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A theory of value in design

by

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This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Nomenclature

Abbreviation	Meaning
A_{cs}	Activity of criteria selection
A_{cj}	Activity of criteria judgement
A_{cp}	Activity of criteria prioritisation
A_d	Activity of design
A_{ei}	Activity of entity interpretation
A_{vd}	Activity of value determination
Cj	Criteria judged by an agent
Cp	Criteria prioritised by an agent
Cs	Criteria selected by an agent
COVE	Customer Oriented Value Engineering
E	Entity interpreted by an agent
FAST	Function Analysis Systematization Technique
G_{cs}	Goal of criteria selection
G_{cj}	Goal of criteria judgement
G_{cp}	Goal of criteria prioritisation
G_d	Goal of design
G_{vd}	Goal of value determination
I_k	Input knowledge
I_{kcj}	Input knowledge to criteria judgement
I_{kcs}	Input knowledge to criteria selection
I_{kcp}	Input knowledge to criteria prioritisation
I_{kvd}	Input knowledge to value determination
K	Knowledge of an agent
O_k	Output knowledge
O_{kcs}	Output knowledge of criteria selection
O_{kcj}	Output knowledge of criteria judgement
O_{kcp}	Output knowledge of criteria prioritisation

O_{kvd}	Output knowledge of value determination
PBR	Principle of Bounded Rationality
S	Situation of an agent
SVS	Schwartz Value Survey
TVD	Theory of Value in the context of Design
V	Value statement of an agent
VA	Value Analysis
VM	Value Management
VDM	Value Determination Model

Abstract

The continual strife to increase value in business economy attracts increasing attention in research. The contribution that design can make to economic value positions it as an important research area (Borja de Mozota, 2006; Daniels, 2006; Desbarats, 2006; Hertenstein and Platt, 2006; Lockwood, 2006; Phillips, 2006). However, investigations reveal that current literature provides different interpretations and highlights different aspects of the value phenomenon, but lacks a more fundamental formalism of value.

A theory of value in the context of design (TVD) is provided in this thesis. The theory provides a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. The value phenomenon was investigated from a value perspective in terms of axiology, economics, psychology, sociology, value interpretations across disciplines, and value types; and from a design perspective in terms of value interpretations in design, product and process value management, economic value of design, and human values in design. Knowledge gaps were identified and it was concluded that there was a need for a more fundamental formalism of value. Value and design theory characteristics were investigated and it was concluded that a theory provides a means for such formalism.

The theory building in this thesis was based on critical realism. The person, cognition, determination, situation, interpretation, entity, and criteria axioms of value were identified, providing insights on the fundamental characteristics of value. A model of value determination (VDM) was then developed, highlighting the role of the cognitive activities involved. Based on the value axioms and the VDM, explanations on value-related phenomena were provided. A theory of value in design was then postulated in terms of key elements and construct relationships. The validity of the TVD was investigated using a protocol analysis, open-interviews, and a requirements analysis. Pros and cons of the work were revealed and further work on taking the research forward was discussed.

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1. Introduction

Organisations continually strive to find ways to increase economic value in terms of higher revenue and/or profit margin. Chief executive officers confirm value as an important parameter for business navigation (Hug, 2003). Authors claim that management should focus on value creation (Copeland, Koller, and Murrin, 2000) and that companies need to shift from a traditional view of seeing business as a set of functional activities to an externally-oriented view, concerned with seeing business as a form of value delivery (Bower and Garda, 1985).

Value management is a challenge of most businesses today, but is often still difficult to distinguish from general management initiatives focusing on customer, enterprise, product, process, and shareholder values. As such, value management is evident in organisational activities such as marketing, engineering, finance, and manufacturing. In this business environment, understanding the value that design contributes (Borja de Mozota, 2006; Daniels, 2006; Desbarats, 2006; Hertenstein and Platt, 2006; Lockwood, 2006; Phillips, 2006) as well as methods and approaches to improve the value of design artefacts and processes (Chase, 1990; Fowler, 1990; Hamilton, 1996; Ashworth and Hogg, 2000; Cather et al., 2007) have increasingly become a focus of attention.

An indicator for the increasing interest on value in design was the first conference on Design Value held in Singapore in 2008, organised by the Design Management Institute (DMI)[1]. This conference focused on design to solve business objectives. According to DMI (2007), the role of design in business has shifted and is now becoming recognised as a key business asset that can add value. With a panel of international experts, this conference focused on the creation of value through design in terms of economic, social, and environmental values. To look at design as a value resource represents a trend in value research. In essence, this trend moves design

[1] The *Design Management Institute* is an international organisation that seeks to heighten awareness of design as an essential part of business strategy (www.dmi.org).

from a project oriented function to a strategic business function, and in terms of industry, from an expense to an asset.

Considerable work has already been carried out in the context of axiology (Lamont, 1956; Rescher, 1982; Holbrook, 1994), economics (Smith, 1904; Bailey, 1967; Allingham, 1982, Borja de Mozota, 2006), psychology (Maslow, 1943; Bretano, 1968; Rescher, 1982; Schwartz, 2006), and sociology (Kluckhohn, 1951; Allport, 1961; Rokeach, 1973; Feather, 1975; Kohlberg, 1983; Neumann, 1986; Pauls, 1990; Schwartz and Bilsky, 1987), but there are inherent differences in the interpretation of value. There is a lack of agreement on the concept of value per se, and on a conceptual framework from which research can be conducted (Hutcheon, 1972).

1.1. Motivation

Based on the author's industrial experience as a value analyst[2], product development in practice has a focus on product innovation in terms of new products and the improvement of existing ones. In most cases, new or improved products are introduced with higher prices corresponding to new or additional functions. Although methods such as value analysis exist, value considerations are not "key criteria" in the product development processes. Despite the body of research work outlined above, it is still difficult for designers to design a "valuable" product, and difficult for customers to distinguish valuable from non-valuable.

In 2003, the author initiated and co-supervised an industrial investigation done by the University of Cooperative Education Mosbach in Germany in the context of an awarded master's degree on the current understanding of value in industry (Hug, 2003). The investigation focused on the current understanding of value in market leading mechanical engineering companies with more than 500 employees. Overall, eight companies were involved, and thirty-two open-interviews were conducted with

[2] The author's industrial experience in value analysis is based on fifteen years in the automotive and machine building industry with a focus on the economic value of products and processes.

six chief executive officers, seven design managers, eleven design engineers, four product managers, and four salespeople. At the time of the investigation, the student executing the interviews did not have any experience in value in a business context in order to avoid a bias. The key findings are summarised as follows:

- Although different understandings of value exist, management looks at value as an important indicator for enterprise navigation.
- The alignment of human and company values is seen as a relevant issue for company success.
- From the interviewees' perspective, there is a link between value and decision making processes.
- Value is seen as abstract, complex, a matter of theory, and related to emotion.
- Adding value is seen as an activity in the production process.

An interesting outcome of the investigation was that none of the designers could clearly articulate an understanding of value. Based on the results of the investigation, it was concluded that there was a lack of knowledge on value in design and on the nature of value in general. Consequently there was a risk to invest resources in the design of non-valuable products and processes. Given this study, the overall motivation of the research work reported in this thesis was to develop a more fundamental formalism of value as a means to support the development of more comprehensive explanations on the value phenomenon. In the long term, these explanations may provide a basis to improve product and process value management in design, economic value of design, and research performance on value in design.

1.2. Scope

A theory of value in the context of design is provided in this thesis. From a value perspective, the work covers value of an entity, as an activity, and human values based on a model of the value determination process. From a design perspective, the work covers design as an activity, as an artefact, and human factors in design based on a protocol analysis of value determination in the context of design activities and open-interviews with designers. Consideration was given to value in the context of design artefacts and value determination based on personal criteria systems. From a theory perspective, the work covers value and design theory based on an analysis of the proposed theory of value in the context of design against design and value theory requirements.

The definition of design as applied in this thesis is aligned to that of Buchanan (2005), as the human activity of conceiving, planning, and bringing to reality physical products that serve human beings in the accomplishment of individual and collective purposes. Although existing design process models helped to characterise the focus of this work, they did not comprehensively describe it. These models focused primarily on value in terms of an evaluation activity, i.e. coping with the value phenomenon in terms of a common "value basis" as usually represented in product specifications (Holbrook, 1994). However, to more comprehensively analyse the value phenomenon in the context of design, it was necessary to consider value relative to entities, as an activity, and as an ethic/moral principle. The term *value determination* is used throughout this work to indicate that value in the context of design is seen as an output of a cognitive process.

The research work reported in this thesis aims to provide new knowledge on the value phenomenon in the context of design. While this research work may provide a basis for the development of methods and/or tools to determine value in the context of design, details of which are not within the scope of this thesis.

1.3. Aim and objectives

The overall aim of the research reported in this thesis was to develop a theory of value in the context of design as a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. The theory is intended to provide an additional perspective on the phenomenon of value in the context of design.

The objectives of the research provided in this thesis were:

- to establish the current state of knowledge on value in the context of design in order to identify shortcomings;
- to identify requirements for a theory of value in the context of design as a means to evaluate the theory presented in this thesis;
- to identify key characteristics of the value phenomenon as a means to investigate underlying mechanisms involved;
- to formulate a theory of value in the context of design and investigate its validity; and
- to evaluate the work in order to identify pros, cons, and areas for future work.

1.4. Structure of thesis

This thesis is structured as follows:

- Chapter 1 provides an introduction to the research of this thesis and highlights the motivation, scope, aim, objectives, and structure.

- Chapter 2 provides an investigation of value in design. This chapter highlights the design definition applied in this thesis and identifies design characteristics that can be seen as challenges in research on value in design (Section 2.1). Value in design is then investigated from the perspectives of value interpretations in design (Section 2.2), product and process value management (Sections 2.3 and 0), economic value of design (Section 2.5), and human values in design (Section 0). Knowledge gaps on value in design are summarised and it is concluded that there is a need for a more fundamental formalism of value in the context of design (Section 2.7).

- Chapter 3 provides an investigation of value theory from the perspectives of axiology, economics, psychology, and sociology (Sections 3.1- 3.4). Value interpretations are then analysed (Section 3.5) and value types are investigated (Section 3.6) to gain further insights on the value phenomenon. Knowledge gaps from value theory are then summarised supporting the need for a more fundamental formalism of value in the context of design and it is concluded that a theory provides a means for such formalism (Section 3.7).

- Chapter 4 provides an investigation on design and value theory characteristics (Sections 4.1and 4.2) as a means to identify requirements for a theory of value in the context of design.

- Chapter 5 provides the research methodology as applied in this thesis.

- Chapter 6 provides investigations of generic characteristics of value where value axioms are identified.

- Chapter 7 presents a model of value determination (VDM) and an interpretation of value as the output of a cognitive process.

- Chapter 8 provides an exploration of value-related phenomena based on the value axioms identified in Chapter 6 and the VDM presented in Chapter 7.

This chapter provides explanations on variables involved in added value (Section 8.1), mechanisms involved in exchange value (Section 8.2), terminology in the context of perceived value (Section 8.3), the relationship of value to benefit and need (Sections 8.4 and 8.5), and explanations on value types (Section 8.6). Insights gained from the exploration are summarised (Section 8.7).

- Chapter 9 presents the overall theory of value in design (TVD) based on the value axioms identified in Chapter 6, the VDM presented in Chapter 7, and the explanations on value-related phenomena provided in Chapter 8. The theory is presented in terms of key elements and construct relationships.

- Chapter 10 provides an evaluation of the TVD. The evaluation approach is outlined (Section 10.1), a protocol analysis identifying value determination in the context of design activities is provided (Section 10.2), open-interviews with designers on the TVD are outlined (Section 10.3), and the TVD is analysed against requirements (Section 10.4). A summary of the results is provided (Section 10.5).

- Chapter 11 provides a discussion on the work presented in terms of pros and cons and highlights future work.

- Chapter 12 presents a summary of the knowledge contributions as they have been presented in this thesis.

2. The nature of value in design

This chapter presents a review of value theories in design and provides an overview on the current state of knowledge.

The chapter starts with outlining the design definition applied in this thesis and identifies design characteristics that can be seen as challenges in research on value in design (Section 2.1). Value in design is then investigated from the perspectives of value interpretations in design (Section 2.2), product and process value management (Sections 2.3 and 0), economic value of design (Section 2.5), and human values in design (Section 0). Knowledge gaps on value in design are summarised and it is concluded that there is a need for a more fundamental formalism of value in the context of design (Section 2.7).

2.1. Design definitions

Establishing what we mean by "design" reveals that there is diversity and breadth in its formal definition[3] when literature is consulted (Buchanan, 2005). Design generally refers to some artefact, entity, and/or object. This serves to emphasise that design is a human creation, typically of utility, and the result of intentional activity (Dipert, 1995; Hilpinen, 1995). This type of definition, where the focus is on the design artefact, has been called the "product view of design" (Marxt and Hacklin, 2005).

Definitions of this type, however, point to a difference between the product and the activity of creation (McKay and Marshall, 2005). Miller (2007) argues that the product of creation is an output of design, but is not design itself. Thus, in contrast to the product view of design, is what can be called the process view of design, i.e. a series of thoughts and activities by which an artefact is created (Andreasen,

[3] A list of considered design definitions is provided in Appendix A.

Mognum, McAloone, 2002; Miller, 2007). Miller (2007) emphasises the importance of broad thought processes in design activities, including insight by which a designer is able to see connections between problems (challenges) and possibilities, intuitions and hunches, and reasoned problem solving, which are synthesised throughout the design process. Close to the process view of design is design as a practice delimited by the design task (Hooker, 2004), or engagement directly in a specific design activity (Fallmann, 2003), i.e. the activity of designing. This view of design emphasises the situatedness of the designer in a real-world context involving uncertainty, ambiguity, and value conflict (Fallmann, 2003).

For the purpose of this thesis, the definition of design is aligned to that of Buchanan (2005), whereby design is seen as the human activity of conceiving, planning, and bringing to reality physical products that serve human beings in the accomplishment of individual and collective purposes. This view of design supports the product, process, and human views of design and as such, provides a basis for research towards a formalism of value in the context of design.

Literature reports various models of design (Gero and Coney, 1985; Wallace and Hales, 1987; Bucciarelli, 1988; Ullman, Dietterich, and Staufer, 1988; Adelson, 1989; Finger and Dixon, 1998) that may be categorised as either descriptive or prescriptive in their approach (Finger and Dixon, 1998). Descriptive models (Ullman, Dietterich, and Staufer, 1988; Smithers, 1990) describe how the design process is carried out, while prescriptive models (Hubka and Eder, 1988; Pahl et al, 1996; Pugh, 1999) prescribe how the design process should be carried out. Overall, design characteristics suggested by design definitions and models may be summarised as follows:

- Design involves artefacts, activities, and human beings; decision making, exploration, and learning activities; and knowledge utilisation and evolution.
- Design is considered as a goal-directed problem-solving process.
- Design is recursive in terms of making and interpreting the environment.
- Design operates within a context, dependent on designers' perceptions.

The characteristics of design may be interpreted as challenges for research on value in design in that the characteristics point to questions on: the relationship of value to artefacts, activities, and human beings; decision making, exploration, and learning; knowledge utilisation and evolution; goal-directed problem-solving processes; the recursive nature of design, and design context and designer perceptions.

2.2. Value interpretations in design

Over the last fifty years, the perspectives of value in design have changed following changes in the corporate competitive environment. These perspectives are characterised by: global competition and purchasing, where customers have greater choice and therefore products must exhibit greater differentiation; rising energy, material, and labour costs increasing the need for products and processes to increase efficiency; and rapid technological change shortening product lifecycles and increasing product variety, which leads to a paradigm shift from high volume and low variety to agile and lean production and product development processes. Consequently, early interpretations of value in design based on product worth and cost (Miles, 1966) from a manufacturer's perspective have evolved and today encompass the customer's perspective in terms of benefit, need, quality, utility, and value of services as outlined in Table 2-1.

Date	Interpretations	Reference
2007	Value is a fair return or equivalent of goods, services, or money for something exchanged.	SAVE (2007)
2006	Value happens by achieving a result superior to that of the competition.	Borja de Mozota (2006)
	Value is determined in terms of product cost reduction and other metrics such as innovation, differentiation, and simplification.	Daniels (2006)
	Value is determined in terms of market share.	Desbarats (2006)
2003	Value is benefits (what you get) divided by sacrifices (what you put in).	Thomson et al. (2003)
2000	Value is a complex entity made of scarcity, utility, costs of production, worth in use, value in exchange, and made by marginal utility. It is influenced by the conditions of supply and demand.	Ashworth and Hogg (2000)
	Value is the relationship between the contribution of the function to the satisfaction of the need and the cost of the function.	British Standards Institution (2000)
1997	Value is function plus quality divided by cost.	Dell'Isola (1997)

Date	Interpretations	Reference
1996	Value is the level of importance that is placed upon a function, item or solution.	Hamilton (1996)
	Value can be considered as the ratio of function achieved to its life cycle cost.	
	Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.	Womack and Jones (1996)
1992	Value is a functional outcome, a goal, purpose, or objective that is served directly through product consumption.	Burns and Woodruff (1992)
1990	Value is a capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer.	Chase (1990)
	Value is a user's initial impression plus satisfaction in use, divided by first cost plus follow-up cost.	Fowler (1990)
1972	Value is the relationship of function cost to actual cost.	Miles (1972)
1966	Value is the relationship of product worth to product cost.	Miles (1966)

Table 2-1: Value interpretations in design

Two different value approaches are inherent to the value interpretations in design, i.e. value as an outcome in return for an input, or value as an outcome per se. Value as an outcome in return for an input (Miles, 1966, Miles, 1972; Fowler 1990; Chase, 1990; Hamilton, 1996, Dell'Isola, 1997; Britisch Standards Institution, 2000; Ashworth and Hogg, 2000, Thomson et al., 2003; SAVE, 2007) refers to an input in terms of cost, price, product consumption, or more general as something exchanged. Value interpreted as an outcome per se (Hamilton, 1996; Borja de Mozota, 2006; Daniels, 2006; Desbarats, 2006), refers to the metrics of market share, innovation, differentiation, or a result superior to that of the competition. From the value interpretations given in Table 2-1, it can be concluded that value as an outcome in return for an input dominates the literature of value in design.

Based on different value interpretations, there are different perspectives of the value phenomenon in design. Borja de Mozota (2006) states that value happens by achieving a result superior to that of the competitor. Daniels (2006) suggests evaluating the money a design saves in product cost over the previous design and other value metrics such as innovation, differentiation, and simplification. Desbarats (2006) suggests the use of market share as a metric to measure how designs add value. The three descriptions point to knowledge gaps on value in design: when does value appear; what is an appropriate metric for value in design; and how can value be added in design? Today, there is a need for more comprehensive answers to these questions. Despite the different interpretations of value, four main streams of the value discussion in design can be identified in current literature with a focus on: (1) product and (2) process value management; (3) economic value of design; and (4) human values in design. The following sections provide investigations on the four main streams to gain further insights on value in design.

2.3. Product value management

Management of product value in design is based on value management theory. However, different interpretations of value management[4] (VM) exist in literature. (Corne, 2001). In general terms, value management can be seen as: a proactive, problem-solving service, using a multi-disciplinary team-oriented approach to make explicit the client's value system, at targeted stages through the development of a project or the life of a facility (Kelly, 1993); a means of group decision support (Green, 1999); and a method to help to better achieve design goals (Connaughton and Gree, 1996; Male, Kelly, and Fernie, 1998). According to Porter (1985), value management directs company knowledge to maximise added value and fulfil customer needs. In the context of design, this suggests that value management supports problem solving, design collaboration, transparency on value systems throughout the development process, decision making, and the generation of knowledge to maximise added value, thus fulfilling specific customer needs.

Corne (2001) argues that different facilitators use different methodologies for VM, but in general cover the following phases: information, objective, analysis, creativity, evaluation, development, and reporting. In the information phase, brief presentations are made by the key stakeholders to ensure that the entire study group is fully aware of the rationale behind a project. In the objective phase, the VM process focuses on the analysis of objectives that the project must satisfy. In the analysis phase,

[4] *Value management* may be equated to the North American term *value engineering*. However, the term *value management* is preferred in this thesis, as related literature has a focus on managing rather than engineering value.

functional rather than physical characteristics of a development are analysed. Concentrating on the objectives/functions identified during the previous phase, techniques are employed to generate alternative ideas of achieving the required outcome in the creative phase. It is during the evaluation phase that assessments of possible alternatives take place. The alternatives identified in the evaluation phase are then technically developed and analysed during the development phase. Finally, in the reporting phase, the participants agree on the outcomes from the study and identify the actions necessary to keep the project on track.

A major focus on the development of value management is on the analysis phase, i.e. on value analysis (VA). VA aims to identify, quantify, and rectify weaknesses in products and processes. The method was originally developed by Miles (1972) as an improvement of cost reduction methods. Today, VA is applied in a variety of fields including civil engineering (Moris, 1998), general management (Copperman, 1998), product development (Mudge, 1989; Fowler, 1990; Boderick, 1992), and service organisation (Marshall, 1998). The technique has been adopted in a European Standard (Commission of the European Communities, 1990; European Committee for Standardisation, 1996) and by the US government (Paley, 1998). However, there are differences in the interpretation of VA. Cather et al. (2001) argue that VA is a means to achieve optimised design referring to the balance of the cost of producing benefits against the value attached to these benefits by the customer. Fowler (1990) refers to VA as an ongoing system applied to all problems of an organisation that concern function and cost and/or to the study of user perception of a product, including performance, cost, and quality. Differences in the interpretation of value in terms of benefit, cost, performance, and quality can be seen as a reason for differences in the definition of VA.

Miles's original VA technique aims to provide a function at the specified quality with the minimum cost (Kermode, 2007). The approach is production-oriented because it centres on providing predefined functions at minimum manufacturing cost. Some customer orientation can be adopted by considering life-cycle cost, which includes all of the post-purchase costs incurred by the customer (Andersen, 1993;

Kirk and Dell'isola, 1995; SAVE International, 1998). This approach is not customer-oriented in the sense that is does not consider whether the customer perceives the function as being important. However, following Miles's work, several developments have been made to VA: an evolved definition of value (COVE); VA in new product development; a systematization of methods (FAST); an exploration of the problem space; and systematic target methods. The following paragraphs provide a brief introduction on the developments.

- Customer Oriented Value Engineering (COVE), originated by Snodgrass (1993), embodies the customer's perspective in that the method applies the principle that the cost incurred by a function should be in proportion to what the customer says it is worth. Customer desire for a function is expressed in terms of absolute price.

- VA as introduced in new product development has a focus on target costing (Harada, Tanaka, and Kato, 1998; Nagoya, 1998; Takubo, 1998), where alternative designs are assessed using function cost allocation.

- The primary developments in function analysis within the VA application have been on function systematization. The primary technique is the FAST (Function Analysis Systematization Technique) diagram developed by Bytheway (1965), where functions are arranged in a "tree" hierarchy as a means to identify the functions specifically required to provide a task.

- The process of analyzing the function rather than the result assists people to learn about the problem situation. In other words, function analysis can be seen as a means of value analysis enabling a design team to learn how to reduce and control product cost, rather than cost reduction per se (Jones, 1981).

- In VA, the interpretation of value can change. The SAVE methodology (SAVE International, 1998) specifies that the study team can define case-specific value metrics during the information phase. Several practical methods have evolved in this context (Kermode et al., 2007): *Pareto analysis* of component cost highlighting, where the most cost is incurred; *Basic function value,* where each basic function is related to its current cost and then evaluated against its hypothetical least-cost benchmark value; *Value index based on customer perception,* where the importance of each function is compared with its cost; and *User mismatch,* where cost is allocated to functions in a FAST diagram along with information about the product user's needs and wants, which is gained through customer research. Value mismatches are defined as the functions whose costs do not match with what the user says the functions are worth, following the COVE principle. Functions with the greatest differences between worth and cost are selected for improvement.

Overall, VA relies on the establishment of the function structure of the product under investigation. The product is then improved according to the operating definition of value whereby the value definition is producer- and/or customer-based. The core definition of value in VA is product-function related and case specific, as expressed in terms of cost, need, want, and worth. An underlying assumption of VA is that value is related to benefit and cost.

From the literature presented in this section, it can be concluded that product value management has a major focus on the analysis phase, i.e. on the analysis of product value in terms of objectives, functions, costs, benefits, user perception, quality, needs, wants, and worth. Though some of the VA approaches consider the relationship between different elements involved (e.g. FAST considers cost, function, needs, and wants) they only address elements in product value and hence provide a limited view of product value in design. Product value management lacks a more fundamental formalism of value as a means to identify the key elements and mechanisms involved.

2.4. Process value management

The issue of analysing design process value is related to the work of Chase (1990), who establishes a link between value management in design and the effectiveness of the product development process. Chase (1990) states that to properly measure the effectiveness of the product development process, we must address the value associated with product development activities at each step of the process. This raises questions on the relationship between value in design and design performance.

Ashworth and Hogg (2000), in the context of value management in design, suggest a range of design techniques (e.g. cost planning, benchmarking, risk analysis) to be applied during the design phases to add value and promote the best interests of the client. This is in line with Cather et al. (2001), who refers to value management in design as the application of techniques to help define and refine business needs, to deliver the best value concept by setting customer objectives and values, and to determine success criteria for projects. In this sense, systematic design methods can be seen as means to improve design process and/or customer value.

Overall, literature on process value management in design is focused on supporting design process value based on the application of design techniques, definition of business needs, settings of customer objectives, and the determination of success criteria. As such, design process value management considers specific techniques to increase and determines process value in terms of needs, objectives, and success criteria. Though some of the approaches consider the relationship between specific elements (e.g. design techniques to support the identification of business needs) they only consider part of the elements involved and therefore provide a limited view on process value management. Design process value management lacks a more fundamental formalism of value as a means to identify the key elements and mechanisms involved.

