies have formal contacts with the users. They trust the information they get from the sellers concerning the users. The experienced contact with the users differs also for the sizes of companies [Janhager et al., 2002]. Small companies consider themselves to have better contact with the users than the larger companies do.

The observation, the questionnaire and the retrospective interview studies confirm a need for the type of methods developed in this work.

7.4 Comments concerning the Research

There is a difficulty with validity regarding the accuracy of causal relationships for a non-experimental study, such as the tests performed on the developed methods. Many aspects could influence the result and it is impossible to control all the variables. Moreover, it is problematic to show that the outcomes from the methods really originate from performing them and are not due, for example, to the test participants being especially creative on a "good" day, being influenced by the presence of the researchers or through having the ability to try something different.

One tactic for data collection is to utilise multiple sources of evidence*,* which should converge towards the result and thereby increase the validity [Yin, 1994]. During the tests of the developed methods, different means were used to acquire results, namely observations, questionnaires, a follow-up questionnaire and group discussions. The results from these means and from a number of tests are in good accordance with each other, which is an indication that the methods are usable.

8 Final Remarks

This chapter proposes areas for future research and recommendations to the industry are given.

8.1 Future Research

This research work has elicited a number of new questions and topics to investigate. The developed theories can be additionally investigated and the methods need to be further tested. The following possible research projects are identified:

- *Further testing of the methods.* The methods need to be tested in more test groups and in new ways, and perhaps modified depending on the outcomes from the tests. Students have tried out the *Function-action tree* informally. However, it is necessary to test the method thoroughly on real product development teams in the concept stage, in order to investigate its merits.
- *Testing/Introducing the interface functions.* An investigation can be made of the consequences of, and need for, introducing the interface functions in the *User-technical process scenario* and the *Function-action tree*. These methods are probably more suitable for products with a great number of user interactions. The question is how these methods support design of advanced user-interfaces.
- *Adaptation to other type of products and other applications.* It was shown during the tests of the methods for investigating users: *User identification, Activities, goals and motives*, *Use profile* and *User relations* that it was feasible to apply them to a product based on software (a management system). Despite the fact that this research work primarily involves artefacts, the test on the management system indicates that it may be possible and valuable to adapt the developed theories and methods to other sorts of products, such as services and information systems. With some modifications, it is probably also possible to use the *UTPS technique* for other products than artefacts. It is relevant to investigate such adoption in future work.
- *Adoption of the interactions.* The various types of interaction between user and product could be supplemented to the *UTPS technique*. In that case, how should they naturally be introduced in the method and could the outcomes from this be naturally exploited in product development problems?
- *Procedure for defining the users.* The reasons for product developers' tendency not to define their intended users (or not to consider the definitions in the case where they exist) should be investigated. Apart from the classifications, further support may be needed for identifying and defining the users. A future area of research is to investigate what should be the characters and conditions of such support. Should the user definitions be based on the users' qualities and abilities, ways of life (family, living and economy), wishes, visions and goals, or physical conditions?

8.2 Recommendations to the Industry

Product developers are recommended to work towards a common view of the design problem and the intended users within the design team and to find a way of communicating this picture outside the group. The presented methods are intended not just as helpful support for analysing and investigating the intended users, but also for bringing the product developers closer to each other and harmonising their views about the users. In order to facilitate the work of designing products that are better suited to the users, the following recommendations are made:

- Define the intended users of the product to be developed. This may be done in many ways, e.g. through use profiles, classifications or user characters.
- Introduce a user focus in the concept stage in other ways than simply analysing the user requirements, namely creating concepts where the user-product interactions are naturally involved in their representations. The *User-technical process* and the *Function-action tree* may provide valuable support for this.
- Learn about methods and try to use them in the right situation. Diverse guidelines and classifications may support the choice of methods. Adapt the methods to the current design problem. There is no intrinsic value in following them strictly.
- Combine different competencies relevant to the design problem in the groups that are to perform the methods and keep the groups small. The literature recommends group sizes of up to fifteen people in a brainstorming session. However, this thesis argues for smaller groups, no more than seven people, in the groups performing the scenario building and the *Function-action tree*. *User identification*, *Use profile*, *User relations* and *Activities, goals and motives* may be carried out by larger groups.
- Use a facilitator to guide the group in performing the methods. He/she should support the participants and encourage them to come up with unconventional suggestions and ensure that everyone in the group is heard. The facilitator should preferably be unbiased and informed about the current design problem, but not an expert on it.
- It is the process itself of performing the methods, i.e. struggling with and discussing the classifications, the conceptions, requirements and problems, that is the most important and valuable of the methods, not the papers where the outcomes are collected.

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