2.5. Economic value of design

The Business Week (Nussbaum, 2005) published a special report on the emergence of a “creativity economy”, in which managers are starting to discover design as a strategic business element. Borja de Mozota (2006) argued that business managers should know about design management’s power to create value, identifying in this context four areas where design management creates economic value:

- Design as a business success in terms of better margins and return on investment, greater market share, increased brand value and sales;

- Design as a differentiator, i.e. as a source of competitive advantage in the market through brand equity, customer loyalty, customer orientation, and price premium;

- Design as an integrator in the sense of design as a resource to improve new product development processes, i.e. by reducing time to market based on modular and platform architecture of product lines; and

- Design as a transformer, i.e. as a resource to create new business opportunities, thereby improving the company’s ability to cope with change.

These four areas may be interpreted as design management objectives to generate contributions to business success. This is in line with Philips (2006), who examined the relationship between industrial design effectiveness and a company’s financial performance in order to assess the contribution of industrial design to this performance. The studies conclude that firms with high design effectiveness had higher returns on sales and on assets, as well as higher stock market returns than firms with low design effectiveness. Borja de Mozota (2006) suggests implementing design as value using the Balanced Score Card tool as a means for measuring the impact of design on the overall business performance. As such, Borja de Mozota suggests a paradigm shift in design management from a focus on project design management to strategic design management as a means to generate economic value.

A more holistic perspective on the economic value of design is provided by the Commission of the European Community (2009), reporting the results of a public consultation aiming to answer, "what is the economic and innovation potential of design?" According to the European Community the findings of micro-economic research on design are conclusive: the use of design has a positive impact on the performance of a company, measured in terms of, e.g. profitability, share price, employment, or exports. A research survey on what companies perceive as being the benefits of design[5] generally shows that one of design's greatest contributions is to strengthen the brand. 53% of Swedish companies consider that design has a major positive impact on brands. 70% of Spanish companies consider that design has a major or considerable impact on company image. According to the report, companies also consider design to have an impact on performance indicators, such as sales and profitability:

- 32% of Swedish companies consider that design has a major impact on sales, while more than 40% of Spanish and British companies and 66% of Norwegian companies consider that design has a major or considerable impact on sales. A survey of Polish companies shows that in the last 12 months, approximately one-third of Polish companies perceive that design has had a positive impact on sales, market share, new market development, and competitiveness. Design was also considered to have a major or considerable impact on new market entry by 65% of Norwegian companies, 56% of Spanish companies, and 46% of British companies.

- With respect to profitability, 60% of Swedish companies agreed totally or partially with the statement that there is a positive correlation between design and profitability. 81% of Spanish companies considered that design has an

[5] *Design* as the term is used in this survey refers to a professional and creative way of working where both functional and aesthetic requirements are essential.

> impact on profits, compared to 75% of Norwegian companies and 42% of UK companies. More than 50% of Spanish companies considered this impact to be major or considerable. The Polish survey shows that around one-third of Polish companies consider that design has had a positive impact on profits in the last 12 months.

The report concludes that with the background in awareness-raising among local consumers and industry, and international promotion of a country's image, recent design policies tend to be more ambitious and focused, emphasising design as a strategic tool for economic progress.

Current literature on design management points to the need to manage the economic value of design. However, the terminology applied in literature on economic value in design is ill-defined (e.g. strategic value, economic potential of design). Current literature on the management of economic value in design is without an underlying formalism identifying the key elements and mechanisms involved as a means to investigate value contributions rising from design as a product and/or process, from management of design, and/or from value management in design.

2.6. Human values in design

Literature on human values in design has tended to focus on design that accounts for human values, decision making processes and ethics, and value alignment in organisations. Different interpretations of human values exist: Bailey (1967) argues that value appears to mean the esteem in which any object is held; Hight (2006) states that value educates about good values, such as honesty, respect, and integrity; Kluckhohn (1951) states that a value is an explicit or implicit concept, distinctive of an individual or characteristic of a group, and desirable, which influences the selection from available modes, means, and ends of actions; Najder (1975) concludes that value is an idea that makes us consider given objects, qualities, or events as valuable; and Rokeach (1973) looks at value as an enduring belief. Despite the different interpretations, consensus on elements related to human values has emerged gradually since the 1950's (Braithwaite and Scott, 1991) in that human values are seen as beliefs, refer to desirable goals, transcend specific actions, serve as standards or criteria, and are ordered in importance relative to each other (Obando, 2008).

Literature on design that accounts for human values has a focus on Value-Sensitive Design, Participatory Design, Computer Ethics, and Computer Supported Cooperative Work. Value-Sensitive Design is an approach to the design and implementation of systems that account for human values throughout the design and implementation process (Friedman, 1997; Friedman, Kahn and Howe, 2000) by conceptual, technical, and empirical investigations. The conceptual investigations relate to a philosophical analysis of the constructs and issues relevant to the system under development. The technical investigations address existing design artefacts and their relationship to value and on how the identification of values can lead to new design artefacts. The empirical investigations address value-oriented perspectives and experiences of stakeholders of a given system. Participatory Design has a focus on the integration of knowledge from different stakeholders (e.g. employees, partners, customers) in the design process for the purpose of a product design that meets their needs and is usable. Traditionally, Participatory Design is related to a commitment to the democratisation of the workplace and human welfare (Greenbaum and Kyng, 1991; Kyng and Mathiassen, 1997*).* Computer Ethics focuses on the utilisation of moral theory to consider ethical issues involving computer technology and on how technological innovations extend the boundaries of ethical concepts (Moor, 1985, Johnson and Miller, 1997). Computer Supported Cooperative Work focuses on the design of new technologies as a means to help people to collaborate in the workplace. The values considered in this context are focused on group activities and workplace issues (Hudson and Smith, 1996; Olson and Teasley, 1996). Overall, literature provides different approaches to integrate human values in design in terms of philosophical analysis of design relevant issues, analysis of design artefacts and their relationship to value, experience of stakeholders, ethical issues, and workplace issues. However, these approaches are without an underlying formalism of value as a means to identify the key elements and mechanisms involved.

Human values can be interpreted as principles that guide people's behaviour (Binde, 2004). In this context, human values can be seen as related to decision-making in design. Marshall and Erlhoff (2008) argue that designers in making decisions in the design process give priority to certain values over others. Literature provides studies on value issues such as the mechanisms of value transfer in meetings (Le Dantec, 2009) and ethical thinking in design (Lloyd, 2009). Manzini (2006) considers ethics in the context of decision making in design looking at design as a creative activity that is "one of choosing between different possibilities" and "the openness of the field of possibilities where designers are operating is one of the factors that characterises their actions" (Manzini, 2006, p.1). A relationship of design to ethics can then be seen in designers adopting criteria for decision-making and on this basis make judgements on what, in their view, is better to do. "Given that ethics is defined as dealing with 'what is good and bad, right and wrong', they have to make ethical choices" (Manzini, 2006, p.1). From the perspective of ethics in the sense of responsibility (Jonas, 1979), one may argue that "what has to be considered as ethically relevant are not only the intentions behind a given action but also its implications and results" (Manzini, 2006, p.1). Different aspects of decision-making are acknowledged in studies (Wallace, 1995, Badke-Schaub and Gehrlicher, 2003, Daalhuizen, 2009, Yang 2010) as experience, use of information from previous projects, intuition, culture, and personality and authors investigating value in design from a designers perspective (MacMillan, 2006; Thomson et al., 2006). It can be concluded that human values, experience, intuition, culture, and personality are relevant to value in design but there is a lack of a fundamental formalism to identify the key elements and mechanisms involved.

Research on the alignment of human values has a focus on the values of individuals, organisations, and society aiming towards business performance improvement and as such is related to design from a business organisation perspective. Kotter and Heskett (1992) found that an organisation's values could drive either high or low performance, depending on the organisation's ability to align with its market and adapt its strategies and practices accordingly. Liedtka (1989) found that those who were aware of their individual and organisational values had the highest level of commitment and a positive attitude towards their work and ethical practices. However, Webley (1999) argues that there are weaknesses in the way organisations formalise their values in that value "origins" may not be identified and value may be confused with strategic goals. Mills et al. (2009) point to additional aspects related to value alignment: the differences in organisational cultures and leadership styles range from power cultures where founders see their own values strategically forming the basis of all organisational decisions, to cultures where individuals work autonomously making decisions framed by their own values (Handy, 1993); the social action and motivation of individuals, where people's perceptions shift and change to make decisions based on individual and social factors, i.e. leaders cannot expect to drive an organisation by articulating abstract or sociological value statements alone, rather they must also consider individuals' values and their alignment with organisational statements (Swindler, 1986); the transfer of individual and organisational values from leaders to employees to increase their understanding of task importance, where leaders must ensure that their values are congruent with their actions to build confidence and trust (Ciulla, 1999); and the guidance of people based on leaders' values embedded in organisational cultures in terms of what leaders pay attention to, measure, and control (Schein, 2004). It may be concluded that the alignment of human values is relevant to an organisation's culture, an individual's motivation, and overall business performance and as such, relevant to design. However, the alignment of individual, organisational, and societal values requires a more fundamental formalism of value to identify the key elements and mechanisms involved. Current theories on value alignment are without such an underlying formalism.

A review of value interpretations (Appendix C) against human values reveals that research on human values (e.g. Rokeach, 1973; Feather, 1975; Harrison, 1998; Hight and Cooper, 2006; Schwartz, 2006) is related to belief, benefit, decision making, desire, expectancy, and utility. This is different from other value types relevant to design, such as economic and product values (e.g. Miles, 1966, Fowler, 1990;

Norman and Ramirez, 1993; Larreche, 2000; Ashworth and James, 2001) related to business relationships, costs, earnings, and new business models. As such, literature provides research with a focus on human values or economic value. However, in design, product, process, economic, and human values are involved. Hence, to identify the key elements and mechanisms involved in value in design requires a more fundamental formalism of value as a means to support research across different value types.

2.7. Summary and conclusions

In Section 2.1, design was introduced as the human activity of conceiving, planning, and bringing to reality physical products that serve human beings in the accomplishment of individual and collective purposes (Buchanan, 2005). This view of design supports the product, process, and human views of design and as such, provides a basis for research towards a formalism of value in the context of design.

Value in design was then investigated from the perspectives of value interpretations, product and process value management, economic value of design, and human values in design (Sections 2.2-0).The investigations revealed knowledge gaps on value in design, which can be summarised as follows:

- Different descriptions of value in design (Borja de Mozota, 2006; Daniels, 2006; Desbarats, 2006) can be interpreted as indicators to key questions for research on value in design: when does value appear; what is an appropriate metric for value in design; and how can value be added in design?

- Product value management in design has a focus on the value analysis phase, i.e. on the analysis of value in terms of objectives, functions, cost, benefits, user perception, quality, needs, wants, and worth. Though some of the VA approaches the relationships between specific elements (e.g. FAST considers cost, function, needs, and wants) they only cover some of the elements involved in product value management and therefore provide a limited view of product value management in design. Product value management lacks a more fundamental formalism of value as a means to identify the key elements and mechanisms involved.

- Design process value management considers specific techniques to increase the design process value in terms of needs, objectives, and success criteria. Though some of the design process value approaches consider the relationship between specific elements (e.g. design techniques to support the identification of business needs), they only consider part of the elements involved and therefore provide a limited view of process value management. Design process value management lacks a more fundamental formalism of value as a means to identify the underlying key elements and mechanisms involved.

- Design management literature points to the need to manage the economic value of design. However, the terminology applied in literature on economic value in design is ill-defined (e.g. strategic value, economic potential of design). Current literature on the management of economic value in design is without an underlying formalism identifying the key elements and mechanisms involved as a means to investigate value contributions rising from design as a product and/or process, from management of design, and/or from value management in design.

- Literature provides different perspectives of human values in design: design that accounts for human values; human values in the context of decision making processes and ethics; and human values in the context of value alignment in organisations. However, these perspectives are without an underlying formalism of value as a means to identify the key elements and mechanisms involved.

- Human values, experience, intuition, culture, and personality are relevant to value in design in the context of decision-making processes with literature pointing to activities, beliefs, criteria, goals, and situations as further elements involved. However, literature on human values in design needs a more fundamental formalism of value as a means to identify the key elements and mechanisms involved.

- Literature provides research with a focus on human values or economic value. However, in design, product, process, economic, and human values are involved. Hence, to identify key elements and mechanisms involved in value in design requires a more fundamental formalism of value as a means to support research across different value types.

- Literature highlights a need for the alignment of personal, organisational, and society values as a means to increase the individual's motivation and overall business performance. However, current theory on value alignment is without an underlying formalism of value as a means to identify the key elements and mechanisms involved.

From the knowledge gaps it can be concluded that current literature on value in design provides different interpretations and highlights different aspects of the same phenomenon. The knowledge gaps refer to a lack of knowledge on the underlying key elements and mechanisms involved in the value phenomenon. Current literature on value in design lacks a more fundamental formalism of value. There is a need for such formalism in that it can provide a means to support the development of explanations on when value appears, appropriate metrics for value in design, how value can be added in design, and on the key elements and mechanisms involved in product and process value management, the management of economic value in design, the integration of human values in design, value alignment, and the relationship of different value types in design.

This chapter provided a literature review on value in design. The following chapter provides an investigation of value literature from axiology, economics, psychology, and sociology perspectives to support comprehensiveness of the review.

3. A review of value theories

The previous chapter provided a review of theories on value in design. The purpose of this chapter is to investigate value theory in a more general sense. The term *value theory* is used in different ways in literature. In a broad sense, value theory refers to philosophical and scientific theories deemed to encompass some evaluative aspect. In a narrative sense, value theory is synonymous with axiology as the study of ethics and aesthetics with a focus on human values.

Theories of value can be classified in axiology referring to general or philosophical theories of value as well as scientific theories including economics, psychology, and sociology. According to Seni (2007), value theories vary in breadth and level of generality, whereby philosophical theories are seen as the more general and scientific theories as the more specific. They also vary as to the kind of questions they answer (Table 3-1).

Classification		Focus
Axiology (or general or philosophical theories)		What is good and how to evaluate it; what ought to be good?
Scientific theories	Economics	How are goods produced, exchanged, and distributed in a society; what imparts goodness to a product or service?
	Psychology	How do individuals develop, believe, assert, and act on values?
	Sociology	How are values in society held and become aspects of culture and institutions?

Table 3-1: Classification of value theories

Axiological or so-called general or philosophical theories of value have a focus on what is good and how to evaluate it. Scientific value theories in economics focus on: how to develop, produce, exchange, and distribute valuable products; what imparts goodness to a product, utility, and/or quality; and what makes a product effective, efficient, and/or flexible. In psychology, value theories focus on how individuals develop, believe, assert, and act on values. Sociology has a focus on how values are held in society and become aspects of culture and institutions.

This chapter provides a review on value theories from axiology, economics, psychology, and sociology perspectives (Section 3.1-3.4) [6]. Value interpretations (Section 3.5) are then analysed and value types (Section 3.6) are investigated as a means to gain further insights on the value phenomenon. A summary of knowledge gaps identified in value theories is provided and it is concluded that there is a need for a more fundamental formalism of value in the context of design (Section 3.7).

3.1. Axiology

Axiology has a focus on questions such as: “What is the value or the goodness of a thing?”; “Is the value of a thing an objective quality or is it a mental construct?”; “How does one value and evaluate?”; “What is a life of value?”; and “What is a good life?”. These questions are related to ethics and moral theories. Seni (2007) highlights the point that both ethics and moral theories rest on the concepts of good and bad, right and wrong, and just and unjust, concluding that ethics and moral theories require an axiology or a theory of value. One debate in axiology is on value as an objective property. Reality can be considered as independent of perception. If one does not exist to perceive it, reality is nevertheless there (Bunge, 1989). In this paradigm, real things have objective properties. These properties are characteristics of real things, i.e. not of our perception of them. Some properties contribute to human needs and wants and it can be argued that these have value for them. The value of goods is explained as a relationship between the attributes of things, human knowledge and judgement about these attributes, beliefs of how these attributes satisfy needs, and judgements about their effects and consequences. In this context, Seni (2007, p.5) suggests an axiological distinction between the concepts of value, valuation, and evaluation: “Value is an objective property of the relationship between

[6] Given the amount of work available, the review is not intended to provide an exhaustive overview, but rather to outline value theories with major contributions to value research.

an animal and the properties of a thing. A thing is of value to someone. Valuation is an attitude or subjective act or disposition of an animal in favour of a particular value relationship. Evaluation is a cognitive act of judgement concerning the value of a thing."

A second debate in axiology is on the intrinsic or extrinsic nature of value, i.e. on the question of whether value is in the valued object or in the person that does the valuing. Value as an inherent property of an entity (Allingham, 1982; Best, 1999) makes the assumption that value exists within an entity. Value as an apprehended property of an entity (Holbrook, 1994; Hamilton, 1996; Harrison, 1998) takes the assumption that value is apprehended in the mind in the context of an entity. Seni (2007) argues that a realistic perspective on this question is that the value of an object to a person resides in the relationship between the property of the object and the person's needs. According to Seni (2007), human beings have needs and wants. Their needs and wants express their search for continuous improvement in living. Some needs are basic and universal (e.g. water, air), while other needs may be individual. Needs are seen as objective in that they are constitutive of well-being, but subjective in the sense that they are felt or are believed as the case may be. "In this regard, a thing of value meets some needs by the function it performs in the meeting of the need of a person. The function is valuable, not the thing itself" (Seni, 2007, p.6). Thus, value in this sense "resides" in the relationship between the functional property of a thing and someone's need.

Value theorists in the axiological tradition consider questions on value "as an end" or for "itself" or "for its own right". The question: "What sorts of things may be reasonably taken to be valued as ends?" is a key question of traditional philosophical ethics. "What is to be valued as an end is pleasure (Cyrenaics), happiness (Aristotle), knowledge (Plato), a good will (Kant), the general welfare (Utilitariants), and so on. Not only are the values that are of interest to ethics "end" values, but conversely, any end value must have an ethical aspect in representing an appropriate target for human aspiration (Rescher, 1982). "Loyalty" or "Honesty", e.g. are prized primarily on their own accounts. "The benefit of realising a value designated in this manner is seen to reside primarily in this realization of itself and for itself" (Rescher, 1982, p.81). However, "certain values are viewed as systematically subordinate to others. In such cases, the benefit seen to reside in a realisation of the value is looked upon as residing in some other 'larger' value and is subordinate. For example, "Generosity" may be prised for its conduciveness to the "Happiness" of others. Values in this subordinate, other-facilitating sort may be characterised as instrumental or means values" (Rescher, 1982, p.18).

Another debate is on value judgement. According to Seni (2007), human beings do not satisfy their needs purely by instinct, but by knowledge of the facts of reality and by the use of that knowledge to judge need satisfaction. In other words, humans do not only value things by belief, but evaluate them in terms of knowledge as well. "The capacity to know leads men to deliberate, to evaluate, and to judge value according to the consequence of their action and behaviour on their circumstances" (Seni, 2007, p.7). Lamont (1956) identifies different types of judgement: value judgement is seen as the assertion that something is good or bad, or better or worse than something else; moral judgement is expressed through such terms as duty, obligation, or right; and efficiency judgements are understood as, e.g. alternative materials to serve specific functions. Holbrook (1994) points to the distinction between the terms value (singular) and values (plural), suggesting that the term "value" refers to a preferential judgement, whilst "values" is used to refer to the criteria by which such judgements are made.

One of the principal tasks that the Austro-German school of value theorists set for itself was that of devising a 'logic of valuation', based on the discovery of general rules basic to the theory of value. These rules are objective in their grounding and universal in their applicability throughout the value domain (Rescher, 1982). Examples of axioms are: When something has value, then its existence is valuable and is more valuable than its non-existence; or when something has value, then the more there is of it the greater the value (Kraus, 1937). "Rules of this sort can certainly be called into question. Suffice it here to indicate, that this exploration of the formally valid rules of valuation in the implementation of its concept of value axiomatic, is one of the salient insights and main contributions of the Austro-German school of value theorists" (Rescher, 1982, p.58). Thus, axioms in the context of value theory refer to rules that are universal in their unrestricted applicability throughout the value domain.

Overall, axiology is related to ethics and moral theories. These theories rest in the concepts of good and bad, right and wrong, and just and unjust. Axiology has a focus on general conceptual questions on value in terms of: the objectivity of value; the intrinsic versus extrinsic nature of value; the beliefs in value; value judgement; and general rules basic to the theory of value.

3.2. Economics

Value theories in economics focus on the social organisation of the production, exchange, and consumption of goods of value in a society. Theories of economic value deal descriptively with how things of value are produced, distributed, exchanged, and consumed. On the other hand, they deal prescriptively with how an economy and a society should be organised aiming towards a high level of social value (Seni, 2007). According to Seni (2007), there are two main classical theories of economic value: the pricing and the labour theories of value.

In the pricing theory, value of a good is considered in terms of value in use or the utility of a good and its value in exchange. Seni (2007) states that economists agree that economics ought to deal only with value in exchange, since value in use and the utility of a good are individual and not social matters. The value of a good in a given economy is then seen as the value that society determines it should have, and that this value is the same as its price. Seni (2007) then highlights the point that this is the case under certain conditions, e.g. every good is bought and sold in an open market; everything of value is freely exchangeable; and every good is produced, bought, and sold in perfectly competitive markets. Under such conditions, buyers express their evaluation by the demand for goods, and sellers by their supply. Seni (2007) concludes that perfect competition ensures that prices are down in cost and consequently that the distribution of resources is optimally allocated. This system is socially just in the sense that each receives in proportion to his contribution.

Value literature argues that value is related to exchange and provides different perspectives on the discussion: value as the amount for which a thing can be exchanged; exchange value as distinguished by its useful value; and value as a feeling that arises when objects are considered as subjects of preference. Allingham (1982) argues that value is interpreted in terms of the amount for which a thing can be exchanged and concludes that value of an asset is defined as a function of usefulness and availability. Fogarty (2008) points to Aristotle who made a distinction between value in use and value in exchange, arguing that there are two uses for everything that we possess: A shoe, for example, is worn and it may also be used for exchange. Bailey (1967) concludes that it is only when objects are considered together as subjects of preference or exchange that the specific feeling of value can arise.

Smith (1904) suggests a distinction between the “real” and the “nominal” value of goods. The “real” value is on the labour involved in making it useful, or the quality and the quantity of work it embodies. The “nominal” value of goods is its value in exchange, which of course depends on its “real” value, since without it there would be no exchange (Seni, 2007). “Approximately one hundred years after Smith’s “Wealth of Nations” first appeared, Marx’s critique of the liberal utopia and the institutions of capitalism laid the way for a second social utopia along with a second theory of economic value based on Smith’s and Ricardo’s labour theory of value” (Seni, 2007, p. 11).

Marx’s critique of the liberal utopia assumed a just distribution of wealth “from the start”. Marx points out the distribution of wealth had already been historically determined by the system of social classes and property rights. “Wealth” is seen as being already in the hands of the capitalists in that the worker, who provided the “real” value of goods in society by his work, had only his labour to sell, and was brought into a labour market in which he was compelled to participate in order to survive. “Moreover, because he (the worker) exchanged labour for wages he became alienated from his labour by the surplus value he created for the capitalists and in which he did not participate” (Seni, 2007, p.11). Overall, Marx’s socialist utopia is founded on the principles of the elimination of private goods and property, the elimination of markets and exchange, the social and democratic planning of quantities of goods of value, and of all prices for these goods.

The liberal theory of value considered social value from the demand side and the customer’s viewpoint. The labour theory of value considers social value to be created by the makers of goods. The idea found particular favour in David Ricardo. Karl Marx adopted it and turned it into a theory of value on which his socialist utopia rested. According to Ricardo and Marx, value is equal to labour, where labour is the quantity of labour that goes into making a good. For Marx and Ricardo, exchange creates no value (Seni, 2007).

The labour theory of value has been criticised by economists on several grounds: The theory relies on the idea that the value of a good is proportional to the quantity of labour rather than the quality; and it does not take into account the needs of individuals, i.e. the demand side of the economy. Seni (2007, p.12) concludes that “no serious economist today would contemplate the faint relevance of the labour theory of value to the economy. The only people who still use these ideas are the engineers, designers, technologists, and managers; although they don’t always know that they are doing so.” They are concerned with designing and making things that really work and with artefacts that function well. All this, as technologists know, depends to a large extent on the quality of thought and work that gets built into their products and that is embodied in the artefact.

Value theories related to engineering and technologies take the pricing and labour theories of value from economics and integrate them into a framework of value for their management (Seni, 2007). The concept of the price of inputs required for producing, acquiring, and using an artefact is derived from the pricing theory. The price of inputs is one of several costs to take a product or service to the market and use. The concept of the performance of functions as the costs of the embedded work in making and using an artefact to perform desired functions is taken from the labour theory. Thus, the "technological" value of an artefact is the cost of producing or acquiring and using the artefact that allows performing the functions of one's needs, given available resources, options, and circumstances (Seni, 2007). Value theories related to engineering and technologies deal with practical value of artefacts, and value issues in the development, production, sales, and use of artefacts. Fundamental to these theories is value expressed in terms of effectiveness and efficiency.

In the context of value theories related to technology, Bunge (2006) argues that these value theories are based on the idea that artefacts meet the needs and ends of a user through mechanism or causal system or network of material relationships; they rely on the idea that the value of a thing does not reside in its form or in its substance (intrinsic value), neither in attitude, beliefs, desires, nor pleasures of a user (extrinsic value). The value of an artefact in meeting needs is seen in the performance of functions through a user-artefact interaction, i.e. in the functions an artefact allows a user to perform.

Value theories in economics can also be considered from the perspective of the social value created by the production, sale, and purchase of artefacts by members of an economy. From this perspective, the exchange value of goods can be considered in terms of the consumer's surplus, i.e. the worth of the product's function minus product price; the worth of the function to the customers in terms of the surplus of profit, i.e. the price minus the cost of production; and in terms of the total value created to the society, i.e. the worth of the product's function to the customers minus the cost of producing these functions (Seni, 2007).

Overall, value theories in economics focus on the creation, exchange, and consumption of goods of value in a society. The main classical theories of economic value can be seen in the pricing and labour theories. In the pricing theory, the value of goods is considered in terms of value in use or the utility of a good, and its value in exchange. The labour theory of value relies on the idea that value is equal to labour, where labour is the quantity of labour that goes into the creation of a good. Value theories are related to engineering and technology, based on the idea that artefacts meet the needs and ends of a user through mechanism or causal system or network of material relationships.

3.3. Psychology

Value theories in psychology focus on how humans value and evaluate with respect to their needs and how their behaviour is directed as meeting needs. A basic idea of psychology in biology is that animals, from which humans are one species, are driven by the need for individual welfare conducive to survival and reproduction. From this it can be concluded that various kinds of "things" are valuable to humans as long as they contribute to welfare, survival, and/or reproduction. Behaviour towards well-being, from this perspective, is genetically programmed. Needs and wants, in a given environment, drive behaviour and are at the origin of value (Seni, 2007).

Value theory in psychology provides concepts on need-based action (Maslow, 1943). A basic idea behind these concepts is that behaviour is triggered by motivations that are in turn determined by needs. Needs and wants are organised by priority. This concept interprets value in terms of individual needs, and value resides in the individual's psychological states. Action is explained in terms of means and ends rather than as a result of valuation. Overall, the concept tends to reduce value to pleasure and desire, with no reference to the properties of an object (Seni, 2007).

The relationship between value and behaviour is addressed in psychology from different perspectives: One perspective is on the rationalization of action, i.e. in decision making in the context of "What am I to do?"; advising in the context of "What are you to do?"; and justification and criteria of action in the context of "What are you to do?". Another perspective is on the relationship between people's values, goals, and visions in that having a certain value is seen as different from having a certain goal or preference. The goals that one adopts or the preferences that one has are seen as indications for one's values (Rescher, 1982). Values are, "things of the mind that have to do with the vision people have of a good life for themselves and their fellows" (Rescher, 1982, p.4). Schwartz (2006) argues that values are abstract goals and the abstract nature of values distinguishes them from concepts such as norms and attitudes. Finally, there is the perspective of the relationship to motivation, criteria, and situation. "To have a value is to be able to give reasons for motivating goal-oriented behaviour in terms of benefits and costs, bringing to bear explicitly a conception of what is in a man's interests and what goes against his interests: to operate within a reason-giving context with reference to a vision of a good life" (Rescher, 1981, p.10). People's values function as constraints and as stimuli (Rescher, 1981). According to Schwartz (2006), values transcend specific actions and situations.

Value theory relates value to benefit and in this context suggests a categorisation of values as self- or other-oriented. "As a concept of the beneficial, a value is invariably bound up to a benefit; namely, that which is seen to ensure upon the realization of this value" (Rescher, 1982, p.16). In other words, "A person subscribes to a value because he sees its realization as beneficial to certain people" (Rescher, 1982, p.18). One approach to classify values "takes its departure from this point and classifies values according to the 'orientation' of the value, that is, according to the relationship obtained between the person who holds the value, the subscriber, on the one hand, and on the other, the presumptive beneficiaries who benefit from the realization of this value. This approach leads to a classification in terms of self-oriented values, e.g. success and comfort, and other-oriented values, e.g. family pride, patriotism, social justice" (Rescher, 1982, p.18).

Value literature provides different perspectives on the relationship between value and emotion: emotion or desire as the basis for value; and emotion in the context of a value experience. Bretano (1874, 1952, 1959, 1968) developed the groundwork of a theory of value, looking at emotions as the basis of valuation, specifically in the contrast between the complexities of favourable emotions (e.g. loving, liking, being pleased) on the one hand, and negative emotions (e.g. hating, disliking, being displeased) on the other (Rescher, 1982). Denying that the basis of value is emotion, Ehrenfels (1887, 1896, 1907) saw the foundations of value in desire. Ehrenfels was followed in this regard by Perry (1914, 1931, 1954), who argued that people value something because they desire it. Desire from this perspective is basic to value, since pleasure is seen as subsequent to desire (Rescher, 1982).

Overall, value theories in psychology focus on how humans value with respect to their needs and how their behaviour is directed as meeting needs. A basic idea is that behaviour is triggered by motivations that are in turn determined by needs, whereby needs and wants are organised by priority. Value and behaviour are discussed in psychology in the context of people's benefit, emotions, goals, and situations.

3.4. Sociology

Value theories in sociology have a focus on how collective values (e.g. tolerance, justice, freedom) emerge and develop, how they are coded in culture and in social norms, and how they are embodied in society (Seni, 2007). Theories in this domain are also concerned with human values held in specific communities, and how those values change under particular conditions. Behind this is the basic idea that different groups of people hold or prioritise different kinds of values influencing social behaviour.

One of the basic value concepts in sociology is value as a means for evaluation. This concept provides support on explanations on human behaviour. As standards of evaluation, values are seen as explanatory variables of individual and social behaviour (Feather, 1975; Neumann, 1986; Rokeach, 1973). A related concept has value as a conception of the desirable and influencing selective behaviour (Kluckhohn, 1951). In this concept, the desirable is what ought to be desired. The concept restricts value to descriptive value inquiry by the application of normative criteria and a preference for one over the other (Pauls, 1990). This is in contrast to Perry (1954), who argued that a broad and comprehensive definition of values includes anything of interest to human subjects, all kinds of desires, duties, interests, needs, wants, and other modalities of selective behaviour.

Value theories in sociology consider a relationship of needs to value. Needs are seen as prerequisites for the development of values. Schwartz and Bilsky (1987), for example, identify value domains from an analysis of the biological and social needs of the human organism. The term *value domain* refers to a group of values that is associated with a particular class of needs. The "distinct" value domain, for example, includes enjoyment, security, social power, and self-direction. In this concept, needs give rise to values and values are related to attitudes, or on a social level to norms. Overall, basic values are derived from three universal requirements of the human condition: needs of individuals as biological organisms; requisites of coordinated social interaction; and survival and welfare needs of groups. Ten basic values are intended to include all the core values recognised in cultures around the world: self-direction, stimulation, hedonism, achievement, power, security, conformity, tradition, benevolence, and universalism (Schwartz, 2006). Schwartz (2006) claims exhaustiveness of the ten basic value categories and argues that it is possible to classify each of the items found in lists of specific values from different cultures into one of these ten motivational types of values. Overall, the work provides a list of human values categories and can be seen as an accepted understanding of human values classification in literature.

Values are seen as being related to attitude and belief. Damasio (2003) argues that an animal, from which humans are one species of, manifests instincts of value and disvalue towards things. In other words, animals have positive and negative attitudes. These attitudes express acts of valuation, wanting, or desire. Wanting and desire require a level of self-consciousness and cognitive development, and a degree of psychological development that relies on the rational and emotional development of animals. According to Seni (2007), this underlines the idea that organisms value what allows them to live, in which case the roots of values would be biological, not social. According to Rokeach (1973), value is seen as the enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence. This interpretation is close to that of Schwartz (2006), who argues that values are beliefs, but tied inextricably to emotion. Values as beliefs are seen as having cognitive, affective, and behavioural components. A value can be seen as cognition, in that it refers to a kind of perception or knowledge about a "correct" end state to strive for, or a correct way of behaving. A value is an affective component, in that people can feel emotional about it, and also a behavioural component, in that it is a variable that leads to action when activated (Rokeach, 1973).

Values held by an individual or group, including the relationships between these values, constitute a value system. A value system is seen as an organised set of preferential standards that are used to: make selections of objects and actions; resolve conflicts; and cope with needs or claims for social and psychological defences of choices made or proposed (Williams, 1979). Values in a value system may conflict with each other. This is considered by Rokeach's notion of value systems (1973, p.5), arguing that "A value system is an enduring organization of beliefs concerning preferable modes of conduct or end-states of existence along a continuum of relative importance". On a group level, terms such as social, cultural, or organisational value systems are used to denote the ordering of the values held by a particular group of people (Pauls, 1990). On an individual level, "Values are ordered by importance relative to one another. People's values form an ordered system of value priorities that characterise them as individuals. This hierarchical characteristic of values also distinguishes them from norms and attributes" (Schwartz, 2006, p.1).

Values are not seen as something that humans are born with. They are learned and developed in interaction with other humans and through the experience of countless decision situations. Values are a function of a person's history, and in particular of early childhood and adolescence (Kohlberg, 1983). According to Pauls (1990), values are taught and learned as absolutes and with little reference to competing values. This is seen to be related to the comparative stability of value systems. Rokeach (1973) argues that we are not taught that it is desirable to be just a little bit honest or to strive for just a little bit of peace. Nor are we taught that such modes or end-states are sometimes desirable and sometimes not. Pauls (1990) argues that as children mature, they are exposed to increasingly complex decision situations, i.e. they encounter situations where several competing values apply that have to be traded off against each other. Consequently, a set of values gradually changes into a complex system of hierarchically ordered values (Pauls, 1990). These value systems change through the rest of one's life and this change is a slow and gradual one (Allport, 1961, Kohlberg, 1983). However, a reordering of the value system associated with a substantial change in the circumstances of one's life may occasionally occur (Pauls, 1990).

Overall, value theories in sociology have a focus on how collective values emerge and develop, how they relate to cultural and social norms, and how they are embodied in society (Seni, 2007). Two basic concepts applied in sociology are the concepts of value as a criterion and as a conception of the desirable. The concept of value as a criterion considers value as a kind of standard for evaluation. Value as a conception of the desirable takes the assumption that the desirable is what ought to be desired, i.e. value tends to be restricted towards a preference of one over the other. Value theories in sociology make a distinction of holding a value, making evaluations, ascribing a value to someone else, and ascribing an evaluation to someone else. Value theories in sociology consider a relationship of value to needs, beliefs, and value systems, and consider value to be learned and developed in interaction with other humans.

3.5. Value interpretations

This chapter provides an investigation of value from a value interpretations perspective as a means to gain further insights on the value phenomenon.

Value is considered in individual disciplines from many different perspectives. The theories of value in design (Section 2.3-0) and value theories in axiology, economics, psychology, and sociology (Section 3.1-3.4) have made significant contributions to the value discussion.

The review of value interpretations across disciplines[7] reveals interpretations of value as the value of an entity, as an activity, and as an ethic/moral principle.

- Value of an entity (e.g. Lamont, 1956; Miles, 1972; Najder, 1975; Allingham, 1982; Porter, 1985; Zeithalm, 1988; Chase, 1990; Fowler, 1990; Anderson, Jain, and Chintagunta, 1993; Hamilton, 1996; Grönross, 1997; Best, 1999; Larreche, 2000; Daniels, 2000; Doyle, 2000; Ashworth and James, 2001; Andriessen, 2003) is based on the underlying assumption that value is seen as a kind of benefit derived from an entity. The term *entity* in the context of this research work is used as a synonym for physical and non-physical objects. The entity may be seen as a value resource. Value in this context is typically defined in terms of availability, exchange worth, cost, price, usefulness, and utility.

- Value as an activity (Zeithalm, 1988; Holbrook, 1994; Hight and Cooper, 2006) refers to the "act of valuing". Value in this context is typically seen as related to preferential judgement (Holbrook, 1994) and decision making processes (Hight and Cooper, 2006).

- Value as an ethic/moral principle (e.g. Bailey, 1967; Rokeach, 1973; Feather, 1975, Rescher, 1982; Holbrook, 1994; Harrison, 1998; Hight and Cooper, 2006; Schwartz, 2006) refers to the principles of right and wrong human behaviour and the "goodness" or "badness" of human character. The principles are typically discussed in terms of "human values", such as helpfulness, honesty, and loyalty as outlined by Schwartz and Boehnke (2004), and characterised by Griseri (1998) as underpinning the activities of business organisations.

Value theories provide interpretations of value as the value of an entity, as an activity, and as human values. A more fundamental formalism of value may provide

[7] An overview of value interpretations considered is provided in Appendix C.

a means to identify the key elements and mechanisms involved to support the development of explanations on the interrelationships between value as an entity, activity, and as human values.

Fundamentally, there are two different approaches in value interpretations: Authors such as (Allingham, 1982; Best, 1999) describe value in the context of properties, while authors such as (Holbrook, 1994; Hamilton, 1996; Harrison, 1998) describe value in the context of cognitive processes. Value as an inherent property of an entity makes the assumption that value exists within a product or activity. Inherent to value as an apprehended property of an entity is the assumption that value is apprehended in the mind in context with an entity. A more fundamental formalism of value may provide a means to identify the key elements and mechanisms involved to support the development of explanations on the interrelationship between the interpretation of value as an inherent and apprehended property.

Inherent to value research are value-related phenomena in terms of benefit (Anderson, Jain, and Chintagunta, 1993; CABE, 2001; Thomson et al., 2003), exchange (Allingham, 1982; Anderson, Jain, and Chintagunta, 1993; Best and De Valence, 1999; Ashworth and Hogg, 2000; CABE, 2001; SAVE International, 2007), need (British Standards Institution, 2000), and perception (Zeithalm, 1988; Anderson, Jain, and Chintagunta, 1993; Daniels, 2000). However, research on the relationship of value in design to benefit, exchange, and perception is without an underlying formalism of value. Such formalism may provide a means to identify the key elements and mechanisms involved to support the development of explanations on the phenomena’s inter-relationships.

Authors defining value in the sense of properties primarily describe value in terms of attractiveness, availability, cost, price, scarcity, utility, worth, and quality. The properties of cost and price can be relatively easily understood, but the concepts of attractiveness, availability, scarcity, utility, worth, and quality are somewhat similar to value per se in their varied interpretations. This reveals a lack of clarity inherent in value interpretations when using ill-defined terminology to describe the phenomenon.

Overall, the different value interpretations describe aspects of the same phenomenon. A more fundamental formalism of value may provide a means to support more comprehensive explanations on value and consequently on value in design.

3.6. Value types

As outlined in the context of the literature review on value theories (Section 3.1-3.4) and value interpretations (Section 3.5), value has been considered in individual disciplines from many different perspectives. Consequently, different interpretations of value exist. This section provides an investigation on the value phenomenon from a value type perspective to rationalise the value discussion and to gain further insights on the value phenomenon.

The review is not intended to represent an exhaustive coverage of all value types, but rather to present a sample to indicate the major value types involved in value research, i.e. brand, customer, economic, exchange, expectancy, human, product, process, relationship, and shareholder values. The value types are discussed in an alphabetical order to give structure to the discussion.
Brand value is the focus of value discussions in marketing. A brand, as defined by the American Marketing Association[8], is a design, name, symbol, or term that distinguishes a product or service from competitive offerings. Aaker (1991) argues that brands may be used to generate economic value. The author states that the marketing battle will be a battle of brands as the company's most "valuable" asset. Jones (1994) provides another perspective on the value of brands in the context of distributors and customers arguing that a brand enables distributors to sell their product over distances, and give added value to the customer when the customer

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[8] The American Marketing Association is one of the largest professional associations for marketers and a leading source of information in the marketing profession (www.marketingpower.com).

cannot personally and/or directly verify the product quality. Thus, brand value is characterised in terms of a benefit occurring from the brand provided to, or perceived by, a stakeholder.

Customer value is considered in value literature across disciplines. In architecture, Sparks et al. (2001) argue that good design brings economic, social, and environmental benefits to stakeholders, referring to people participating in architectural design, including the customer. In operations management, Andriessen (2003) points to the importance for companies to make use of knowledge to generate customer value. The author recommends not focusing on the creation of knowledge per se, but rather on the use of knowledge to create value. Berry and Yadav (1996) propose strategies to make services more valuable to customers, focusing on benefits, relationships, and effective operation pricing. Literature in marketing ranges from customer value assessments (Anderson, Jain, and Chintagunta, 1993), to the link between customer value and competitive advantage (Woodruff, 1996). Overall, customer value is characterised by a benefit provided to the customer who may be seen as a specific stakeholder. Knowledge and strategies may be seen as resources to generate customer value. Customer value causing a competitive advantage may be interpreted as a contribution to economic value and, if the customer is interpreted in terms of a person, it may be seen as contributing to human values as well.

Economic value is the focus of business, strategic, and operations management literature. Amit and Zott (2001) conclude that the main question of the value chain is about what activities a firm should perform and how and what configuration of the activities would enable it to add value to the product and compete in industry. Campbell and Goold (1988), on the basis of research carried out in British industry, conclude that the creation of value is influenced by the management style of an organisation. Hamel and Prahalad (1989) argue that value emerges from the inventiveness and versatility of organisations to build competitive advantage. Larreche (2000) suggests that the two main drivers of value creation are: the continuous development of fundamental capabilities; and the creation of new business models, i.e. innovation. Ramirez (1999) proposes the continuous reconfiguration of business opportunities as a critical element to enable firms to provide value over time, i.e. change as a value resource. Teece (1998) looks at knowledge as a dimension to deliver value to an enterprise. It can be concluded that economic value is characterised by the benefit provided to an enterprise. Management style and the management of organisations, fundamental capabilities, business models, etc, are seen as resources to generate economic value.

Exchange value is the focus of business management. Allingham (1982) concludes that value is the amount for which a thing can be exchanged. Marx (1872) points out that a commodity's exchange value can be expressed simply as a quantity of money. When commodities are in a position to exchange, the exchange value manifests itself into something totally independent of its use value. Sparks et al. (2001) argue that good design adds economic value in the form of higher asset exchange value. From this, it may be concluded that exchange value is characterised by an exchange situation, an exchange item (i.e. a thing or commodity to be exchanged), and an exchange rate in terms of, e.g. a currency. In literature, exchange value is mainly interpreted as contributing to economic value.

Expectancy value is the focus of marketing and psychology. Feather (1982), in the context of expectation and behaviour, points out that a person's behaviour bears a relation to the expectations the person holds in the subjective value of consequences that may occur following action. Levitt (1981), for example, argues that from a buyer's perspective, the product can be seen as a cluster of value expectations of which its intangible parts are as integral as its tangible parts. In general terms, expectancy value is characterised by an expected benefit someone holds in mind in terms of consequences that may occur following action.

Human values are discussed in the context of psychology and sociology. Feather (1975) refers to value systems as the way in which humans organise values into hierarchies of importance and argues that values are influenced by the person engaged in valuing properties that relate to the person's background experience. Griseri (1998) argues that human values are complex and in practice, it may be difficult to identify what values someone really holds. Harrison (1998), in his research on managerial decision making, points out that the human values of decision makers and the values of the organisation influence the entire process of decision making. Holden (1999) identifies categories of values as aesthetic, economic, political, religious, social, and theoretical, arguing that aesthetic value has a focus on fulfilment and harmony, economic value on usefulness and worth, political value on power, religious value on unity, social value on love of people, and theoretical value on truth. Thus, human values may be seen as referring to a person's individual system of values applied in decision making processes.

Product value is the focus of marketing and operations management. Burns and Woodruff (1992) refer to product value in the sense of a benefit to a user in a use situation of a product. Fowler (1990) argues that a product must fulfil a user's needs or wants in order to have value. Hamilton (1996) states the reduction of unnecessary costs has the largest effect in enhancing product value. From this it can be concluded that product value is characterised by a benefit to a stakeholder and based on a product. Resources are required to generate product value, satisfy stakeholder needs, and reduce cost in order to contribute to economic value.

Process value is the focus of operations management. Amit and Zott (2001) look at process value in terms of value chain analysis and it is understood as the decomposition of a company's processes into activities along with the study of economic implications of these activities. They conclude that the main question of the value chain is about what activities a firm should perform and how and what configurations of the activities would enable it to add value to the product and to compete in industry. Ashworth and Hogg (2000) suggest strategies and techniques (e.g. cost planning, life cycle costing) that can be applied during the design and construction processes to add value and promote the best interest of the client. Gage (1969) focuses on value as the maximisation of process efficiency through the identification and elimination of waste at the business process level. From this it may be concluded that process value is characterised by a benefit occurring from the management of activities.

Relationship value focuses on business management and marketing. Norman and Ramirez (1993) introduced the value constellation as a criticism of Porter's value chain. The authors argue that the focus of strategic analysis should not be the company or industry, but a value creation system understood to be a set of economic factors working together to co-produce value. The authors conclude that mutual value is developed as a consequence of a reciprocal and interactive relationship between organisations and stakeholders. This view is supported by Crosby (1990) and Gummerson (1999), who state that value comes as a result of interactions and relationships between customers, suppliers, and different stakeholders. Wilson and Jantrania (1993) identify three dimensions of relationship value: behavioural, economic, and strategic. Behavioural dimensions are understood as culture, social bonding, and trust; economic dimensions as concurrent engineering, cost reduction, investment quality, and value engineering; and strategic dimensions as business goals, core competencies, strategic fit, and time to market. Thus, it may be concluded that relationship value is characterised by a benefit occurring from cooperation between stakeholders.

Shareholder value is discussed in the field of business management and marketing. Ashworth and James (2001) recommend, in the context of value-based management, that companies need to consider a broader perspective to deliver superior shareholder value: managing the investor community; developing strategies to create optimal value; and delivering value through integrated performance management. Doyle (2000) concludes that strategies maximising shareholder value focus on growth opportunities and building competitive advantage. This is in contrast to maximising profitability in terms of cutting cost and shedding assets to produce quick improvements in earning. Thus, shareholder value is characterised by a benefit for shareholders. There are numerous resources to generate shareholder value, such as strategy development and business management.

A synthesis of the identified value types reveals that value types may be classified in terms of their source, target, and benefit, as illustrated in Table 3-2.

Value					
Type	Source	Target	Benefit	Context	Reference
Brand	brand	customer	supports decision making if customer cannot personally and directly verify the quality of a product	Marketing	Jones, 1994
		distributor	enables to sell products over a long distance		
		investor	brand dominance		Aaker, 1991
Customer	design	stakeholder	economic, social, environmental benefit	Architecture	Sparks et al, 2001
	knowledge	customer	--	Knowledge Management	Andriessen, 2003
	service		relationship, pricing	Operations Management	Berry and Yadav, 1996
Economic	capability development	enterprise	--	Strategy Management	Larreche, 2000
	business model creation				
	business opportunity reconfiguration				Ramirez, 1999
	management style				Campbell and Goold, 1988
	product		competitive advantage		Amit and Zott, 2001
	organisations inventiveness		--		Hamel and Prahalad, 1989
Exchange	design	--	economic value in the form of higher asset exchange value	Architecture	Sparks et al, 2001
	exchange		--	Value Management	Allingham, 1982
	exchange of commodity		quantity of money	Economy	Marx, 1872
Expected	expectation from promise	Buyer	--	Marketing	Levitt, 1981
	expectation from consequence that may occur following action	Person		Psychology	Feather, 1982

Value					
Type	Source	Target	Benefit	Context	Reference
Human	aesthetic	Person	fulfilment and harmony	Marketing	Holden, 1999
	economy		usefulness and worth		
	politics		power		
	religion		unity		
	social environment		love		
	theory		truth		
	properties that relate, especially to a person's background experience		--	Education	Feather, 1975
	social environment		love		
Product	product	user	benefit to the user in a use situation	Strategic Management	Burns and Woodruff, 1992
		--	reduction of unnecessary costs		Hamilton, 1996
		user	fulfilment of need and want	Operations Management	Fowler, 1990
Process	economic implications of activities	--	to add value to a product and compete in industry	Operations Management	Amit and Zott, 2001
	maximisation of process efficiency		identification and elimination of waste		Gage, 1969
	strategies and techniques	client	product value increase		Ashworth and Hogg, 2000
Relationship	behaviour	--	social bonding, trust, culture	Marketing	Wilson and Jantrania, 1993
	economy		investment quality, concurrent engineering, cost reduction		
	strategy		core competencies, strategic fit, time to market, business goals		
	interactions and relationship between		--		Crosby, 1990

Value					
Type	Source	Target	Benefit	Context	Reference
	customer, suppliers and different stakeholders				
	interactive relationship between organisations and stakeholders	organisations and stakeholders		Strategic Management	Norman and Ramirez, 1993
	set of economic factors working together	--			
Shareholder	managing the investor community	shareholder	--	Operations Management	Ashworth and Hogg, 2000
	developing strategies				
	integrated performance management				
	strategies		focus on growth opportunities and competitive advantage	Marketing	Doyle, 2000

Table 3-2: Value types across disciplines

The term *value source* as utilised in Table 3-2 suggests that entities serve to generate value. Value sources range from brand (Aaker, 1991; Jones, 1994), design (Sparks et al., 2001), knowledge (Teece, 1998; Andriessen, 2003), and product (Fowler, 1990; Burns and Woodruff, 1992; Hamilton, 1996), to integrating performance management (Doyle, 2000), and managing the investor community (Ashworth and Hogg, 2000). Thus, a value source may refer to physical or non-physical entities.

In value research, numerous value targets are involved referring to someone or something to whom/which value is provided or perceived. A buyer (Levitt, 1981), customer (Jones, 1994; Berry and Yadav, 1996; Sparks et al., 2001; Andriessen, 2003), distributor (Jones, 1994), or enterprise (Campbell and Goold, 1988; Hamel and Prahalad, 1989; Teece, 1998; Ramirez, 1999; Amit and Zott, 2001; Larreche,

2000) are all examples of value targets. However, considering the nature of value targets, the majority of them represent human beings in specific situations. An exception may be seen in the value target enterprise, referring to a business consisting of assets, organisations, and people, although it can be argued that value provided to assets and organisations is provided to people in the end.

Inherent to value research is expressing value in terms of benefits. Numerous value types refer to economic benefits in terms of, e.g. brand dominance, competitive advantage, and quantity of money, while others refer to ethic/moral benefits in terms of, e.g. fulfilment, power, and unity. Economic and ethic/moral benefits represent major benefits as discussed in value research. To express value in terms of benefits suggests a "positive nature" of value in the sense of representing an advantage rather than a disadvantage or handicap; and the discussion of value in the context of economic and ethic/moral benefits may be seen as an indicator that authors discuss the same phenomenon while applying different terminology.

Analysing value types in terms of benefits provided reveals that numerous benefits, e.g. brand dominance, reduction of unnecessary cost, and investment quality, may be interpreted as a contribution to economic value, while, e.g. fulfilment, power, and love may represent a contribution to human values. From this perspective, brand, customer, exchange, product, process, relationship, and shareholder values contribute to economic value, while aesthetic, political, religious, social, and theoretical values contribute to human values. This suggests economic and human values as central value types, i.e. the major areas of value contribution in current value research.

It should be recognised that value types exist that do not fit in the taxonomy of value. Value in use, for example (Marx, 1872; Burns and Woodruff, 1992), may be categorised as a sub-type of product value in that this value type refers to product value in a specific situation. Perceived value (Lappierre, 2000; Sanchez-Ferandez and Iniesta-Bonillo, 2008) may be seen as a value type pointing to the aspect of perception in the context of customer value. Thus, analysing value types in terms of benefits does not capture all value types involved in value research, but it provides a means to give structure to the value discussion.

In general terms, the blank areas in the analysis of value types may be interpreted as weaknesses in value research: in the context of economic value, authors tend not to express their understanding of occurring benefits (Campbell, 1988; Teece, 1998; Ramirez, 1999; Larreche, 2000). In describing exchange (Marx, 1872; Allingham, 1982; Sparks et al, 2001) and relationship values (Crosby, 1990; Norman and Ramirez, 1993; Gummerson, 1999), authors tend not to define value targets.

Overall, major value types in value literature were identified in this section in terms of brand, customer, economic, exchange, expectancy, human, product, process, relationship, and shareholder values. A more fundamental formalism of value may provide a means to identify the key elements and mechanisms involved in different value types and support the development of explanations on their relationship.

3.7. Summary and Conclusions

Value theories were investigated in Chapters 2 and 3 to establish the current state of knowledge on value in the context of design. Throughout this investigation, knowledge gaps in value theories were identified and can be summarised as follows:

- Based on different interpretations of value in design, three key questions related to value in design can be identified: when does value appear; what is an appropriate metric for value in design; and how can value be added in design? A more fundamental formalism of value may provide a means to identify the key elements and processes involved to support the development of explanations to these key questions.

- Product value management in design has a focus on the value analysis phase, i.e. on the analysis of value in terms of objectives, functions, cost, benefits, user perception, quality, needs, wants, and worth. Though some of the VA approaches the relationships between specific elements (e.g. FAST considers cost, function, needs and wants) they only cover some of the elements involved in product value management and therefore provide a limited view of product value management in design. Product value management lacks a more fundamental formalism of value as a means to identify the key elements and mechanisms involved.

- Design process value management considers specific techniques to increase the design process value in terms of needs, objectives, and success criteria. Though some of the design process value approaches consider the relationship between specific elements (e.g. design techniques to support the identification of business needs), they only consider part of the elements involved and therefore provide a limited view of process value management. Design process value management lacks a more fundamental formalism of value as a means to identify the underlying key elements and mechanisms involved.

- Design management literature points to the need to manage the economic value of design. However, the terminology applied in literature on economic value in design is ill-defined (e.g. strategic value, economic potential of design). Current literature on the management of economic value in design is without an underlying formalism identifying the key elements and mechanisms involved as a means to investigate value contributions rising from design as a product and/or process, from management of design, and/or from value management in design.

- Literature provides different perspectives of human values in design: design that accounts for human values; human values in the context of decision making processes and ethics; and human values in the context of value alignment in organisations. However, these approaches are without an underlying formalism of value as a means to identify the key elements and mechanisms involved.

- Human values, experience, intuition, culture, and personality are relevant to value in design in the context of decision-making processes. Literature points to activities, beliefs, criteria, goals, and situations as further elements involved. However, literature on human values in design is without a more fundamental formalism of value as a means to identify the key elements and mechanisms involved.

- Literature provides research with a focus on human values or economic value. However, in design, product, process, economic, and human values are involved. Hence, identifying the key elements and mechanisms involved in value in design requires a more fundamental formalism of value as a means to support research across different value types.

- Literature highlights a need for the alignment of personal, organisational, and societal values as a means to increase the individual's motivation and overall business performance. However, current theory on value alignment is without an underlying formalism of value as a means to identify the key elements and mechanisms involved.

- Value theory provides interpretations of value as the value of an entity, as an activity, and as human values. A more fundamental formalism of value may provide a means to identify the key elements and mechanisms involved to support the development of explanations on the interrelationships between value as an entity, activity, and as human values.

- Value theory approaches value in terms of an inherent or apprehended property. A more fundamental formalism of value may provide a means to identify the key elements and mechanisms involved to support the development of explanations on the interrelationship between the interpretation of value as an inherent and apprehended property.

- Inherent to value theory are value-related phenomena such as added value, benefit, exchange, need, and perception. However, research on the relationship of value in design to added value, benefit, exchange, need and perception is without an underlying formalism of value as a means to identify the key elements and mechanisms involved to support the development of explanations on the phenomena's inter-relationships.

- Major value types in value literature were identified in terms of: brand, customer, economic, exchange, expectancy, human, product, process, relationship, and shareholder values. A more fundamental formalism of value may provide a means to identify the key elements and mechanisms involved in different value types and support the development of explanations on their relationships.

Overall, current literature provides different interpretations and highlights different aspects of the value phenomenon. The knowledge gaps support the need for a more fundamental formalism of value in the context of design. In general terms, there is a "lack of consensus on a satisfactory conceptual framework from which research could be launched" and "those working in this area have been handicapped by the lack of any consistent body of theory on the nature of the human being as a valuing organism; and even by an obvious lack of agreement as to the meaning of the concept of value itself" (Hutcheon, 1972, p.176). From a theoretical perspective, "the fundamental questions of how to conceptualise value still merit further investigation" (Ulaga, 2001, p.318). Thus, there is a need for a more fundamental formalism of value in that such formalism can provide a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design.

To develop such formalism can be seen as the key research problem of this thesis and requires answers to key research questions, which can be derived from the knowledge gaps and the need for formalism:

- What are the generic characteristics of value?
- What are the key elements and mechanisms involved in value determination?
- How is value related to phenomena such as added value, benefit, exchange, need, and perception?
- How can value be formalised in the context of design?

From a declarative knowledge perspective, one of the central activities in formalising the value phenomenon is to make an examination on the generic characteristics of value, e.g. to support explanations on the relationship between the value of an entity, value as an activity, and human values. The knowledge gaps identified in the context of value in design, e.g. when value appears and how to add value in design, highlight the procedural knowledge perspective and the need to identify the key elements and mechanisms involved in the value determination process. Inherent to value literature are value-related phenomena such as added value, benefit, exchange, need, and perception. An investigation in value-related phenomena provides a means to increase clarity on how these phenomena relate to value as well as in the terminology to be applied in a value formalism context.

Based on the need to formalise value, the question arises of how to formalise value in the context of design. On the one hand, the multiple observations, assumptions, correlations, propositions, laws, classifications, interpretations, concepts, models, and suppositions in current value theory provide a basis for developing a more fundamental formalism of value in the context of design, describing how value "works" by showing its elements and their relationship to one another. On the other hand, they may be seen as indicators that a theory may provide a means for such formalism in that a theory can be seen as a vehicle to support explanations about the general properties, characteristics, and underlying processes and mechanisms of all instances of a phenomenon (Smithers, 1999). In this context it should be noted that a number of theories may co-exist, each supporting specific explanations.

Theory characteristics are investigated in the following chapter as a means to identify requirements of a theory of value in the context of design.

4. **The nature of design and value theory**

In Section 3.7, it was concluded that there is a need for a more fundamental formalism of value in the context of design and that a theory may provide a means for such formalism. This chapter brings design (Section 4.1) and value theory characteristics (Section 4.2) together (Section 4.3). These characteristics can be seen as restrictions on what can be recognised as a theory of value in the context of design, i.e. can be interpreted as requirements for such a theory.

4.1. Design theory characteristics

Research on design theory focuses on theory building, components, differentiation with models, evaluation, goals/purposes, integration, modification, need in the context of research, affiliation to design versus natural science, and scope. The theoretical descriptions of these areas are interpreted, aiming to identify design theory characteristics (Table 4-1).

Theory Focus	Description	Interpretation
Building	(i) An axiom is a sentence or proposition that is not proven or demonstrated. It is considered as self-evident or as an initial consensus for theory building or acceptance. An axiom is taken for granted as true, and serves as a starting point for deducing and inferring other (theory dependent) truth (Columbia Electronic Encyclopaedia, 2009). (ii) Rossi and Sein (2003) propose five steps in design research: identify need, build, evaluate, learn, and theorise. (iii) Smithers (1999), in the context of science, argues that developing and testing theories involves the development and use of terms and concepts that can be operationalised to make them effective in forming explanations. (iv) Nunamaker, Chen, and Purdin (1991) argue that theory building includes: development of new ideas and concepts; construction of conceptual frameworks; new methods or models; and theories.	Axioms provide a basis for theory building. Axioms provide a means for initial necessary consensus or acceptance because axioms are considered as self-evident and therefore taken as true (i). Theory building is seen as an integrated part of design research, including the development of ideas, concepts, conceptual frameworks, methods, models, terms, and other theories (ii/iv). Terms and concepts are required to support explanation forming (iii).

Theory Focus	Description	Interpretation
Components	(i) Lynne (2002) argues that a design theory includes concepts of a particular class of user requirements, a type of system solution to the problem, and effective development practices for achieving the development and implementation of a particular solution to a particular problem.	A theory includes user requirements and a solution to the problem (i). However, this is different from the activity of developing a solution in terms of analysing, modelling or structuring (ii), which is seen as a part of theory building.
	(ii) Friedmann (1999) argues that the word *theory* has a clear meaning in that theory involves modelling, structure, and analysis. However, not all theory involves science or even qualitative data.	
Differentiation	(i) Vaishaniv and Kuecher (2004) argue that models differ from natural science theories primarily in intent: natural science has a focus on truth, whereas design research focuses more on situated utility. Thus a model is presented in terms of what it does and a theory is described in terms of construct relationships. However, a theory can be extrapolated to what can be done with the implicit knowledge and a set of entities. A proposed relationship can always be expressed as a theoretical statement of how or why the output occurs.	A theory: can be described in terms of construct relationships (i); is made up of general statements; and does not depend upon particular instances of the phenomenon they are supposed to be a theory about (ii).
	(ii) Smithers (1999) argues that theories are general statements that make no reference to and do not depend upon particular instances of the phenomenon they are supposed to be theories about. Models on the other hand, do refer to particular instances or classes of instances of a phenomenon; they must in order to be models since models must be models of something.	A model is presented in terms of what it does (i) and must refer to an instance or instance class of a phenomenon (ii).
Evaluation	Rossi and Sein (2003) argue that in theory evaluation, internal and external criteria are proposed. Among the internal criteria is a "match" between the artefact and the abstract idea, i.e. how well the artefact embodies the abstract idea that is being researched. Among the external criteria is an advancement of design theory, i.e. the abstracted idea is generalisable to other contexts or at least advances our understanding of other design context.	A theory can be evaluated in terms of how well the artefact embodies the abstract idea; on the generalisability to other concepts; and on the contribution of knowledge that an idea delivers to the design discipline.
Goal/Purpose	Smithers (1999) looks at theories in science as vehicles for delivering general understanding and explanation. They are seen as abstract statements about the general properties, characteristics, and underlying processes and mechanisms of all instances of a real phenomenon.	A theory is a vehicle for delivering a general understanding and explanation about the general properties, characteristics, and underlying processes and mechanisms of all instances of a real phenomenon.
	Smithers (1999) argues that a theory must be able to support the construction of effective explanations of particular instances or classes of the phenomenon covered.	A theory supports the construction of explanations of particular instances or classes of the phenomenon covered.

Theory Focus	Description	Interpretation
	Reich (1995) highlights that no theory (in design) can capture all of design. Each theory provides one perspective that may improve design understanding and practice.	A theory in design science provides a perspective of design; it cannot capture all of design.
	According to Reich (1995), design theory has two interrelated goals: the first is to improve the activity of designers when standard and pragmatic design methods are not sufficient; the second is to better understand the specific nature of design when compared to classic problem solving or decision theory.	A theory in design science improves design activities and/or provides insights on the nature of design.
Integration	Hevner et al. (2004) argue that design artefact creation relies on existing core theories that are applied, tested, modified, and extended through the experience, creativity, intuition, and problem solving capabilities of research.	Theory building can integrate other theories.
Modification	Nunameker, Chen, and Purdin (1991) highlight the point that difficulties encountered in system development activities may lead to modification of the concepts or theories from which information systems are derived.	Theory evolves.
Need	Smithers (1999) argues that the history of science shows that theoretical understanding is not a necessary prerequisite for the development and effective application of technology. Good empirical understanding is sufficient, but theoretical understanding can and does result in better, more effective, more efficient, and more acceptable applications and products. Theory also makes new ideas, techniques, and applications possible since we cannot discover everything from empirical practice and investigation alone.	A theory is not a necessary prerequisite for research. Rather, a theory aims towards improving the design artefact, process, practice, and/or research performance.
Scope	Walls, Widmeyer, and Sawy (1992) highlight the point that, e.g. Information System Design Theories need to address both the design product and the design process used to derive the product.	Theory has scope.

Table 4-1: Design theory characteristics

From the interpretations above, a theory in design should:

- be built upon axioms and/or generalised characteristics of the phenomenon;
- describe the phenomenon in terms of constructs, construct relationships, mechanisms, and variables involved;
- provide a vehicle for delivering a general understanding and supporting the construction of explanations on general characteristics and underlying processes of the phenomenon, i.e. novel insights;

- support explanations on instances on the phenomenon;
- provide a perspective of the phenomenon; it cannot capture all of the phenomenon and consequently requires a defined scope;
- provide a means to improve design artefact, process, practice, and/or research performance
- integrate or relate to other theories; and
- be evolutionary, in that difficulty in applying the theory may lead to modification.

These characteristics put restrictions on what can be recognised as a theory in design, i.e. the characteristics can be interpreted as requirements for a design theory.

4.2. Value theory characteristics

Theories of value can be classified in axiology referring to general or philosophical theories of value as well as scientific theories including economics, psychology, and sociology (Chapter 3). Descriptions of theory in these areas are interpreted, aiming to identify value theory characteristics (Table 4-2).

Discipline	Description	Interpretation
Axiology	"How should we do axiology? There is no obviously suitable methodology for this discipline, but a way to start in all matters philosophical is with a preliminary conceptual analysis. How should value be analysed? Moore (1993) stated that value, or 'the good', cannot be analysed, being a simple notion." (Bengtsson, 2004, p.3)	A theory of value should support explanations on value analysis.
	"What can we require from a theory of value? Reasonably, we can require from it that it makes sense of exactly those things that we already know about value." (Bengtsson, 2004, p. 3)	A theory of value should support explanations on the relationship to other value theories and/or integrate theories.
	In the context of an introduction to value theory, Rescher (1982) outlines philosophical and scientific value issues and approaches.	A theory of value should support consistent explanations on the philosophical and scientific value discussion.
	The philosophical discussion of value has a focus on conceptual issues (e.g. how to analyse value) and substantive problems (e.g. what values things actually have) (Rabinowicz, 2007).	A value theory should support explanations on conceptual issues and substantive problems.

Discipline	Description	Interpretation
Economics	Literature acknowledges the difficulties involved in defining value (Woodruff, 1997). Origins of difficulties are seen in the subjectivity of value, variations between customers, cultures, situations, and between tangible and intangible offerings (Chernatony, Harris, and Riley, 2000). Value is considered as "one of the most overused and misused terms in marketing and pricing today" (Leszenski and Marn, 1997, p.99) (i).	A theory of value should provide a value definition (i, ii, iii).
	In an attempt to consolidate the diverse definitions of value, Woodruff (1997, p.142) proposed "Customer value is a customer's perceived preference for an evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate achieving the customer's goals and purposes in use situations." Although the multiple contexts, tasks, and criteria in Woodruff's definitions reflect the richness and complexity of current value concepts, they impede its translation into a measurable operational definition (Parasuraman, 1997) (ii).	A theory of value should support clarity on the variables and mechanisms involved in the phenomenon under investigation.
	"The history of economic thought is replete with struggles to establish a meaning of value, both what it is and how it is measured." (Constanza, 2004) (iii)	A theory of value should support explanations on what value is and how it can be measured (if so).
	Priem (2001, p.233) in the context of value creation in a company, argues that value strategy literature has "blurred the distinction between value capture and value creation".	A theory of value should support explanations on value capture and creation.
Psychology	The value concept is able to unify the apparently diverse interests of all the sciences concerned with human behaviour (Rokeach, 1973).	A theory of value should support consistent explanations on value across disciplines, including axiology, economics, psychology, and sociology.
	"Theories specify which variables are important and for what reasons, describe and explain the relationships that link the variable, and identify the boundary conditions under which variables should or should not be related." (Klein and Zedeck, 2004, p.1)	A theory of value should support clarity in variables involved in the value phenomenon.
	"Theories help identify and define problems, prescribe a means for evaluating or solving the problems, and facilitate responses to new problems." (Klein and Zedeck, 2004, p.1)	A theory of value should support explanations on problems related to the value phenomenon.
	In the context of theory in applied psychology, Klein and Zedeck (2004) identify characteristics of a "good" theory. They recommend the following key characteristics: a theory offers novel insights; is grounded in the relevant literature; offers more than a review or relevant literature integration; presents constructs and thoughtful explanations of how and why the constructs in the model are linked; and is testable (Klein and Zedeck, 2004).	A theory of value should offer novel insights, be grounded in relevant literature, present defined constructs, provide explanations on construct relationships, and be testable.

Discipline	Description	Interpretation
	"Value theory has been an important issue in cross-cultural psychology since Rokeach's (1973) seminal work. Values have since then been used as independent variables to understand attitudes and behaviour and as dependent variables of basic differences among social groups and categories. This last property has encouraged cross-cultural psychologists to seek common dimensions of values and to study differences among cultures." (Spini, 2003)	A theory of value should support explanations on the behaviour of individuals and social groups, within and across cultures.
Sociology	"Theorists have sought to explain values as identifiable components of either cultural, social or personality systems, but seldom have these perspectives been adequately related to action within one comprehensive model." (Hutcheon, 1972)	A theory of value should support explanations on relationships of value to cultural, social or personality systems, and actions.
	"We know that it is common during the pre-scientific stage of a discipline's growth for many theories to contend for acceptance in one area of study – each as plausible as the others, but all of them imparting different meanings to the data in question, and thereby producing widely varying conclusions. This is well illustrated by the many theories of value change competing for consensus in sociology today, and the inconsistent research findings which they have provided. It is only when a theory is accepted by the majority of researchers in a given problem area that we can say that it has achieved a status of a paradigm and that the subject explained by it is thereby becoming scientific." (Hutcheon, 1972, p.176)	A theory of value should support explanations on existing value-related theories.
	"Why should sociology be concerned with the study of values? The obvious reason is that they may well provide the key to a more adequate understanding of the human being in society." (Hutcheon, 1972, p.172)	A theory of value may support the understanding of the human being in society.
	There is confusion surrounding the concept of value as behaviour probabilities, beliefs, cultural ideals, generalised attitudes, norms, objects, and orientations (Hutcheon, 1972).	A theory of value should support explanations on value as behavioural probabilities, beliefs, cultural ideals, generalised attitudes, norms, objects, and orientations.

Table 4-2: Value theory characteristics

From the interpretations above, a value theory should:

- integrate or relate to other theories and consider relevant literature;
- support explanations on issues related to the philosophical and scientific value discussion;

- support conceptual issues and substantive problems;
- provide a value definition;
- describe the phenomenon in terms of constructs, construct relationships, variables, and mechanisms involved in the value phenomenon;
- support explanations on value creation, analysis, and measures;
- provide novel insights;
- support explanations on value related to the behaviour of individuals and social groups, within and across cultures;
- support explanations on value related to attitudes, beliefs, cultural ideals, needs, norms, objects, orientations, and probabilities; and
- be testable.

These characteristics put restrictions on what can be recognised as a value theory, i.e. the characteristics can be interpreted as requirements for a value theory.

4.3. Summary and conclusion

Literature lacks a pre-defined set of requirements for a theory of value in the context of design. However, there are characteristics of design (Section 4.1) and value theory (Section 4.2) that can be interpreted as requirements for a theory of value in the context of design. The requirements are summarised in Table 4-3.

Requirement	Origin		ID[9]
A theory of value in the context of design should:	Design theory	Value theory	
provide novel insight	√	√	R1
provide a value definition		√	R2
describe the phenomenon in terms of constructs, construct relationships, mechanisms, and variables involved	√	√	R3
provide a perspective of the phenomenon; it cannot capture all of the phenomenon	√		R4
support explanations on conceptual issues and substantive problems		√	R5
support explanations on issues related to the philosophical and scientific value discussion including explanations on attitudes, beliefs, needs, behaviours, emotions, objects, and norms		√	R6
support explanations on instances of the phenomenon	√		R7
support explanations on value creation, analysis, and measures		√	R8
integrate or relate to other theories and consider relevant literature	√	√	R9
have a defined scope	√		R10
be built upon axioms and/or generalised characteristics	√		R11
be testable		√	R12
be evolutionary	√		R13
provide a means to improve design artefact, process, practice, and/or research performance	√		R14

Table 4-3: Requirements for a theory of value in design

From a design perspective, a theory of value should improve design artefact, process, practice, and/or research performance. From a value perspective, a theory of value should support consistent explanations on value across disciplines, including explanations in the context of the philosophical and scientific value discussion. Given the requirements, it can be concluded that a theory provides a means to formalise value in the context of design.

The overall research methodology applied to develop a theory of value in the context of design is outlined in the following chapter and the rationale of the choice is explained.

[9] An identification code for theory requirements is introduced here as a unique reference to support the requirements analysis on the TVD (Section 10.4.)

5. Research methodology

The objective of this chapter is to elaborate on the research methodology chosen in the research work reported in this thesis. [10]

Research can be understood as a systematic enquiry whose goal is to create new knowledge. Design research can be extended as a systematic enquiry towards knowledge of, or in, the embodiment of the configuration, composition, structure, purpose, value, and meaning in man-made systems (Archer, 1981). Design research shall produce laws, guidelines, and insights to improve the quality of design (Wallace, 1981). The overall aim of the research reported in this thesis is to develop a theory of value in the context of design as a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. Research methodology can be described as a collection of methods for doing research and the interpretations of those methods (Reich, 1994).

Distinctions between design and science may affect the choice of a research methodology. The goal of design can be seen as taking action and producing changes in man's environment. The goal of science is to produce knowledge. Science is understood as knowledge of the natural world (Reich, 1994). Thus, science studies the natural world while design studies the "man-made" world (Cross, 1982). Science is analytic while design is constructive (Gregory, 1966). On the other hand, science and design interact with each other in that scientific knowledge is intimately involved in design. Scientific knowledge is part of designing (Willem, 1990). However, it should be noted that design involves the use of non-scientific knowledge. In science research an experiment can be repeated using the same process (Wu, 2004). However, it is difficult to carry out a repeatable experiment in design, in particular in the context of value determination, which is interpreted in this

[10] The research methodology embraces the work reported in previous chapters and is presented here to include the specific approaches used to address the identified research requirements.

thesis as a cognitive process while designing. It is unlikely for different designers approaching the same design problem to have the same design result and determine the same values. It should also be noted that there is a desire to interpret design in ways similar to those in which science is interpreted; however, there are declarations that design is not like science. The attraction of the creation of a design science lies not in the method of science, but in the “values” of science in terms of rationality, objectivity, and universalism (Cross, Naughton, and Walker, 1981).

Overall, the research task involves a series of steps initiated by research challenges leading to a proposed solution. The overall aim of the research reported in this thesis was to develop a theory of value in the context of design. Developing such a theory, however, requires a research methodology. A research methodology is desirable to ensure that research: conclusions are based on a degree of rigour, relevance, and significance; is conducted with as much integrity and independence as practical; and is as much as possible based on valid and reliable procedures, methods, and techniques in as an unbiased process as can be expected. One approach to adopt is what is generally known as the scientific approach. Smith and Dainty (1991) encourage researchers to adopt a research perspective that may be defined by different possibilities, assumptions, values, and paradigms. By considering the different perspectives, one or several approaches that best serve the research purpose can be adopted. According to Reich (1994), there is a variety of research methodologies that can be considered. Thus, before adopting a particular research methodology in the context of this thesis, some of these methodologies are presented. The nature of the phenomenon of value in design may influence the methodology adopted, hence the rationale for the choice is discussed before the adoption.

5.1. Adopted world view

Research methodology is strongly linked with and constrained by the world view it serves (Reich, 1994). Thus, before the introduction of the research methodology applied in this thesis, the concept of a world view is presented. The concept of a world view can be modelled by three aspects (Guba, 1990): ontology, epistemology, and methodology:

- Ontology deals with the nature of the things we know about the world or the nature of the world. The central question of ontology is, “do we know things about the ‘real’ world, or is our knowledge a reflection of our manipulation of the world?” Thus, ontology is concerned with knowledge of the world itself.
- Epistemology deals with the relationship between humans and their knowledge. The questions can be, “What can we know?”, “How do we know?”, “What is truth?”, “How can we recognise truth?”, and “How are knowledge and action related?”
- Methodology is concerned with the methods for creating knowledge about the world and the interpretation of this knowledge in light of the ontological and epistemological positions. It deals with questions such as, “How is research planned and executed?”, “How are theories created and tested?”, and “How are the tests interpreted?”

5.1.1. Scientism

The research methodology of scientism is one of the most prominent methodologies in science and engineering. Scientism represents the essence of world views such as rationalism, positivism, and logical empiricism. The position of scientism regarding the three aspects can be described as (Guba, 1990):

- Ontology - Realist: Reality exists, “out there.” Reality operates according to cause-and-effect and free-context laws. By discovering these laws, science achieves its goal to predict and control phenomenon.
- Epistemology - Objectivist: Researchers can acquire objective knowledge about the real world through the employment of methodology.
- Methodology - Experimental or manipulative: Hypotheses are stated in advance and are subjected to tests under carefully controlled conditions.

A research methodology of scientism starts with training and a literature review. Based upon the results of the observations, a research problem is identified and hypotheses are made based on induction and deduction. The hypotheses are tested. The test results can reject the hypotheses, which will then be revised. This process can be repeated until the hypotheses are accepted. The tested hypotheses become laws. The laws are used to control and predict the nature of the world (Wu, 2004)

5.1.2. Practicism

A research methodology of practicism is used in areas such as social science concerned with social value, ethics, and human nature issues. The position of practicism about the three aspects can be described as (Guba: 1990):

- Ontology - Relativist: Reality exists in the minds of people and within a certain value-laden theoretical framework. By interacting with the world, people can reconstruct their perception of it in their minds. When the interaction involves technological or organizational changes, the goal of the inquiry may be to achieve an improved practice.
- Epistemology - Critical subjectivism: Since theories about reality are value-laden, there can only be a subjective interaction with the world. To avoid misuse of subjectivism, a critical methodology must be adopted.
- Methodology - Critical hermeneutic or dialectical: Reality is constructed through the identification of multiple (including contradicting) constructions and their critical comparison, thus improving the grounds for making informed choices between constructions. Reality is constructed and explained from the perspective of the researcher in a certain research context.

A research methodology of practicism is outlined in Figure 5-1 (Smith and Dainty, 1991). In practicism, the research output is influenced by the background, the previous research experience of the researcher, and the context of the research. The context consists of the institution, questions, perspective, and methods. The elements of the research methodology are linked with each other. The researcher's experience has an influence on the research output that serves as experience in future research (Wu, 2004).

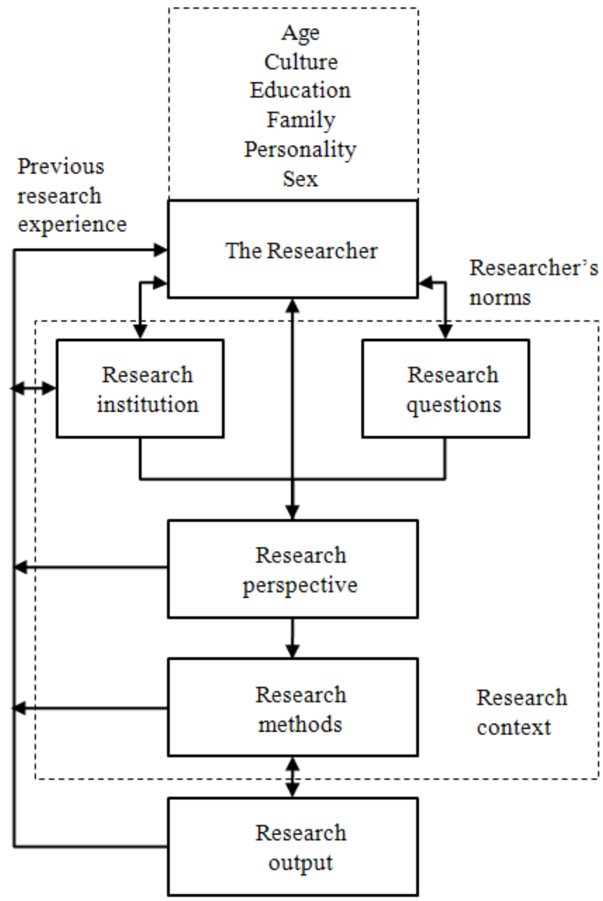

Figure 5-1: A research methodology of practicism

(Smith and Dainty, 1991)

In the research work reported in this thesis, the world view of practicism is adopted, but influenced by that of scientism. This is because the aim of the work is to develop a theory of value in the context of design. While value and design are linked to social science by human values and cognitive processes, a theory of value in the context of design should have the characteristics of science wherever possible, namely: rationality, objectivity, and universalism. A world view of scientism cannot be exclusively adopted for the development of a formalism of value in the context of design, since there is fundamental distinction between design and science as outlined above.

In essence, research is conducted within the philosophical assumptions and paradigms of ontology and epistemology. These assumptions can be described in terms of two main paradigms, i.e. positivism and realism. Within positivism, truth is gained through a series of predictions or hypotheses about the nature of the phenomenon under study. The predictions are verified through empirical fieldwork. Within realism, truth is gained when different perspectives of the phenomenon are in agreement. The facts of the situation are dependent upon the viewpoints of the observers. The observers are involved within the phenomenon. Thus, a variety of viewpoints is required to establish findings within this research paradigm.

5.1.3. Critical realism

Despite the prevalent position among the rest of the paradigms, positivism is criticised for "naïve realism", in which reality can be apprehended and knowledge easily captured and generalised in a context-free form (Guba, 1994). In reaction to this critique, a number of post-positivism paradigms have emerged. These paradigms address ontological and epistemological weaknesses of positivism. Among these is critical realism, which is largely established by the writings of Bhaskar (1975, 1978, 1989). Critical realism captures central aspects of natural and social science and provides a paradigm within which research on value in design can be conducted.

From the ontological perspective of critical realism, reality exists and it is possible to conceptualise it and make theories in order to describe it. However, critical realism does not claim a totally comprehensive understanding of a certain problem or establish a "complete" perspective. Instead, critical realism regards knowledge as fallible in the sense that a scientific insight of a phenomenon is a partial insight of certain aspects, deliberately chosen and due to change. Thus, the theory of value in design as provided in Chapter 9 provides a perspective on the value phenomenon in a design context, but does not claim a totally comprehensive understanding of the phenomenon of value in design.

Ontologically, i.e. reality in critical realism is divided into different domains: At the empirical domain, observations of "experiences" can be made, referring to visible observations of the phenomenon under study. These experiences constitute parts of the "events" that can be identified at the actual domain. The "events" in turn are the outcome of "mechanisms" at the real domain (Jeppensen, 2005). An example may be seen in the observation of value statements in a design protocol at the empirical domain. A value statement in turn can be seen as the output of a value determination event at the actual domain, which in turn is the outcome of the mechanisms involved in value determination at the real domain.

From an epistemological perspective, critical realism aims to explain the relationship between experiences, events, and mechanisms. The focus is on "how and why" a phenomenon came into being and to its specific characteristics. In other words, emphasis is on the explanation of the constitution of empirical phenomenon and not to provide predictions (Jeppensen, 2005). Within critical realism different kinds of reasoning are required: inductive, i.e. reasoning from a specific case or cases and deriving a general rule; deductive, i.e. starting with a general case and deducing specific instances; abductive, i.e. explaining something that is experienced or observed in some way and where there is no specific knowledge to explain the phenomenon, creating a hypothesis that may or may not be true and which may require further work to verify; and retroductive, i.e. "a mode of inference in which events are explained by postulating mechanisms that are capable of producing them" (Sayer, 1992, p.107). Retroduction is seen as a preferable way of reasoning because, "it links the empirical from induction with the theoretical from deduction in a continually evolving process" (Sayer, 1992, p. 245). The research work reported in this thesis is based on a retroductive reasoning process that links the empirical from induction (e.g. the value axioms in Chapter 6), with the theoretical from deduction (e.g. the value determination model in Chapter 7) in a continually evolving process.

According to critical realism, investigating conditions within social science is based on premises and a characteristic such as “openness”, i.e. closure does not exist. From a critical realism perspective, our understanding and analysis is theory-laden and concept-dependent, i.e. the theories and concepts that we use impact our study, but they don’t determine the outcome. Finally, the context influences the phenomenon we study (Jeppensen, 2005). The work reported in this thesis provides a theory of value in the context of design. Value theories (Chapters 2 and 3), design and value theory characteristics (Chapter 4), a protocol analysis from a design episode (Section 10.2), and open-interviews with designers (Section 10.3), impact the study.

Different applications of the critical realism paradigm have been elaborated and Sayer’s work (1992) especially contributes to the development of critical realism fieldwork (Jeppensen, 2005). Sayer (1992) emphasises scientific/methodological coherence and the relevance of different methods of data collection according to different types of problems. He advances four types of research, i.e. abstract, concrete, generalisation, and synthesis. Abstract research involves only the theoretical analysis; concrete research involves the theoretical and empirical analysis; generalisation research involves only the empirical analysis; and synthesis research is an interdisciplinary analysis, covering different perspectives and fields. Three types of critical realism research were applied in this thesis: Abstract research and synthesis was applied in the context of the identification of value axioms (Chapter 6) and based on the analysis of value interpretations across disciplines (Section 3.5); and concrete research was applied in the context of the development of the value determination model (Chapter 7) and the overall theory of value in design (Chapter 9). Theoretical analysis was involved in terms of a literature review on value theories (Chapters 2 and 3) and empirical analysis was involved in terms of, e.g. open-interviews with designers (Section 10.3). According to Sayer (1992), this is a preferable way to understand a concrete problem as, “our concepts of concrete objects are likely to be superficial or chaotic at the outset (why we) in order to understand their diverse determinations first must abstract them systematically” (Sayer, 1992, p.87). The combination of abstract and concrete levels of analysis diminishes the risk of overextending a single research strategy, which refers to "expecting one type (of research) to do the job of the others" (Sayer, 1992, p.38).

Sayer (1992) distinguishes between two types of research design, i.e. extensive and intensive. "The extensive research shows us mainly how extensive certain phenomena and patterns are in a population, while the intensive is primarily concerned with what makes things happen in specific cases" (Sayer, 1992, p.20). As such, the choice of research design is more complementary than competitive. Critical realists do not believe that results from research can be made into general laws of social events. "Generalizations may also be either simple descriptive summaries of a given situation, or extrapolations – rough predictions of what other situations may be like. The former usage is obviously informative, while the latter is problematic." (Sayer, 1992, p.100). Standardised interviews and statistical analysis are typical methods for extensive research. Intensive research mainly applies qualitative methods and analysis (Sayer, 2000). The research work reported in this thesis included an intensive research design to obtain in-depth knowledge about the phenomenon of value in the context of design in terms of an analysis of value interpretations (Section 3.5), a design protocol analysis (Section 10.2), and open-interviews (Section 10.3) to gain insights from designers on the value phenomenon. However, Sayer bases the intensive research design on the assumption that sufficient literature and knowledge of a given field exists (Jeppensen, 2004), which was not the case in the context of research on value determination. While value literature highlights different aspects of the value phenomenon a rather limited amount deals with a more fundamental formalism of value in the context of design. Thus, it was found necessary to begin the work reported in this thesis with an explorative research design that entails a literature review covering value interpretations in design (Section 2.2), product and process value management (Sections 2.3 and 0), economic value of design (Section 2.5), human values in design (Section0), and axiology (Section 3.1), economics (Section 3.2), psychology (Section 3.3), and sociology (Section 3.4). The need for explorative research is highlighted by Olsen and Pedersen (2008), stating that a qualified conceptualization of an inadequately understood phenomenon requires an explorative research method. The descriptive and explorative research design contributes to the development of the analytical framework, i.e. it provides support on the identification of what to study and what to analyse in order to address or evolve research questions (Section 3.7).

Based upon the discussion so far, it is evident that critical realism does not commit to a single type of research, but rather endorses a variety of research methods chosen according to the aim of the research work. The stratified ontology of critical realism allows for the "legitimate" combination of qualitative and quantitative methods. From a methodological perspective, critical realism provides support in looking for causal mechanisms and how they work, e.g. the mechanisms involved in value determination (Section 7.6). Empirical inquiry entails examining the range of possible mechanisms at play, analysing which are to be studied and which are felt to have relevant impact in the particular context being studied.

Based on the above, the world view adopted is described as:

- Ontology: Reality exists and it is possible to conceptualise it and make theories in order to describe it. However, there is no claim for a totally comprehensive understanding of a certain problem or for a "complete" perspective.
- Epistemology: The aim is to explain the relationship between experiences, events, and mechanisms. Emphasis is on "how and why" a particular phenomenon came into being and got its specific character, and on the explanation of the constitution of empirical phenomenon.
- Methodology: Emphasis is on looking for causal mechanisms and how they work. Empirical inquiry entails examining the range of possible mechanisms at play and analysing which are to be studied and which are felt to have relevant impact in the particular context being studied.

5.2. Adopted methodology

The overall aim of the research reported in this thesis was to develop a theory of value in the context of design (Section 1.3). Developing such a theory requires an appropriate research methodology to ensure that research: conclusions are based on a degree of rigour, relevance, and significance; is conducted with as much integrity and independence as practical; and is as much as possible based on valid and reliable procedures, methods, and techniques in as an unbiased process as can be expected. The research methodology adopted in this work is presented in Figure 5-1.

There are a variety of research methodologies that can be considered (Reich, 1994). However, the research methodology is strongly linked with and constrained by the world view it serves (Reich, 1994). While value and design are linked to social science by human values and cognitive processes, a theory of value in the context of design should have the characteristics of science wherever possible, namely rationality, objectivity, and universalism. The research methodology adopted is based upon critical realism. Critical realism captures central aspects of natural and social science and provides a paradigm within which research on value in the context of design can be conducted (Section 5.1.3). From the ontological perspective, the research methodology is based on the world view that reality exists and it is possible to conceptualise it and make theories, i.e.to describe the theory of value in design. Insights gained from the investigations on the phenomenon of value in the context of design, i.e. value axioms, the value determination process, and explanations on value related phenomena, are seen as partial insights of certain aspects, i.e. there is no claim for a totally comprehensive understanding of the phenomenon of value in the context of design.

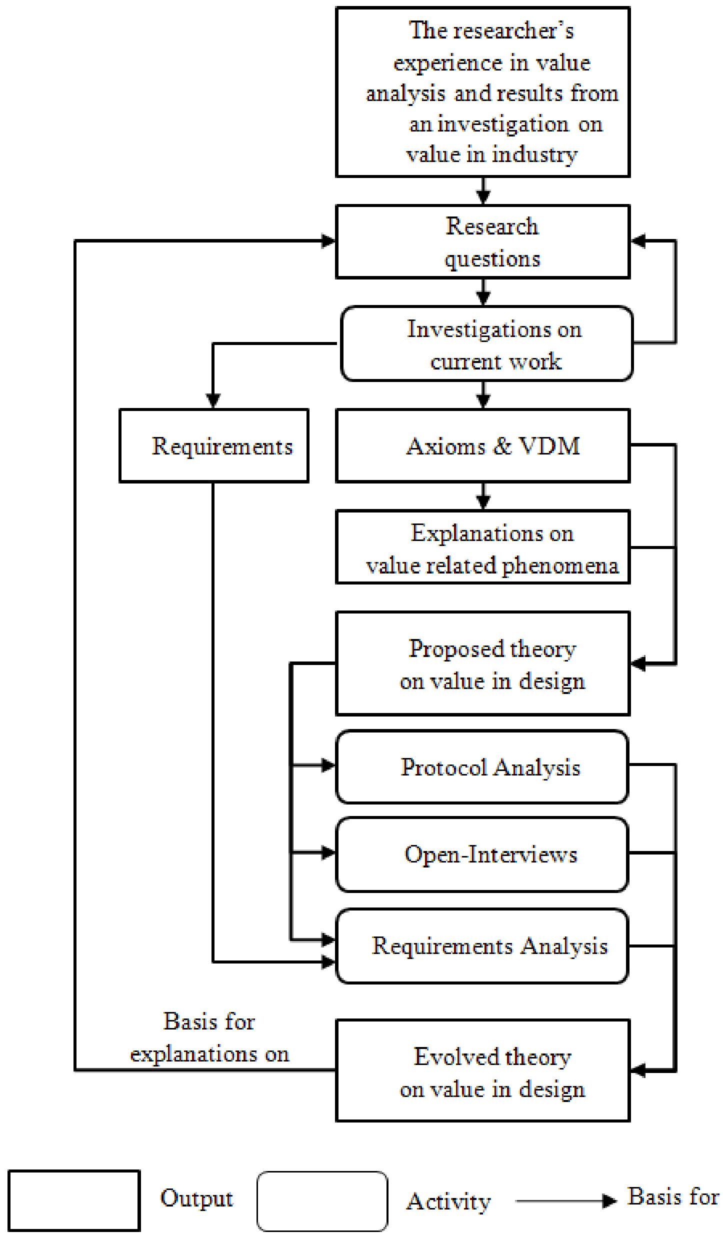

Figure 5-2: Research methodology adopted

The focus of the research methodology is on the relationship between key elements and mechanisms involved. Retroduction, as a preferable way of reasoning (Sayer, 1992), links the empirical from induction, e.g. the value axioms (Chapter 6), with the theoretical from deduction, e.g. the value determination model (Chapter 7) in a continually evolving process. Investigations on current work in terms of value theories (Chapter 2 and 3), design and value theory characteristics (Section 4.1 and 4.2), an analysis of a design protocol (Section 10.2), and open-interviews with designers (Section 10.3), impact the work, i.e. the study is context dependent.

The adopted research methodology integrates different methods for data collection: abstract research and synthesis in the context of the identification of value axioms (Chapter 6) and based on the analysis of value interpretations across disciplines (Section 3.5); and concrete research in the context of the development of the value determination model (Chapter 7) and the overall theory of value in design (Chapter 9). Theoretical analysis was involved in terms of a literature review of value theories (Chapter 2 and 3) and empirical analysis in terms of, for example, open-interviews with designers (Section 10.3). According to Sayer (1992), this is a preferable way to understand a concrete problem.

While value literature highlights different aspects of the value phenomenon a rather limited amount deals with a more fundamental formalism of value in design. Thus, there was a need for an explorative research design (Olsen and Pedersen, 2008) that entails a literature review covering value interpretations in design (Section 2.2), product and process value management (Sections 2.3 and 0), economic value of design (Section 2.5), human values in design (Section0), and axiology (Section 3.1), economics (Section 3.2), psychology (Section 3.3), and sociology (Section 3.4). An intensive research design was applied to obtain-in-depth knowledge about the phenomenon of value in the context of design in terms of an analysis of value interpretations (Section 3.5), a design protocol analysis (Section 10.2), and open-interviews (Section 10.3) to gain insights from designers on the value phenomenon.

From a process perspective, the research methodology may be described as follows:

- From the researcher's practical experience in value analysis and based on the results from an investigation on value in industry initiated and supervised by the researcher (Hug, 2003), it was concluded that there is a lack of knowledge on value in design and on the nature of value (Section 1.1). This initial conclusion serves as a basis for an investigation on current work on value theory (Chapters 2 and 3), where the conclusion was identified as the case.

- While investigating value in design and value theory, the research questions evolved from: “When does value appear in design?”; “What is an appropriate metric for value in design?”; and “How can value be added?” (Section 2.7), to more fundamental questions such as: “What are the generic characteristics of value?”; “What are the key elements and mechanisms involved in value determination?”; “How is value related to phenomena such as benefit, exchange, and need?”; and “How can value be formalised in the context of design?” (Section 3.7).

- From the investigations it was concluded that there is a need for a more fundamental formalism of value in that such formalism can provide a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design (Section 3.7). On the one hand, the multiple observations, assumptions, correlations, propositions, laws, classifications, interpretations, concepts, models, and suppositions in current value theory provide a basis for the development of a more fundamental formalism of value in design. On the other hand, they are seen as indicators that a theory may provide a means for such formalism in that a theory can be seen as a vehicle to support explanations about the general properties, characteristics, and underlying processes and mechanisms of all instances of a phenomenon (Smithers, 1999).

- Design and value theory characteristics (Sections 4.1 and 4.2) are derived from design and value literature as a means to identify requirements for a theory of value in the context of design. Based on the requirements it is concluded that a theory provides a means to formalise value in the context of design. The requirements are summarised in Section 4.3.

- Investigations in current value theory provide the basis for the identification of value axioms in Chapter 6 and the development of a value determination model (VMD) in Chapter 7. The value axioms and the VDM provide the basis for explanations on value-related phenomena in Chapter 8. The axioms, the VDM, and the explanations on value-related phenomena serve as a basis to describe and propose the theory of value in design (TVD) in Chapter 9. The TVD is descriptive in that it describes the key characteristics of value (Chapter 6), the key elements and mechanisms involved in value determination (Chapter 7), and the relationship of value to related phenomena (Chapter 8). The validity of the proposed TVD is investigated based on a protocol analysis of a design session in Section 10.2, open-interviews with designers in Section 10.3, and an analysis against theory requirements in Section 10.4. Based on the investigations the TVD evolves in the particular aspect of a value entity's context as an opportunity to change a value statement (Section 10.5).

- Explanations on the key research questions (Section 3.7) are provided in terms of the key characteristics of value (Chapter 6), the key elements and mechanisms involved in value determination (Chapter 7), value-related phenomena (Chapter 8), and the TVD as a formalism of value in the context of design (Chapter 9).

Protocol analysis and open-interviews can be seen as key methods applied within the research methodology. The following sections provide a discussion of the two methods to highlight the choice rationale.

5.2.1. Protocol analysis approach

As much as possible of what designers are thinking during the design process needs to be revealed in the investigation of value in the context of design. Protocol analysis has become the most likely method to bring out into the open the cognitive abilities of designers (Cross, 1996). Protocol analysis relies on the verbal data produced by subjects of their own cognitive activities. In consequence, there are doubts about the method of protocol analysis, which can be summarised in terms of: completeness, i.e. the verbal reports may yield an incomplete record of the cognitive process; relevance, i.e. the subject may, quite intentionally, give irrelevant accounts, reporting parallel but independent thoughts to those that are actually being employed in the task (Kok, 2000); and subjectivity, i.e. the encoding of verbal protocols cannot be made soundly and objectively.

Ericsson and Simon (1984) marshalled evidence for their hypothesis that the information that is heeded during performance of a task is the information that is reportable. The information that is reported is the information that is heeded, which refutes the objection of the completeness of verbal reports. On the issue of relevance, Anders Ericsson and Herbert (1993) conclude that with great consistency, the experimental evidence that was gathered demonstrates that verbal data are not in the least epiphenomenal, but instead highly pertinent to and informative about subjects' cognitive processes and memory structures. Furthermore, the encoding of data can be to some degree subjective, but complementary methods can assist in improving the objectivity, such as the use of the context of the verbal data and of key words, phrases, or sentences. Value entities, for example, can be identified in the context of verbal statements of a design episode as a design process, concept, parameter, resource, or risk (Figure 10-4). Key words, phrases, and sentences provide hints as to the content of the verbal data (Ericsson and Simon, 1984).

Protocol approaches can be divided into concurrent and retrospective types (Ericsson and Simon, 1984; Gero and Tang, 2001). In concurrent protocols, subjects design and simultaneously verbalise their thoughts. In retrospective protocols, subjects reveal information preserved in short- and long-term memory (Gero and Tang, 2001). Videotapes may be used during the retrospection to assist in the recall of activities. To investigate the validity of the TVD, a design protocol established by Kok (2002) was analysed (Section 10.2). The design protocol was based on a concurrent approach, given that the retrospective protocol analysis has the disadvantage that details may be omitted due to the decay of long-term memory (Ericsson and Simon, 1984; Gero and Tang, 2001).

The key activities in protocol analysis can be identified as data segmentation, coding, analysis, and interpretations (Gero and McNeill, 1998). In segmentation, the recorded data is segmented into independent parts in order to facilitate the analysis of every segment independently. The traditional approach is to segment by inferring the categories that may exist in the recording or part of it and then analyse the frequencies of occurrence in the full record. It should be noted that there is a move away from the traditional approach towards imposing an externally derived structure of the protocol (Purcell et al, 1996). Segmentation of a protocol can be generated based on other criteria, e.g. pauses in the flow of words or some hypotheses that researchers have on the design process model (McNeil, Gero, and Warran, 1998; Loyd and Scott, 1994). Gero and McNeill (1998), for example, defined a segmentation based on the subject's intentions, such that a change in the subject's intention or in the contents of their thoughts or actions flags the start of a new segment. Since the prime purpose of the protocol analysis provided in this thesis is on analysing value determination in the context of design activities, the activities that designers used throughout the protocol were identified first and then analysed against value determination. In other words, the design activity serves as the basis to segment the protocol depicting the various design activities that the designer engaged in during the design task. However, the task of identifying these design activities is difficult, given the variety and complex nature of the design activities (Kok, 2000). Thus, Kok (2000) identified key words or phrases uttered by the designer suggesting the nature of the activity and hence aid in their identification. The design activities and codes applied for segmentation are outlined in Section 10.2.2 in further detail. The segments of the protocol in terms of design activities provide the basis for the analysis of design activities against key elements of value determination, i.e. value entities, value criteria, and value statements (Appendix E).

Based on the discussion so far it is concluded that protocol analysis provides a means for an analysis of value determination in the context of design activities. The rationale is supported by protocol studies conducted by researchers analysing designers' activities in architectural, engineering, and electronic design (Kok, 2000).

This section provides the rationale of applying protocol analysis in the research on value in design. Section 5.2.2 provides the rationale for the applied open-interview approach.

5.2.2. Open-interview approach

Interviews are a means to determine those things that we cannot directly observe. The issue is not whether observational data is more desirable, meaningful, or valid than self-reported data, but that one cannot observe everything, e.g. feelings, thoughts, or intentions. The purpose of open-ended interviewing in the context of the research work reported in this thesis was to elicit the perspectives of practicing designers on key elements of the TVD.

Qualitative interviewing begins with the assumption that the perspective of others is meaningful, comprehensible, and able to be made explicit. There are three basic approaches to collecting qualitative data through open-ended interviews (Patton, 1990). The informal conversational interview relies on the spontaneous generation of questions in the natural flow of a conversation. This is typical for an interview that occurs as part of an ongoing participant field observation. The general interview guide approach involves outlining a set of issues to be explored with each respondent. An interview guide serves as a checklist to make sure that all relevant topics are covered. The standardised open-ended interview consists of a set of specifically worded questions and is arranged with the intention of taking each respondent through the same sequence and asking the same questions with the same words.

An interview guide approach was selected to elicit the perspective of designers on key issues addressed in the TVD, i.e. the value axioms, the value determination process, and explanations on value-related phenomena. An interview guide was prepared (Table 10-8) to make sure that all relevant issues are considered from the individual designers. At the same time, the interviewer remained free to build a conversation within the area of value in design, to word questions spontaneously, and to establish a conversational style while focusing on dedicated issues. An advantage of the interview guide was that it helped the interviewer carefully decide how best to use the limited time available in the interview situation. The guide also helped to make interviewing a number of different people more systematic and comprehensive by defining in advance the issues to be explored. Examples of interview guides used in the conduction of sociological research are outlined by Lofland (1971).

An interview question can be seen as a stimulus generating a response from the person being interviewed. For a qualitative inquiry, questions should be clear, neutral, and open-ended (Patton, 1990). It is the responsibility of the interviewer to articulate unambiguously to the interviewee what is being asked. Asking singular questions, applying terminology commonly used by interviewees, and supporting complex issues based on sketches and pictures helps to make things clear. Consequently, singular questions embedded in the interview context are applied, e.g. "What is the value of a crane?" (Appendix E, p.315), and questions are supported by showing images of, e.g. a crane (Figure 10-6) as an object well known by the interviewee. Neutral questions do not for example suggest a "yes" or "no" answer. An objective of an in-depth interview is to get the person being interviewed to talk about experiences, feelings, opinions, and knowledge. Presuppositions can be useful in interviewing because the interviewer presupposes that the respondent has something to say, and as such increase the likelihood that the respondent will have something to say. For example, the question, "What is the value of …?" (Section 10.3.1) presupposes that the respondent can identify value. Of course, the person being asked has the option to respond, "I cannot identify value." However, it is more likely that the interviewee will go directly to the issue of what value to report, rather than dealing first with the question of whether or not something has value. It is critical that questions be asked in a truly open-ended fashion, i.e. the question should permit respondents to respond in their own terms. Open-ended questions allow the person being interviewed to select from the person's full repertoire of possible responses.

A number of decisions must be made in planning an interview: what questions to ask, how much detail to solicit, how long to make the interview, and how to word the actual questions. These are all decisions that will affect the quality of interview responses. There are basically six types of questions that can be asked: behaviour, opinion, feeling, knowledge, sensory, and background (Patton, 1990).

Opinion questions aim to understand the cognitive and interpretative processes of people. Answers to these questions tell the interviewer what people "think" about some issues. These questions typically carry an implication of respondent rationality and decision making. Opinion questions on the TVD are the prime type of questions in the open-interview applied, since the main purpose is to get insights on what the designers think about the key elements of the TVD. However, during the interview questions regarding experience, background and knowledge are also raised to increase the researcher's understanding of the key elements under investigation. The questions are asked in the present tense to gain insight on the respondent's current understanding. The sequence of the questions is arranged from general to specific, i.e. from general characteristics in terms of the value axioms to questions on explanations on value-related phenomena (Table 10-8).

Overall, this section provides the rationale of applying an open-interview approach aiming to elicit the perspective of practicing designers on key elements of the TVD. It is concluded that requirements to support the quality of the interview responses are satisfied.

5.3. Elaboration of methodology

The research methodology is elaborated in Figure 5-3 with the steps of the research mapped to the thesis structure. The research methodology includes three parts and eight steps: research problem formalisation (steps 1 and 2), solution development (steps 3 to 6), discussion (step 7), and conclusion (step 8).

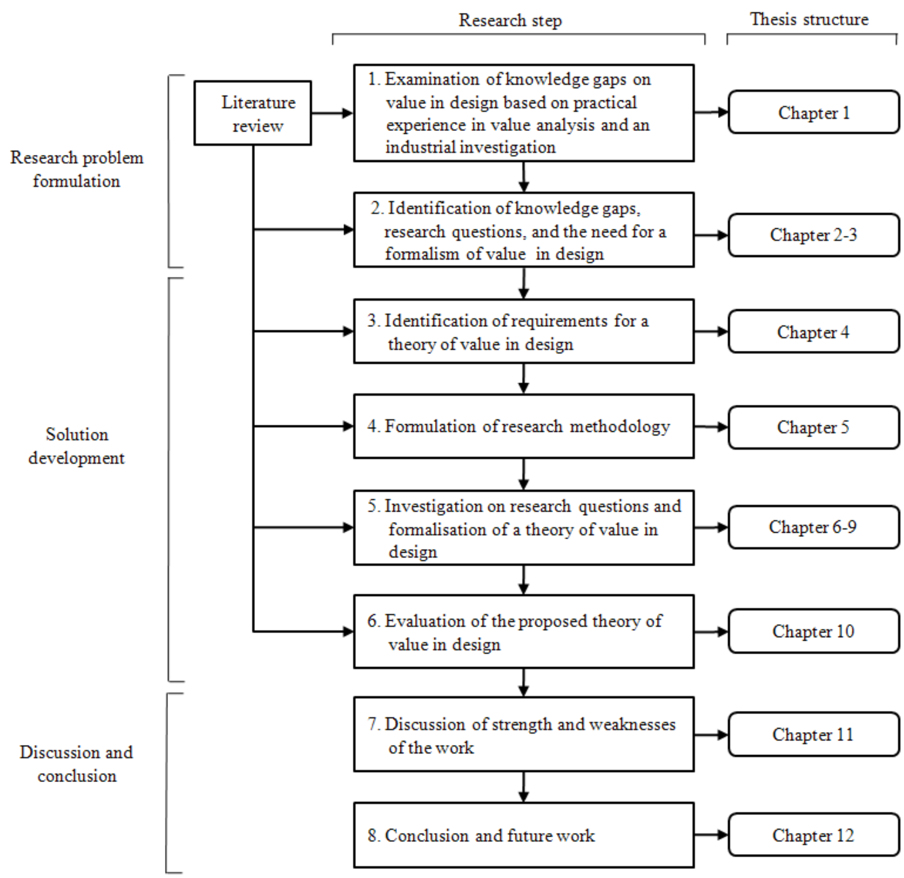

Figure 5-3: Elaboration of research methodology

Step 1: A knowledge gap on value in design is considered based on practical experience in value analysis and an industrial investigation (Chapter 1).

Step 2: Value theory is reviewed. Knowledge gaps, key research questions, and the need for a theory of value in the context of design are identified (Chapters 2 and 3).

Step 3: Requirements for a theory of value in the context of design are derived from design and value theory characteristics (Sections 4.1 and 4.2). The requirements are summarised (Section 4.3).

Step 4: The research methodology is formalised (Chapter 5).

Step 5: Research questions are investigated. Output of the investigation are value axioms (Chapter 6), a model of value determination (Chapter 7), explanations on value-related phenomena (Chapter 8), and a proposed theory of value in design (Chapter 9).

Step 6: The validity of the proposed theory of value in design is investigated by a protocol analysis (Section 10.2), open-interviews with designers (Section 10.3), and a requirements analysis (Section 10.4), resulting in an evolved theory of value in design (Section 10.5).

Step 7: Pros and cons of the theory of value in design and the research approach are discussed (Chapter 11).

Step 8: Conclusions of the work are made and future work is identified (Chapter 12).

5.4. Summary

In this chapter the research methodology was elaborated and the rationale of choice was discussed. There is a distinct difference between design and science although they interact with each other; this affects the choice of the research methodology. Two research methodologies in terms of scientism and practicism were introduced. It was argued that other research methodologies will fall into the range of these two (Reich, 1994).

To investigate the phenomenon of value in the context of design, the research work reported in this thesis adopted the world view of practicism but was influenced by that of scientism. While value and design are linked to social science in terms of human values and cognitive processes, a theory of value in the context of design should have the characteristics of science, namely rationality, objectivity, and universalism.

Research was conducted within the philosophical assumptions and paradigms of ontology and epistemology. These assumptions can be described in terms of two main paradigms, i.e. positivism and realism. Within positivism, a degree of truth is gained through a series of predictions or hypotheses about the nature of the phenomenon under study. Within realism, a degree of truth is gained when different perspectives of the phenomenon are in agreement. In reaction to critiques of the realism paradigm, a number of post-positivism paradigms have emerged addressing the ontological and epistemological weaknesses of positivism. Among these is critical realism, the one adopted in this thesis, which captured central aspects of natural and social sciences and consequently provided a paradigm within which research on value in the context of design can be conducted.

The research methodology was elaborated with the steps mapped to the structure of this thesis (Section 5.3). The research methodology includes three parts and eight steps: research problem formalisation (steps 1 and 2), solution development (steps 3 to 6), discussion (step 7), and conclusion (step 8). Protocol analysis and open-interviews were key research methods applied in this thesis. The choice of this research methods was justified and the approaches itself were detailed (Sections 5.2.1 and 5.2.2).

In conclusion, the adopted research methodology provides an acceptable methodology in the sense of a means to support the research effort based on a degree of rigour, relevance, and significance; conducted with as much integrity and independence as practical; and based on valid and reliable procedures, methods, and techniques in as unbiased a research process can be expected.

6. **A set of value axioms**

Value theories were investigated in Chapters 2 and 3. Knowledge gaps were identified and it was concluded that a theory provides a means to formalise value in design. Requirements for a theory of value in design were identified (Chapter 4) and it was concluded that a theory of value in design should be built upon axioms and/or generalised characteristics of a phenomenon (Section 4.3). This chapter provides an investigation on the general characteristics of value and identifies value axioms. In other words, the chapter provides answers to the first research question identified (Section 3.7): "What are the general characteristics of value?"

Axioms may be characterised as rules that are objective in their grounding and universal in their applicability (Rescher, 1982). Thus, value axioms can be seen as general rules basic to a theory of value and consequently basic to a theory of value in the context of design. However, it should be noted that critical realists (Section 5.1.3) argue that "generalizations may be either simple descriptive summaries of a given situation or extrapolations – rough predictions on what other situations may be like" (Sayer, 1992, p.100). Furthermore, critical realism regards knowledge as fallible in the sense that a scientific insight of a phenomenon is a partial insight of certain aspects, deliberately chosen and due to change.

The value axioms formulated in this chapter are the output of inductive research based on the literature review provided in Chapters 2 and 3.

6.1. The person axiom

In the context of research on human values, Rokeach (1973) points to the issue that one may say that an object possesses value and that a person has value. He suggests that for value research, it may be important to decide whether a systematic study of value will focus on the values that persons are said to have or on values that objects are said to have. Feather (1975) concludes that Rokeach's distinction between the values of a person and an object may not be adequate: *value* relates to persons and objects, while *values* involve the person engaged in valuing and an object that is being valued. From Feather's perspective, values do not exist independently of persons and objects.

The literature review provided in Chapters 2 and 3 supports the concept that value does not exist independently of a person. It is a person that apprehends the value of entities (Lamont, 1956; Miles, 1972; Najder, 1975, Allingham, 1982; Porter, 1985; Zeithalm, 1988, Chase, 1990; Fowler, 1990; Anderson, Jain, and Chintagunta, 1993, Hamilton, 1996; Grönross, 1997; Best, 1999; Larreche, 2000; Daniels, 2000; Doyle, 2000; Ashworth and James, 2001; Andriessen, 2003); a person that values as an activity (Zeithalm, 1988; Holbrook, 1994; Hight and Cooper, 2006); and a person that holds values in the sense of ethic/moral principles (Bailey, 1967; Rokeach, 1973; Feather, 1975, Rescher, 1982; Holbrook, 1994; Harrison, 1998; Hight and Cooper, 2006; Schwartz, 2006). Engineers focus on the creation of product value (Fowler, 1990; Hamilton, 1996; Ashworth and Hogg, 2000); economists analyse the value of an enterprise (Copeland, Koller, and Muttin, 2000; Andriessen and Tissen, 2000), and industrialists express their understanding of value in terms of business ethic principles (Hug, 2003). While the existence of value independently of persons and objects as suggested by Feather (1975) is an issue not investigated in this thesis, it is concluded based on what has been written, that value is based on people. From this, the first axiom is introduced:

The person axiom: Value is people-based. (Axiom 1)

An analysis of value definitions against people involved (Appendix D) provides further evidence on the personal nature of value. All value definitions refer, in an explicit or implicit manner, to people. Some definitions utilise a consumer (Zeithalm, 1988; Burns and Woodruff, 1992), customer (Allingham, 1982; Ashworth and Hogg, 2000; Andriessen, 2003), and human being (Bailey, 1967; Rokeach, 1973; Najder, 1975; Fowler, 1990; Holbrook, 1994; Hamilton, 1996; Best and De Valence, 1999), while others utilise an enterprise (Allingham, 1982; Porter, 1985; Ashworth and

Hogg, 2000) and organisation (Harrison, 1998). In essence, they all represent humans or groups of humans.

6.2. The cognition and determination axioms

Two questions that are fundamental to value research in general and value research in design in particular are: “Is value a property of entities?”; or “Is it a cognitive determination?” This issue is a matter of ongoing debate in literature and despite the research effort that has been expended on the value phenomenon, there is as yet no agreed upon answer.

A source of contention in defining the value phenomenon can be seen in three different research approaches as mentioned by Lamont (1956): approaching value in terms of characteristics an entity has in itself, such as value made up of cost, time, and quality according to Atkin (1990); approaching value in terms of characteristics an entity is said to possess only when an entity is in relation to some other entity, such as asset exchange value according to Sparks et al. (2001); and indicating value as a state of mind in appreciating an entity in terms of ethic/moral principles, such as value as a belief according to Rokeach (1973). The current position in research is one of stalemate.

To overcome the contention with current research approaches, Lamont (1956) suggests an alternative approach for investigating the value phenomenon, instead of starting with the assumption that value is “something”, for example, a property or a relation, and then going on to inquire about its status in an objective order. The alternative is to start with the assumption that in attributing value, this attribution is an activity occurring within the human mind, and then to go on to analyse the nature of this activity. On this second approach, the issue is not one concerning the status of value, but one concerning the nature of the process of value determination. Lamont’s approach provides a basis common to all parties to the controversy: The acceptance is that, whether value is an intrinsic property or not, there is a cognitive process involved in value determination. From this, the second axiom is introduced:

The cognition axiom: Value is an output of a cognitive process. (Axiom 2)

People express value in terms of a statement such as, “A is of value”. The statement may be seen as an output of a cognitive process. To formalise a value statement requires value determination, i.e. a cognitive process of establishing value aiming towards a value statement. The process per se may be conscious or unconscious, but without such a process, value is not revealed and cannot be consciously derived. Consequently, the following axiom can be introduced:

The determination axiom: Value requires determination. (Axiom 3)

A review of value interpretations (Sections 2.2 and 3.5) supports evidence on the cognition and determination axioms: Bailey (1967) and Rescher (1982) argue that value denotes an effect produced in the mind. Rokeach (1973) and Schwartz (2006) conclude that values are beliefs, i.e. held in the mind; Ehrenfels (1887, 1896, 1907) saw the foundation of value in desire; Harrison (1998) concludes that value is a concept of what an individual regards as desirable; and Hamilton (1996) argues that value is the level of importance that is placed upon a function, item, or solution. Holbrook (1994) concludes that *value* refers to a preferential judgement, while *values* refers to the criteria by which such judgements are made. All of these interpretations refer to value as cognitive concepts, i.e. an effect produced in the mind, belief, desire, level of importance, and criteria by which judgements are made, providing support on the cognition axiom. The interpretation of Holbrook (1994) looking at value as a preferential judgement may be seen as highlighting the determination process of value and supporting the determination axiom.

6.3. The situation and interpretation axioms

Research on situated cognition claims that every human thought and action is adapted to the environment where it is situated, because what people perceive, how they conceive their activity, and what they physically do all develop together. What a person brings to a situation comes from his or her knowledge and understanding (Clancey, 1997). The term *knowledge* as applied in this thesis refers in a broad sense to basic physical needs, derivative desires, experiences, expert knowledge, implicit theories on how the physical world behaves, inborn qualities, outcome foci, and self-esteem needs. The term *understanding* as applied in this thesis refers to the ability to perceive the intended meaning of words (Oxford English Dictionary, 2009).

In design, Gero (2002) approaches situatedness by introducing three different kinds of environments that interact with one another:

- The external world is composed of representations outside an agent; it is the part of the overall environment an agent is aware off. The term *agent* as applied in this thesis refers to a person that takes an active role or produces a specified effect (Oxford English Dictionary, 2009). Agents in this sense are autonomous, embodied, engaged, specific, and social: autonomous in that each agent decides by itself what action to take; embodied in that actions by the agent are part of a dynamic with the world and result in sensory feedback; engaged in that they have ongoing interactions with the environment; specific in that actions by the agent constrain its behaviour and provide a context within which one reasons and acts; and social in that they are located in a society of agents (Wilson, 1999).

- The interpreted world exists inside of an agent in terms of sensory experiences, perceptions, and concepts, i.e. it is the internal representation of that part of the external world that the designer interacts with.

- The expected world is the world that imagined actions will produce; it is the environment in which the effects of actions are predicated according to current goals and interpretations of the current state of the world; the expected world is located within the interpreted world.

According to Gero (2002), these three worlds are recursively linked together by three classes of processes: (1) transforming the interpretation of variables sensed in the external world into the interpretation of sensory experiences, perceptions, and concepts that compose the interpreted world; (2) focusing on some aspect of the interpreted world as goals in the expected world and suggesting actions, which if executed in the external world should produce states that reach the goals; and (3) action as an effect that brings about a change in the external world according to the goals in the expected world. The different environments connected to one another form the situation consisting of both the person's external and interpreted worlds. The dynamics of the situation stem from the interaction of the external, interpreted, and expected worlds. Potentially, every change in one of the worlds brings about and is brought about by changes in another world.

Value, as outlined above, is an output of human thought in terms of a cognitive process and consequently it is concluded that value is subject to situatedness.

The situation axiom: Value is subject to situatedness. (Axiom 4)

To model situatedness in terms of world views not only provides insights on the situated characteristic of value, but also provides an opportunity to derive two further conclusions on the phenomenon. The first is based on the assumption that agents interpret entities in the external world. Consequently, value is determined on interpreted entities rather than on entities of the external world, since agents cannot bypass the interpretation process.

Secondly, if value determination of an entity in the external world is based on an entity's interpretation, this suggests that the principles of value determination for both external and interpreted world entities are the same. The determination process in each situation is based on an entity's interpretation. Consequently, the following axiom is derived:

The interpretation axiom: Value is subject to interpretation. (Axiom 5)

The different interpretations of value (Sections 2.2 and 3.5) support evidence on the situation and interpretation axioms per se, in that authors from different disciplines can be seen as interpreting value according to their individual situations and interpretations. However, literature provides further support on the situation and interpretation axioms: Harrison (1998), e.g. argues that value is defined as a concept of what an individual regards as desirable; it may be argued that desire is dependent on the individual situation and interpretation. Allingham (1982) concludes that the value of an asset is defined as a function of usefulness and availability, i.e. two variables dependent on situation and interpretation. Ashworth and Hogg (2000) argue that value is influenced by the conditions of supply and demand, i.e. dependent on situation. Mile (1966) argues that value is the relationship of product worth to product cost, which in turn can be seen as dependent on situation and interpretation. Womack and Jones (1996) and Chase (1990) argue that value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer; the "right time" and the "appropriate price" are dependent on the customer's situation and interpretation. Hamilton (1990) concludes that value is the level of importance that is placed upon a function, item, or solution; this level of importance can be seen as dependent on situation and interpretation. Finally, Holbrook (1994) concludes that *value* refers to a preferential judgement while *values* is used to refer to the criteria by which such judgements are made. It can be argued that preferential judgements are dependent on situation and interpretation - these are criteria by which such judgements are made.

6.4. The entity and criteria axioms

So far, it has been an underlying assumption that value is related to entities because it needs to be the value of “something”. This assumption is supported by the different value approaches provided in literature in terms of the value of an entity, as an activity, and in the sense of an ethics/moral principle. Lamont (1956) argues that value is based on the characteristics of an entity and on those characteristics an entity is said to possess only when it is in relation to some other entity. In the context of value as an activity, it can be argued that “valuing” requires “something” to be valued. Finally, in the context of value as an ethic/moral principle, this principle represents entities per se to which value is ascribed (e.g. the value of honesty). In each case, value is related to an entity.

An analysis of value definitions (Appendix D) from the perspective of entities involved illustrates value referring to entities in terms of assets, end-states of existence, events, exchanges, functions, items, modes of conduct, objects, products, qualities, solutions, things, and “what is regarded as desirable”. The entities are physical (e.g. products) or non-physical (e.g. exchanges) in nature. Numerous definitions (Bailey, 1967; Rokeach, 1973; Najder, 1975; Allingham, 1982; Burns and Woodruff, 1992; Anderson, Jain, Chintagunta, 1993; Hamilton, 1996; Harrison, 1998; Best and De Valence, 1999) refer explicitly to entities. Other definitions (Porter, 1985, Zeithalm, 1988; Chase, 1990; Fowler, 1990; Ashworth, 2000; Cather et al., 2001) do not refer explicitly to entities, but the entities can be derived from the interpretation of the definition’s context. Cather et al. (2001) for example, define value as a capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer in the context of product development. Thus, the definition is interpreted as referring to a “product”. From this it is concluded that value is of “something”, and is therefore related to an entity.

The entity axiom: Value is entity-connected. (Axiom 6)

Another aspect illustrated in the value definition analysis (Appendix D) is that value definitions incorporate criteria ranging from economic criteria, such as “low price” (Zeithalm, 1988), “cost of production” (Ashworth and Hogg, 2000), and the “amount buyers are willing to pay” (Porter, 1985), to human criteria, such as “desirability” (Harrison, 1998), “level of importance” (Hamilton, 1996), and “personally and socially preferable” (Rokeach, 1973). All value definitions utilise at least one criterion suggesting criteria to be a key element of the value phenomenon. This is supported by Zeithalm (1988), who argues that values refer to the criteria by which judgments are made, and Schwartz (2006), arguing that values serves as standards or criteria.

The criteria axiom: Value is criteria-connected. (Axiom 7)

Finally, it should be recognised that some of the criteria are measurable and others are not. This may be seen as related to the ongoing debate in value research on the tangible or intangible nature of value in that intangible value refers to non-measurable criteria (e.g. value in the sense of ethic/moral principles), while tangible value refers to measurable criteria (e.g. value in terms of cost). Furthermore, the measurable criteria may provide a basis to prove or improve value.

6.5. Summary

The set of value axioms outlined in the previous sections can be summarised and the requirements for the theory of value in design can be derived as follows:

- The person axiom (Axiom 1) indicates that value is connected to people. A theory of value in the context of design requires a means to reflect the personal characteristics of the value phenomenon.

- The cognition axiom (Axiom 2) and the determination axiom (Axiom 3) indicate that value is an output of a cognitive process and a value statement requires a determination process. The theory of value in design requires further explanations on the value determination process. A model of value determination provides a means to gain further insights on the phenomenon.

- The situation axiom (Axiom 4) indicates that value is a matter of a given situation. The interpretation axiom (Axiom 5) indicates that value is determined on the interpretation of entities rather than on entities per se. A theory of value in the context of design requires a means to provide explanations on the situated and interpreted natures of value. A model of value determination that integrates theories on situatedness and interpretation provides an opportunity to provide such explanations.

- The entity axiom (Axiom 6) and the criteria axiom (Axiom 7) point to the nature of value to be connected to entities and criteria. A theory of value in the context of design is expected to provide explanations on the relationship among entities, criteria, and value. A model of value determination integrating entities and criteria provides a means to derive the explanations.

The value axioms provide a basis for the development of the theory of value in design. However, the theory requires a model of value determination as a means to derive further insights on value in the context of design in general and the relationships among value determination, situatedness, interpretation, entities, and criteria in particular. Such a model of value determination is proposed in the following chapter.

7. A model of value determination

The value axioms identified in Chapter 6 are seen as formal rules basic to the theory of value. Based on the axioms, value is characterised as connected to people, entities, and criteria; subject to situatedness and interpretation; and the output of a cognitive process. These axioms and in particular the cognition and determination axioms (Section 6.2), support the need for an investigation on the key elements and mechanisms involved in the process of value determination, i.e. the second research question identified in Section 3.7. This chapter provides this investigation by introducing a model of value determination (VDM).

The VDM is based on a generic formalism of design activities, i.e. on cognitive activities that process knowledge. The activities involved in value determination are discussed in detail. The key elements of value determination are summarised and the VDM is reviewed against key characteristics of the value phenomenon, i.e. the value axioms.

7.1. Design process models

Models can be seen as abstract organisational ideas derived from inferences based on observations (Smithers, 1999; Solso, 1991). One of the purposes of building models is to make observations more comprehensible.

Design as a human activity has been studied from a variety of perspectives and there are many attempts in literature to draw up models of the design process[11]. Researchers have reviewed models of the design process (Hubka and Eder, 1992; Cross, 1993; Karandikar and Shupe, 1995; Tate and Nordlund, 1995; Evbuomwan, Sivaloganathan, and Jepp, 1996) and models of the design process have been classified according to whether they are descriptive, prescriptive, or computer-based

[11] A list of considered design process models is provided in Appendix B.

(Dixon, 1987; Finger and Dixon, 1989). Descriptive models are said to describe the sequences of activities that occur in designing while prescriptive models prescribe an improved pattern of design activities (Cross, 1994). Thus, the distinction between descriptive and prescriptive is related to the model purpose. The purpose of the value determination model in the context of the work reported in this thesis is to provide explanations on the cognitive process of value determination "as it is", rather explanations on how value determination ought to be i.e. the model of value determination as provided in this thesis is descriptive in nature.

Despite the variety of design process models in literature, yet, there is no consensus as these models do not depict the reality of design (Hales, 1987). Researchers who view design as a cognitive process have proposed cognitive theories of designing. Smithers (1999) concludes that, since cognitive science as a discipline does not have any well-established theoretical understanding of the cognitive capabilities used during design, the development of cognitive theories of design is not untenable at the moment. He advocated the need for a knowledge level theory of the design process (Nowell, 1981) as a practical alternative to the need for a cognitive theory of designing.

Hubka and Eder (1996) consider design activities as the level of abstraction that the rational cognitive activity in design can be decomposed into. Designing, as a rational cognitive activity, occurs at the knowledge level (Newell, 1981). The knowledge level facilitates the prediction and understanding of design behaviour, without having an operational model of the cognitive processing that is actually being done by the agent (i.e., the designer). Newell argues that although the agent's cognitive activities are internal to the agent, they are relatively stable characteristics that can be inferred from the behaviour and can be conveyed by language.

From a problem solving level of abstraction, Smithers and Troxell (1998) view design as a process of identifying incompleteness, inconsistency, imprecision, ambiguity, and impossibility as statements of requirements. These are then modified and refined into well-formed problem statements from which to generate solutions.

Sim and Duffy (2003) argue in this context, designing as a problem-solving process can be abstracted at the knowledge level as a knowledge process. A design activity is finally defined as "a rational action taken by a design agent to achieve a knowledge change of the design and/or its associated processes (i.e. sequence of action), in order to achieve some design goal" (Sim and Duffy, 2003, p.202).

What is common among design process models is the depiction of the design process as consisting of conceptually distinct stages or activities (Birmingham et al., 1997; Maffin, 1998) that transform the design from a set of requirements to a final design solution. But these models do not explicitly define the design activities but rather the different stages of the design process (Hansen, 1995). In this context, Sim and Duffy (2003) point to the need of an ontology of design activities so that proponents of models or theories of design and practitioners have a shared understanding of what each specific design activity entails. They present an ontology of generic design activities based on published literature and corroborated by design practice. The ontology is seen as providing a consistent and coherent description of the interpretation of typical design activities upon which system developers and design researchers can further work in design research and practice. In this context, Sim and Duffy (2003) propose a generic design activity concept which applies a design activity formalism at the knowledge level. By abstracting design at the knowledge level, a design activity is based on the knowledge of a designer in the context of the evolving design. This is distinct from the design activity related to state(s) of the design according to Hubka and Eder (1996) and Gero (1990).

A model describing the value determination process in the context of design should provide explanations on observable instances of the value phenomenon. Based on the cognition axiom (Section 6.2) value can be seen as output of a cognitive process. Thus, a model of value determination is required to provide explanations on the cognitive activities involved. Since cognitive science lacks well-established theoretical understanding of the cognitive capabilities used during design (Smithers, 1999), there is a need for a knowledge level model of the value determination process. Given these requirements for a value determination model, a rational decision can be made to adopt the generic design activity concept (Sim and Duffy, 2003) which applies a design activity formalism at the knowledge level. The formalism is outlined in the following section.

7.2. Design activity formalism

Cognitive science is the interdisciplinary study of mind and intelligence including artificial intelligence, anthropology, neuroscience, linguistics, philosophy, and psychology (Stanford Encyclopaedia of Philosophy, 2009). Smithers (1999) advocated the need for a knowledge level theory on the design process since cognitive science as a discipline did not have a well-established theoretical understanding of the cognitive capabilities used during designing.

The notion of knowledge level was introduced by Newell (1981) as a way to rationalise the behaviour of an agent. The agent acts based on knowledge it possesses in an attempt to reach specific goals. It chooses actions according to the principle of rationality. Beneath the knowledge level resides the symbolic level. Whereas the knowledge level is "world oriented", i.e. concerned with the environment in which the agent operates, the symbolic level is "system oriented", and includes the mechanisms the agent has available to operate.

The origins of human knowledge may be summarised in terms of three positions: (1) a person is born with innate knowledge, i.e. nativism; (2) knowledge is learned through experience, i.e. empiricism; and (3) knowledge is produced through some reasoning process, i.e. rationalism (Kemp, 1976). However, no definition of knowledge is universally accepted by all researchers. According to Nowell (1980), knowledge may be described as whatever can be ascribed to an agent, such that its behaviour can be computed according to the principle of rationality.

Knowledge can be categorised as either tacit or explicit (Nonaka and Takeuchi, 1995). Tacit knowledge can be further classified as: declarative (know what), procedural (know how), and causal (know why). Tacit knowledge is personal, context-specific, and therefore hard to formalise and communicate. Explicit knowledge refers to knowledge that is transmittable in a formal and systematic language (Sim, 2000).

Within design, Zhang (1999) categorised the knowledge involved in the design process in terms of: design knowledge concerned with the nature of the design artefact; design activity knowledge related to how particular design activities can be carried out; and design process knowledge about how design activities can be organised and how the design process can be executed. Design knowledge can be further decomposed into working knowledge, i.e. knowledge the designer is working on at a particular moment in time, and domain knowledge, i.e. knowledge of past designs in a domain. Domain knowledge consists of general knowledge that can be used in different design cases and specific knowledge of past design cases. Overall, design knowledge is declarative, while activity and process knowledge is procedural.

By defining a design activity at the knowledge level, the input and output to the activity are basically design knowledge that can be represented by some symbolic structure. The input knowledge to the design activity is influenced by the agent's perception of the design context. A goal prompts an action that entails the selection of relevant knowledge to process input knowledge to output knowledge. The output of a design activity may be some symbolic structure believed by the design agent to represent a solution (or partial solution) to the original goal. However, because the design agent is governed by the PBR[12], no such solutions may be produced; instead a new goal results. This output goal prompts a new design activity to be invoked and so the design process proceeds. In general, a design goal may cause several design activities to be performed in sequence or in parallel. The process terminates when the original design goal is achieved or when no further action is being performed by the

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[12] The Principle of Bounded Rationality (PBR) states, that given a goal, an agent may not possess perfect or complete knowledge of, or be able to economically compute or access, the correct action that will lead to the attainment of the goal.

agent (Sim and Duffy, 2003). Thus, the basic elements of a design activity (A_d) may consist of:

- Knowledge that directs the activity, Goals (G_d);
- Knowledge presented prior to the activity, Input knowledge (I_k); and
- Knowledge presented as a result of the activity, Output knowledge (O_k).

Sim and Duffy (2003) suggested that the basic elements of a design activity (A_d) may be related as shown in Figure 7-1:

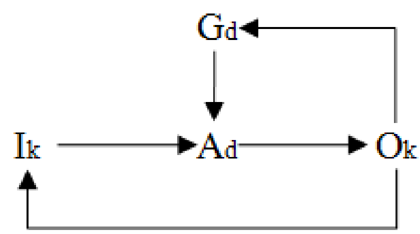

Figure 7-1: Design activity formalism

The concept adopted is that knowledge can be differentiated and structured into different types of design activities. Input knowledge (I_k) can be categorised as tacit or explicit knowledge (as outlined above). Goals (G_d) can be specified or derived. Specified goals are those inferred from the design requirements. Derived goals are those invoked in the course of the design process. This may lead to a sub-goal hierarchical relationship. Output knowledge (O_k) stems from the application of the activity based upon input knowledge, to enable the design to progress towards the design goals. The output of each activity therefore contributes to a change in the knowledge of the design. As such, the design agent acquires additional knowledge of the design. With the acquired knowledge, the design agent may act rationally or competently by invoking the next activity that may bring the design nearer to the final solution. The nature of the output knowledge is therefore dependent on the design activity and the evolving design solution (Sim and Duffy, 2003).

In the generic design activity concept Sim and Duffy (2003) adopt an IDEF0 modelling techniques. This modelling technique is particularly suitable to model value determination because: a process can be represented without fixed start and end points; activities can be represented in terms of knowledge processed within it; activities can be represented in relation to each other independent of sequence; each activity transforms knowledge input to output and the internal mechanisms of the transformation may not be modelled, i.e. it is not required to know internal mechanisms; and each activity or process can be partitioned to show details on another diagram, ensuring a single diagram does not become too cumbersome. Furthermore, IDEF0 models share positive characteristics with data flow diagrams in that they are capable of top down analysis, are easily readable because of their graphical nature, and the consistency of the diagrams can be easily checked. However, there are also disadvantages of the IDEF0 diagrams, e.g. they can give a "false sense" of sequence, and it is difficult to decide where some of the data originates. Without fixed start and end points a description may be required in addition to the model.

In summary, the generic design activity concept (Sim and Duffy, 2003) provides a means to model value determination. The knowledge level provides a means of abstracting away from the particularities of human cognition; design activities can be considered as the level of abstraction that the rational cognitive activity in design can be decomposed into. This may support the explanative characteristics of the value determination model.

The following section outlines the generic design activity concept (Sim and Duffy, 2003) as adopted in the context of value determination.

7.3. Value determination activity

In modelling value determination, the generic design activity concept (Sim and Duffy, 2003) is applied. This formalism provides a means to model in terms of a shared understanding of design activities and of abstracting away from the particularities of human behaviour.

The value axioms in Section 6.2 characterise value as the output of a cognitive determination activity. This activity is introduced here as the activity of value determination (A_{vd}). A model of the A_{vd} is illustrated in Figure 7-2:

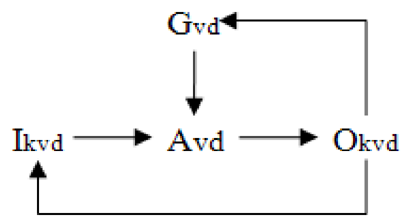

Figure 7-2: Activity of value determination

The model of the activity of value determination applies the following terminology:

A_{vd}	=	Activity of value determination
G_{vd}	=	Goal of value determination
I_{kvd}	=	Input knowledge to value determination
O_{kvd}	=	Output knowledge of value determination

The value determination activity (A_{vd}) is a cognitive activity aimed towards determining value (G_{vd}). This activity processes input knowledge (I_{kvd}) into output knowledge (O_{kvd}). The following classes of knowledge are involved:

- Input knowledge (I_{kvd}) refers to the initial knowledge of an agent, i.e. knowledge prior to the value determination activity. The input may be an interpreted entity. The entity may exist in the agent's external world (e.g. a physical product) or in the agent's interpreted world (e.g. an idea). However, to determine value on external world entities, the entities are interpreted by the agent and therefore become part of the agent's internal world. Thus, no differentiation is required here for value determination on external or internal world entities.

- The goal (G_{vd}) refers to knowledge that directs and constrains the value determination activity. Goal knowledge refers to a future situation, which is perceived by the goal originator to be more desirable than the current situation. Goals in design are almost ubiquitous, although they are often implicit or ill-defined (O'Donnel, 2000). The overall goal in value determination is a determined value expressed in terms of an explicit or implicit value statement

- Output knowledge (O_{kvd}) of value determination is a value statement (e.g. "An entity is of value.") on the entity under consideration. This value statement may be seen as an increase to the agent's design knowledge and may prompt a new design activity to be invoked and so the design process proceeds.

In abstracting the value determination activity to a knowledge level model, an agent is represented as a knowledge resource. People are generally viewed as the core resources in design (Frankenberger, Brandke-Schaub, and Birkhofer, 1997), but other resources, such as methods, techniques, and tools are also used and may be categorised among human, material, and informational (Eynard, Girard, and Doumeingts, 1999). However, for value determination purposes, all resources may be represented as forms of knowledge that can be utilised within the cognitive process.

In the context of the value determination activity, the term knowledge is applied in a broad sense that includes tacit and explicit knowledge. It should be noted that for the purpose of modelling value determination, this knowledge also includes desires, ethic/moral principles, experiences, goals, implicit theories on how the physical world behaves, inborn qualities, outcome foci, and needs. This interpretation of knowledge provides a means to integrate value-related concepts from other disciplines (e.g. Maslow's "Hierarchy of need" from the "Theory on Human Motivation" (Gree, 2009)) into the theory of value in design. This looks at desires, experiences, needs, etc. in terms of knowledge resources utilised in value determination.

While the model of the value determination activity provides a means to derive declarative knowledge on the value phenomenon, it does not provide procedural insights, i.e. knowledge on "how" value is determined. The model also does not support explanations on the criteria-connected characteristics (Axiom 7) of the value phenomenon. Therefore, a more detailed analysis of value determination is required. This analysis is provided in the following section.

7.4. Criteria selection and judgement activities

Section 7.3 provided general explanations on the elements involved in the value phenomenon and their relationships. A model of the value determination process is developed in the following sections as a means to provide further insights on the phenomenon.

The model of the value determination activity illustrates that knowledge of an interpreted entity is processed in value determination towards a value statement. In terms of logic, the value statement can be interpreted as a declarative sentence that is either true or false (Strawson, 1952). This indicates that a value statement can be seen as the output of a cognitive judgement. In formulating judgements, a formal process of evaluation applies. This formal process can be described as a set of criteria that must be satisfied in order for a judgement to be made. Thus, it is argued here that value determination involves a judgement activity.

In general terms, criteria in value determination are dependent on the agent's knowledge. This is, for example: first, because an agent not knowing a criterion is not able to consider this for a judgement; second, dependent on an agent's knowledge that the agent may or may not consider certain criteria; and third, because an agent may judge value based on knowledge, e.g. on standards and roles within a certain community. Criteria applied for value determination are introduced here as value criteria.

In formulating a value statement, agents must select value criteria from their knowledge. In selecting the criteria, the agent must consider knowledge on the interpreted entity. In other words, agents in selecting criteria establish a cognitive link between the interpreted entity and the set of criteria required to formulate the value judgement. Thus, there is a need for a criteria selection activity as the activity of selecting and connecting criteria to interpreted entities. The relationship between a judgement based on criteria and the criteria selection activity is illustrated.

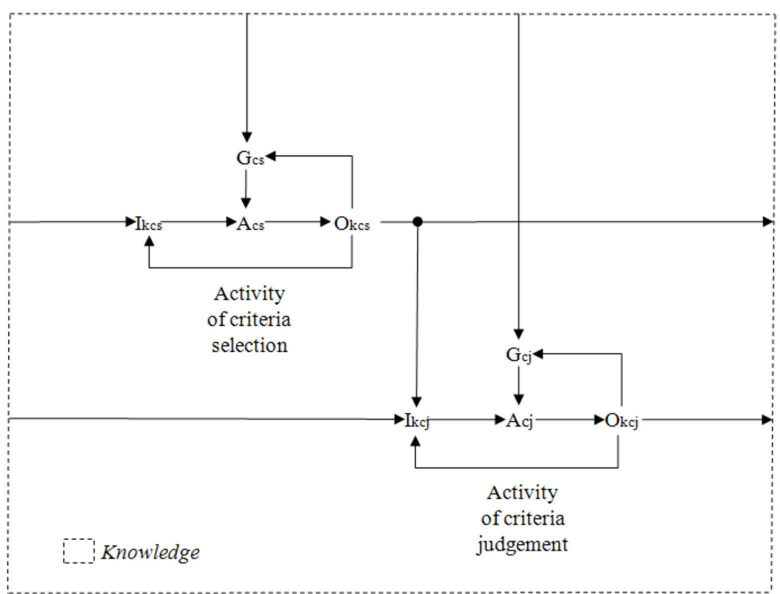

Figure 7-3: Criteria selection and judgement

The following terminology is applied in Figure 7-3:

A_{cs} = Activity of criteria selection

G_{cs} = Goal of criteria selection

I_{kcs} = Input knowledge to criteria selection

O_{kcs} = Output knowledge of criteria selection

A_{cj} = Activity of criteria judgement

G_{cj} = Goal of criteria judgement

I_{kcj} = Input knowledge to criteria judgement

O_{kcj} = Output knowledge of criteria judgement

The criteria selection activity (A_{cs}) is the cognitive activity of selecting criteria for value determination based on an agent's knowledge. The following classes of knowledge are involved:

- The Goal of criteria selection (G_{cs}) may be described in terms of a selected criterion or a set of selected criteria.

- Input knowledge (I_{kcs}) refers to knowledge on the entity under consideration. This may include knowledge of past designs in a domain, e.g. criteria that can be used in different design cases, and knowledge on criteria from specific past design cases. However, knowledge on the interpreted entity must be included as a basis to select appropriate criteria for judgement.

- Output knowledge (O_{kcs}) is a criterion or a set of criteria that serves as input knowledge (I_{kcj}) to criteria judgement. The selected criteria provide a contribution to the agent's overall knowledge.

The criteria judgment activity (A_{cj}) is a cognitive activity judging to what extent the interpreted entity satisfies criteria. The following classes of knowledge are involved:

- Input knowledge (I_{kcj}) refers to knowledge on the criteria to be applied, i.e. output knowledge (O_{kcs}) from the criteria selection activity (A_{cs}) and knowledge of the interpreted entity.

- The goal of criteria judgement (G_{cj}) is a judgement on the extent criteria are satisfied.

- Output knowledge (O_{kcj}) refers to the knowledge of an overall judgement on the extent individual criteria are satisfied by the interpreted entity. This knowledge is expressed in terms of a value statement and provides a knowledge contribution to the agent.

The criteria selection (A_{cs}) and judgement (A_{cj}) activities terminate if criteria are identified or a value statement is derived. However, because the design agent is governed by the PBR as outlined in Section 7.2, no such solutions may be produced; instead new goals result that invoke new design activities.

Overall, the value determination activity (A_{vd}) is modelled here in terms of two sub-activities: (1) criteria selection (A_{cs}), selecting criteria for value determination based on the interpreted entity under investigation; and (2) criteria judgement (A_{cj}), judging the extent individual criteria are satisfied by the interpreted entity. This "extent of criteria satisfaction" is expressed in terms of a value statement as the output knowledge of value determination. From this, it can be concluded:

***Value* refers to a judgement on the extent**
an interpreted entity satisfies an agent's criteria.

From the criteria selection (A_{cs}) and judgement (A_{cj}) activities, it can be concluded that criteria represent key elements in value determination. The following section introduces a personal criteria system as a means to provide further explanations on the value phenomenon.

7.5. Criteria prioritisation activity

Value, as outlined in Section 7.4, refers to a judgement on the extent an interpreted entity satisfies criteria. From the criteria selection and judgement activities it can be concluded that criteria are key elements of value determination. In design, criteria vary considerably because agents consider a range of different aspects such as cost, flexibility, lead-time, performance, quality, and/or risk. However, it may be argued that expert knowledge of an agent is not the exclusive resource for criteria selection, but rather criteria selection makes use of an agent's entire knowledge as interpreted in a broad sense, including desires, experiences, needs, etc. as outlined in Section 7.3.

The criteria selection activity (A_{cs}) provides a means for explanations of activities involved in criteria judgement, but lacks support on "how" criteria are selected. What is suggested here is that criteria selection involves a selective use of criteria derived from an agent's personal criteria system. This concept provides a means for the value determination activity (A_{vd}) to take into account that designers in real life determine value as experts in their domain, but at the same time inseparable as human beings.

The personal characteristic of value is approached in the value determination activity by an agent's individual knowledge and consequently by individual criteria selected for value determination. The mechanisms involved in this selective use of criteria may be described analogous to mechanisms involved in personal value systems (Rokeach 1973) in terms of an enduring organisation of beliefs concerning preferable modes of conduct or end states of existence along a continuum of relative importance. However, what is suggested here is not to introduce an enduring organisation of beliefs, but rather an enduring organisation of criteria with relative importance, i.e. a personal criteria system for value determination.

To introduce personal criteria systems for value determination rather than adopting value systems as defined by Rokeach (1973) provides an alternative perspective on values in the sense of ethic/moral principles, i.e. on human values. Human values can be interpreted as synonyms for criteria applied in value determination, rather than as values per se. A person holding the “value” friendship, for example, may consider criteria such as honesty for value determination, while one holding business success as a “value” may determine value based on criteria such as effectiveness and efficiency. Overall, what is suggested here is that agents hold personal criteria systems, i.e. personal and ongoing systems of criteria and their priority. Personal criteria may be shifted on a priority list; new criteria may appear on the list, while other criteria may disappear if they are no longer appropriate. The personal criteria system provides a means to reflect the agent’s individual preference of criteria in value determination.

The more general characteristics of personal criteria systems may be analogous to the mechanisms of personal value systems, as outlined by Williams (1968). However, the system described here is a system of personal criteria, and not a system of values: “It is the rare and limiting case, if a person’s behaviour is guided over a considerable period only by one criterion. More often particular acts or sequences of acts are steered by multiple and changing clusters of criteria. After a criterion is learned, it becomes integrated somehow into an organised system of criteria wherein each criterion is ordered in priority with respect to other criteria. Such a relative conception of criteria enables us to define changes as a reordering of priorities and, at the same time, to see the total criteria system as relatively stable over time. It is stable enough to reflect sameness and continuity of a unique personality socialised within a given culture and society, yet unstable enough to permit rearrangements of criteria priorities as a result of changes in cultural, societal, and personal experiences. Variations in personal, societal, and cultural experiences will not only generate individual differences in criteria systems but also individual differences in their stability. Both kinds of individual differences can reasonably be expected as a result of differences in such variables as intellectual development, degree of internalisation of cultural and institutional criteria, identification with sex roles, political identification, and religious upbringing.”

Another important aspect of the introduction of personal criteria systems can be seen in providing a means for a consistent value approach across the different interpretations of value (Section 3.7) as the value of an entity, as an activity, and as human values; in each case, value determination can be seen as based on personal criteria systems.

In general terms, personal criteria systems provide a means to support explanations on the personal characteristic of value based on a personal prioritisation of criteria applied in value determination. This can be formalised in terms of a criteria prioritisation activity in the context of criteria selection as outlined in Figure 7-4.

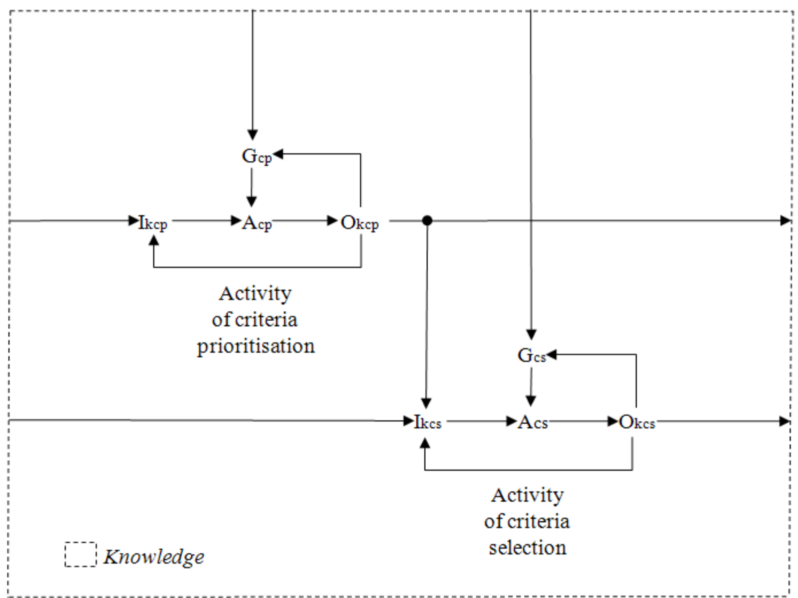

Figure 7-4: Criteria prioritisation and selection

The following terminology is applied to formalise criteria prioritisation (A_{cp}):

A_{cp}	=	Activity of criteria prioritisation
G_{cp}	=	Goal of criteria prioritisation
I_{kcp}	=	Input knowledge to criteria prioritisation
O_{kcp}	=	Output knowledge of criteria prioritisation

The criteria prioritisation activity (A_{cp}) is an ongoing cognitive activity shifting criteria on a personal criteria priority list, adding new criteria to the list, and removing criteria as appropriate.

- The goal of criteria prioritisation (G_{cp}) is "up-to-date" prioritised criteria.

- Input knowledge (I_{kcp}) refers to an agent's knowledge in a broad sense.

- Output knowledge (O_{kcp}) refers to an up-to-date list of criteria at the moment in time when criteria are required for criteria selection in the context of a specific interpreted entity. Output knowledge (O_{kcp}) is the input knowledge to criteria selection (I_{kcj}).

The criteria selection activity (A_{cs}) is seen as capturing a "snapshot" of prioritised criteria from the A_{cp} at the time criteria selection is required.

7.6. Value determination model

Having established the criteria selection (A_{cs}) and judgement (A_{cj}) activities in Section 7.4 and the criteria prioritisation activity (A_{cp}) in Section 7.5, a model of the value determination process is illustrated:

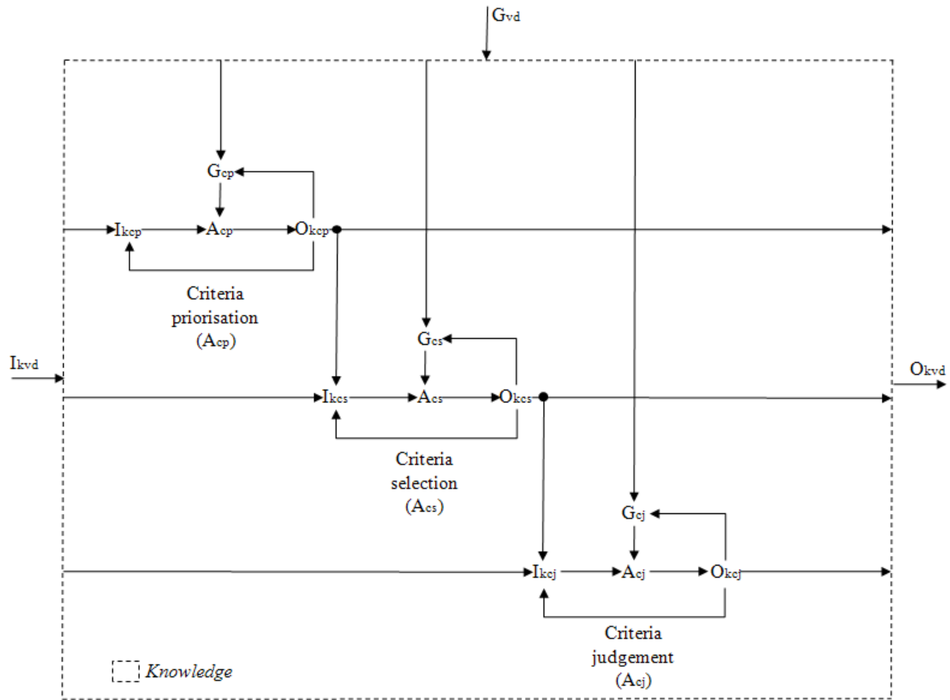

Figure 7-5: Value determination model (VDM)

The model of the value determination process illustrates the activities involved in value determination. Value determination is modelled here in terms of activities aimed towards determining value (G_{vd}) by processing input knowledge (I_{kvd}) of an interpreted entity into output knowledge (O_{kvd}) in terms of a value statement. The process may be described as follows:

Knowledge of an interpreted entity is provided to criteria selection (A_{cs}) as input knowledge (I_{kcs}). To make a selective use of criteria, criteria selection (A_{cs}) prompts criteria prioritisation (A_{cp}) to provide up-to-date and prioritised criteria as input knowledge. Based on knowledge of the interpreted entity and knowledge of up-to-date criteria, criteria selection (A_{cs}) makes a selective use of criteria in the context of the interpreted entity and provides the selected criteria to criteria judgement (A_{cj}) as input knowledge (I_{kcj}). Criteria judgement investigates the extent criteria are satisfied by the interpreted entity and provides a value statement as the output knowledge (O_{kcj}).

The value axioms identified in Chapter 6 are related to the VDM as illustrated in Figure 7-6.

- The person axiom (Axiom 1) is considered in the VDM in terms of personal knowledge as a resource of value determination and in particular in terms of input knowledge to value determination (I_{kvd}), criteria prioritisation, (I_{kcp}), selection (I_{kcs}), and judgement (I_{kcj}); and knowledge on the goals of value determination (G_{vd}), criteria prioritisation (G_{cp}), selection (G_{cs}), and judgement (G_{cj}).

- The cognition axiom (Axiom 2) and determination axiom (Axiom 3) are considered in the VDM in that value is interpreted as the output knowledge (O_{kvd}) of a cognitive value determination process based on the output knowledge (O_{kcp}, O_{kcs}, O_{kcj}) from criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement (A_{cj}).

- The situation axiom (Axiom 4) is considered in the VDM in that value is interpreted as the output knowledge (O_{kvd}) of a cognitive value determination process based on an agent's knowledge and in particular on the input knowledge to value determination (I_{kvd}), criteria prioritisation (I_{kcp}), selection (I_{kcs}), and judgement (I_{kcj}). The personal criteria system in terms of the criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement activities (A_{cj}) represent further elements related to the situated characteristic of value.

- The interpretation axiom (Axiom 5) and entity axiom (Axiom 6) are considered in terms of an entity's interpretation as the input knowledge to value determination (I_{kvd}) and the criteria selection activity (A_{cs}) that establishes a cognitive link between the interpreted entity and the criteria selected for judgement.

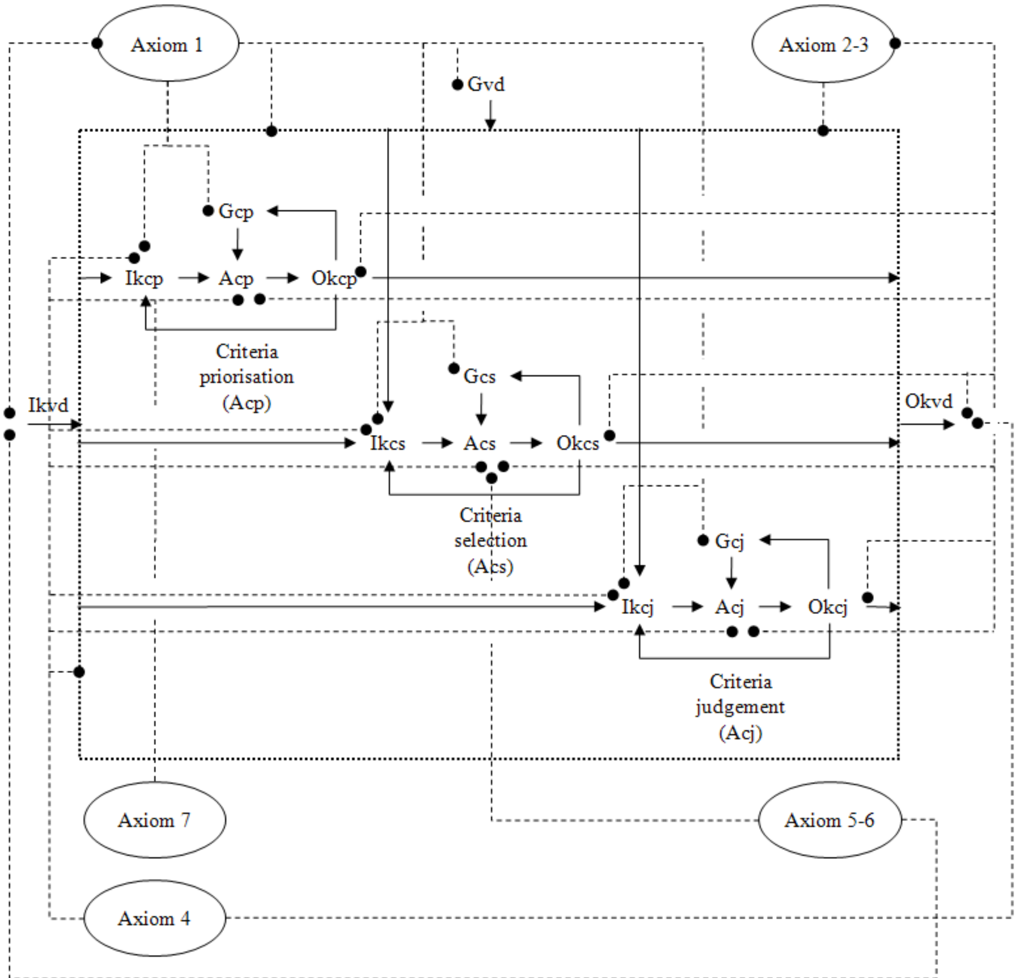

Figure 7-6: Relationship of value axioms to VDM constructs

- The criteria axiom (Axiom 7) is considered in terms of the criteria prioritisation (Acp), selection (Acs), and judgement activities (Acp). Overall, value according to the VDM refers to the judgement on the extent an interpreted entity satisfies criteria.

From the investigations on the relationships it can be concluded that the key elements of the VDM are consistent to the value axioms identified in Chapter 6.

7.7. Summary

In this chapter a model of value determination was introduced. Based on the need for a knowledge level model of a cognitive value determination process, a rational decision was made to adopt the generic design activity concept (Sim and Duffy, 2003), i.e. a design activity formalism at the knowledge level (Section 7.1). The design activity formalism was outlined (Section 7.2). Value determination was then modelled as a knowledge processing activity defining its goal, inputs, and outputs (Section 7.3). Further investigations identified criteria selection and judgement (Section 7.4) and criteria prioritisation (Section 7.5) as activities involved in value determination. Based on the activities identified, a model of value determination (VDM) was illustrated. The relationship between key elements of the value determination model and the value axioms identified in Chapter 6 were investigated and it was concluded that the value determination model is consistent to the axioms (Section 7.6).

In the review of value theories (Chapters 2 and 3), a need was identified to investigate the relationship of value to related phenomena (Section 3.7). The value axioms identified in Chapter 6 and the value determination model introduced in this chapter provide a means for investigations on this relationship, as outlined in Chapter 8.

8. Exploration of value-related phenomena

A model of value determination (VDM) was provided in Chapter 7 and it was argued that value refers to a judgement on the extent that an entity satisfies criteria. The VDM is based on value axioms identified in Chapter 6 and on the generic design activity concept (Sim and Duffy, 2003) outlined in Section 7.2. The VDM and the axioms provide support on an investigation of value-related phenomena, i.e. on the third research question identified in Section 3.7. This chapter provides an investigation on added value, on exchange and perceived values, on the relationship of value to benefit and need, and on the relationship between value types as key phenomena inherent to the value discussion.

8.1. Added value

In Chapter 7 it was concluded that value, expressed in terms of a value statement, refers to a judgement on the extent an interpreted entity satisfies criteria. The value determination activity (A_{vd}) is a cognitive activity that processes an agent's knowledge of an interpreted entity into a value statement. Value determination as a cognitive process is situated and dependent on an agent's knowledge at the time of value determination. In this context, the following variables are involved:

E	=	Interpretation of an entity
S	=	Situation of an agent
K	=	Knowledge of an agent
A_{ei}	=	Activity of entity interpretation
A_{cp}	=	Activity of criteria prioritisation
A_{cs}	=	Activity of criteria selection
A_{cj}	=	Activity of criteria judgement

In the context of situatedness and knowledge, the variables provide a fundamentally different view on value and suggest a non-static value world. An agent's situation, knowledge, and interpretation as well as criteria prioritisation, selection, and judgement, are seen as the key variables of value determination. A change in these variables is suggested to influence a value statement as follows:

- Situation (S): Research in situated cognition, as outlined in Section 6.3, claims that every human thought and action is adapted to the environment in which it is situated (Clancey, 1997). Situatedness is approached by Gero (2002) in terms of three different kinds of environments that interact with one another: the external, interpreted, and expected worlds. The different environments connected to one another form an agent’s situation. What is suggested here is that changes in an agent’s external, interpreted, and/or expected world provide a means to influence the agent’s value statement. The realisation of a physical prototype, for example, may represent a change in an agent’s external world in that a design proposal becomes available to the agent’s sensory experience that was not available before. Consequently, an agent may apply different or additional criteria or judge the degree of satisfaction on certain criteria differently.

- Knowledge (K): An agent’s knowledge, as outlined in Section 7.2, refers to tacit and explicit knowledge. A change in an agent’s knowledge may lead to different interpretations of entities and different priorities, selections, and judgements on criteria. In other words, changing an agent’s knowledge is fundamental to changes in value statements.

- Entity Interpretation (A_{ei}): An agent’s interpretation transforms variables sensed in the external world into interpretations of sensory experiences, precepts, and concepts that compose the interpreted world (Wallace, 2006). Therefore, there are three alternatives to influence an agent’s value statement based on a change in interpretation: (1) changing the agent’s sensory experiences, e.g. in providing a physical prototype someone can touch; (2) changing the knowledge on general rules regulating the agent’s behaviour or thoughts, e.g. on the basis of incentives; and (3) changing the agent’s knowledge on the general concepts one keeps in mind on "how the world works", e.g. based on information on future market trends.

- Criteria prioritisation (A_{cp}): An agent's input knowledge to criteria prioritisation (I_{kcp}) refers to an agent's tacit and explicit knowledge (K) as outlined above. Changes in this knowledge may lead to different criteria considered in the personal criteria system and/or to different criteria priorities. In this context, it should be noted that knowledge (K) processed in value determination (A_{vd}) is dependent on the point in time when value is determined. In particular, output knowledge of criteria prioritisation (O_{kcp}) is time dependent, in that the prioritised criteria represent a "snapshot" of the criteria and those priorities derived from the personal criteria system at the time of value determination.

- Criteria selection (A_{cs}): The input knowledge to criteria selection (I_{kcs}) is knowledge on the interpreted entity and prioritised criteria from the criteria prioritisation activity (A_{cp}). Thus, a change on the interpretation of entities and/or a change in criteria and their priorities may lead to different output knowledge (O_{kcs}).

- Criteria judgement (A_{cj}): Criteria judgement (A_{cj}) refers to a judgement on the extent an interpreted entity satisfies criteria. Depending on knowledge, an agent may judge differently. However, judgement on the extent of criteria satisfaction may also depend on the resources available at the time of value determination in terms of tools, techniques, and methods. A designer with access to thermodynamic simulation techniques, for example, may come up with more or less precise results on the extent an entity satisfies certain criteria and judge accordingly. From a value determination perspective, resources can be seen as a means to change criteria judgement, which may lead to a different value statement.

Overall, a change to an agent's knowledge is fundamental to changes to an agent's value statement. Changing an agent's situation, interpretation, and criteria prioritisation, selection, and judgement provide a means for a change in value statements. Although these changes provide an opportunity to influence value statements, by no means is there a guarantee for a value statement change. This is because an agent: may not consider a change as relevant and ignore the change; may consider a change as relevant but not change criteria priority, selection, and judgement; or may change the value criteria but judge the extent of criteria satisfaction as before.

Value refers to a judgement on the extent an interpreted entity satisfies an agent's criteria (Section 7.4). From this perspective, added value may be interpreted as an increase in the extent an entity satisfies criteria. The previous paragraphs identified opportunities to change a value statement. However, the change that may occur in the value statement lacks control towards an increase in the extent an entity satisfies criteria, which may be seen as related to the terminology of value adding as frequently used in literature. The following provides explanations on the mechanisms involved.

In criteria selection (A_{cs}), agents select specific criteria in the context of the interpreted entity (Section 7.4). In doing so, agents establish a cognitive link between the interpreted entity and criteria because they select criteria in the context of the entity, i.e. agents add criteria cognitively to the entity. The selected criteria are the input to criteria judgement (A_{cj}) and consequently the basis for the value statement. In other words, the selective use of criteria makes a value statement entity specific. Adding value in the context of the cognitive link established by an agent may then be interpreted as the activity of adding criteria increasing the degree of satisfaction and/or replacing added criteria with more satisfactory ones.

8.2. Exchange value

Explanations on exchange value represent one of the ongoing issues throughout the value domain. An often cited interpretation of exchange value is, “the quantity of money for which a thing can be exchanged” (Marx, 1872; Allingham, 1982; Sparks, 2001). However, there is no consensus on the exchange value phenomenon in literature. This section provides an explanation on the nature of exchange value based on the value determination process.

Exchange value interpreted in terms of the VDM refers to a specific situation where two entities are involved but the focus of value determination is on the entity’s “exchange” rather than on the entity’s value statement per se. The value determination activity (Avd) in this particular situation is illustrated.

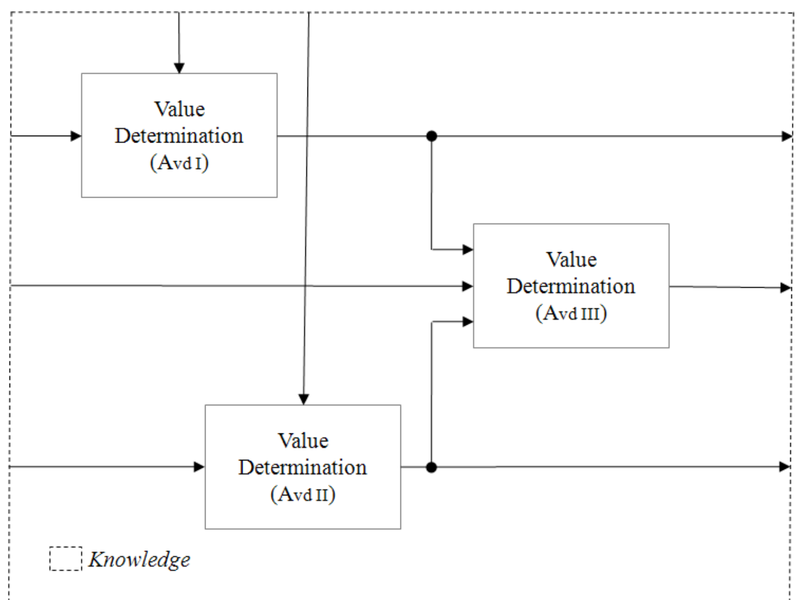

Figure 8-1: Value determination on exchange

An agent in the situation to judge value on the exchange of entities (e.g. money against a product) determines the value of these entities (Avd I, Avd II), which results in value statements. The value statements become the input knowledge to value determination on the “exchange” of the entities (Avd III). The value statements determined in A_{vd} I and II are seen as the input knowledge to A_{vd} III, but may not be of relevance to the value determined on the "exchange" of the entities. This is because in determining value on the "exchange" of the entities, criteria other than the value of the individual entity may be applied. In a situation where, for example, the exchange of a product against money is considered, an agent may come to the conclusion that the product satisfies the agent's criteria to a higher extent than the money. However, in determining value on the exchange of the product against money, the agent may apply a criterion such as "saving money to reduce risk" and come to the conclusion that the value of the entity's exchange is low. Finally, it should be noted that more than two entities may be involved in the determination of value on exchange.

So far, exchange value has been considered from the perspective of a single agent. Thus, exchange value does not require the exchange of entities between agents. In practice, however, exchange value is also determined in multi-agent environments, i.e. between agents. According to the VDM, these agents may come up with different value statements on entities they consider because of, e.g. the agents' individual knowledge. It should be noted here that agents in a multi-agent environment may tend to agree on the exchange of entities if they come up with opposing value statements. For example, in an agreement on the exchange of agent A's money against agent B's product, A may determine that the extent the product satisfies criteria is high and that of money is low, while B may determine that the extent money satisfies criteria is high and that of the product is low. Consequently, the agents may agree on the entity exchange. Value determination in the context of a multi-agent environment is recommended as an area for future work (Section 11.7.3).

Overall, exchange value refers to the extent an "exchange of entities" satisfies an agent's criteria. What is exchanged here is not value, but rather entities linked to value statements.

8.3. Perceived value

The concept of perceived value in literature is poorly differentiated from value types such as those investigated in Section 3.6 . Various interpretations of perceived value have been offered in marketing literature (Anderson, Jain, and Chintagunta, 1993; Zeithalm, 1988), whereby Zeithalm's interpretation (1988) is commonly cited as the customer's overall assessment of the utility of a product based on perceptions of what is received and what is given.

The VDM illustrates value as the output of a cognitive process, where value refers to the extent an interpreted entity satisfies criteria. Thus, value is not perceived in the sense of the ability to see, hear, or become aware of something through senses. However, what may be perceived in value determination is an entity in the agent's external world. That is, an interpreted entity is the input knowledge to value determination and this entity may be perceived through the senses. Consequently, it is suggested to apply the terminology of determined value and perceived entity, rather than perceived value.

Another interpretation of perceived value is related to the idea of receiving and providing value analogous to physical products. As outlined above, value is interpreted as the output of a cognitive process and requires determination. Consequently, value cannot be received or provided, i.e. one cannot "transfer" value. Even if there would be a consensus by the agents involved in value determination on the interpreted entity and criteria priority, selection, and judgement, by no means is value transferred from a conceptual point of view.

Overall, an interpreted entity is input knowledge to value determination (A_{vd}). This entity may be perceived based on an agent's senses in the case that the entity exists in the agent's external world.

8.4. Value and benefit

An ongoing issue in research on value is its relationship to benefit. Anderson, Jain and Chintagunta (1993), for example, define value in business markets as the perceived worth in monetary units of the set of economic, technical, service, and social benefits received by a customer's firm in exchange for the price paid for the product offering, considering alternatives. As with other related terms in value research (e.g. need), benefit has several distinct meanings. In the context of design, for example, Sparks et al. (2001) state that "good" design brings economic, social, and environmental benefits. Although it is not in the scope of this thesis to define benefit, in general the term refers to an advantage or profit, something that adds or promotes well-being, and/or something that is "good" or "helpful" (Oxford English Dictionary, 2009).

An underlying assumption in value literature on the relationship between benefit and value is that a benefit ascribed to an entity makes the entity "valuable". However, based on the VDM there are fundamental differences between a benefit and a value:

- A benefit refers to an advantage or profit, while value refers to a value statement, i.e. to the extent an entity satisfies criteria.

- A benefit with high value to one agent may be of no value to another, although it is the same benefit. That is, a benefit may be the input knowledge to value determination and judged on the extent the benefit satisfies value determination criteria.

- An entity providing a benefit by no means must be an entity of value; it is only in the specific case where criteria in value determination are related to the benefit (e.g. an advantage) that a "beneficial" entity may be of value to an agent.

- An entity may provide a benefit, but value may not be determined at all.

From this it is concluded that a benefit is related to value in that a benefit (or beneficial entity) may serve as the input knowledge to value determination.

8.5. Value and need

The relationship between value and need is an ongoing issue in value research. Fowler (1990), for example, argues that a product must fulfil a user's need or want in order to have value, and the British Standards Institution (2000) refers to value as the relationship between the contribution of the function to the satisfaction of the need and the cost of the function. The following paragraphs provide explanations on this phenomenon.

Three main interpretations of the concept of need can be found in literature (Thomson, 1987; Thomson, 2005): (1) needs that drive behaviour are often seen as equal to desires; (2) needs that are considered so essential that claims of getting them satisfied become justified; and (3) needs that are requisites for achieving something.

Need and behaviour are considered to be linked in Maslow's Theory on Human Motivation (1943), in that an unsatisfied need serves as a motivator for action. According to Maslow (1943), the perfectly healthy, normal, fortunate man has no sex or hunger needs, or needs for safety, love, prestige, or self-esteem, except in stray moments of quickly passing threat. However, Max-Neef (1991) argues that needs should be understood within a broader context and time frame in that they are not only immediately felt and occasionally lack resources, but are more permanent drivers for action. Also, the perfectly healthy man may understand that acting towards establishing a safe environment makes sense, even though there are no immediately felt threats. Hence, human action can be seen to be driven by both satisfied and unsatisfied needs at any particular point in time. These motivational needs are subjective and contextual, and may vary depending on the choices available.

The notion of basic need (Thomson, 1987) is sometimes used to refer to what is necessary for survival or for minimal subsistence. Working to satisfy basic instead of general needs in Maslow's (1943) terms leads to the notion of fundamental needs (Thomson, 1987; Thomson, 2005) being linked to political decision making concerning the fair allocation of limited resources in social politics (Percy-Smith, 1995), global economics (Brock, 2005), or ecologically sustainable development (Wiggins, 2005). The identification of fundamental needs among a population can be used as an argument for corrective actions taken by another population who has the means to satisfy the needs, and thus, the concept of fundamental needs is interpreted as normative (Thomson, 1987; Max-Neef, 1991; Percy-Smith, 1995; Brock, 1998). According to Wiggins (1998), the fundamental needs of A should be given priority over the desires of B. Lowe (2005) suggests that needs have the right sort of logical shape to constitute reasons for (moral) action. According to Lowe (2005), a moral actor being in a position to influence others works on satisfying fundamental needs prior to and rather than just gratifying desires. This interpretation of need may be related to ethical design in that designers enable users to take the necessary actions to satisfy their needs.

Fundamental needs are seen as normative requirements, and the existence of the needs is known by decision makers who may not be needy themselves (Keinonen, 2009). Consequently, relatively objective needs assessments have to be carried out. Knowing about needs becomes a domain of experts or something that can be defined through a dialogue between the experts and the people in need, but not purely subjectively by the individuals in need themselves (Percy-Smith, 1995; Witkin, 1995). The idea of human-centred design, user-centred design, and co-design, for example, share the objective of making common sense between the users and the experts (Keinonen, 2009).

In the context of political decision making, the focus is on populations rather than on individuals. This directed the attention of authors to general and universal needs rather than needs specific to individuals (Keinonen, 2009). In the attempt to provide explanations on the specific versus general characteristics of need, authors (Max-

Neef, 1991; Brock, 2005) suggest making a distinction between fundamental needs and satisfiers. Fundamental needs are permanent or slowly changing, and there is a manageable amount of them making it possible to present at least approximate lists of universal needs. The way needs are satisfied changes from culture to culture (Max-Neef, 1991). In this context, satisfiers can be seen as instrumental needs, i.e. necessary conditions for achieving a goal (Thomson, 1987).

Overall, characteristics of need may be interpreted as follows[13]:

- context dependent;
- driver of human motivation;
- a matter of change;
- person specific or general;
- satisfaction related; and
- subjective or objective.

Based on these characteristics of need, it is concluded that need has characteristics in common with value in that value is context dependent, a matter of change, person specific, related to satisfaction, and subjective. However, there are also distinctions in that value:

- is related to motivation only in the specific case where criteria in value determination are related to motivation;
- cannot be satisfied like need; and
- is not objective.

While the investigation on the relationship between value and need provided descriptive insights on the phenomena, it lacks procedural insights. It is therefore appropriate here to investigate need in the context of the VDM.

[13] It is not the intention here to provide a comprehensive list of need characteristics, but rather to point to characteristics that may be interpreted as also related to the value phenomenon.

As outlined in Section 7.3, need is considered in the VDM in terms of an agent's knowledge. However, knowledge on need may be processed in the VDM differently. That is, knowledge on need may:

- as a driver of motivation, trigger a value determination activity (A_{vd}), i.e. may initiate an A_{vd} to be executed;
- change priorities and criteria in an agent's personal criteria system; and
- provide criteria for value determination. For example, an instrumental need referring to an agent's goal "to get from A to B", initiates value determination on the extent a car satisfies related criteria.

Overall, this section provided explanations on the relationship between value and need. It is concluded here that value is not dependent on need, although the concepts of value and need have characteristics in common.

8.6. Value types

In Section 3.6, brand, customer, economic, exchange, expected, human, product, process, relationship, and shareholder values have been identified as key value types in literature. In Chapter 7 a model of value determination was provided. This section provides explanations of the key value types identified in Section 3.6 from a VDM perspective as a means to investigate validity of the VDM.

Brand value: Aaker (1991) argues brands may be used to generate economic value and Jones (1994) argues brands give added value to the customer when the customer cannot personally and/or directly verify the product quality. In the VDM, economic value relates to a degree of satisfaction of selected criteria, i.e. a brand value may be considered in terms of economic criteria, in which case brands may be seen as a means to generate economic value. However, it should be noted that the criteria applied for value determination of brands may be independent of economy, e.g. there may be criteria applied related to beauty, in which case a brand may be seen as generating aesthetic value. As mentioned by Jones (1994) and according to the VDM, added value relates to an increase in the extent an entity satisfies criteria. A brand may be seen as an entity supporting the verification of product quality, even if the quality cannot be verified directly by the customer. This is because customers cognitively relate to the brand quality criteria. Thus, the added value to the customer refers to an increase in the satisfaction of the product verification criteria.

Customer value: Andriessen (2003) points to the importance for companies to make use of knowledge to generate customer value. In terms of the VDM, knowledge can be seen as a value resource that can be used to increase the extent an entity satisfies a customer's criteria. In other words, knowledge on the customer's criteria to judge value may be seen as an important value resource. Berry and Yada (1996) refer to service value based on benefits, relationships, and effective operation pricing, which in terms of the VDM may be seen as value criteria. Finally, customer value assessments as mentioned by Anderson, Jain, and Chintagunta (1993) in terms of the VDM may be seen as assessments on a customer's value criteria.

Economic value: According to Amit and Zott (2001), companies should focus on activities to add value to products and to compete in industry. In terms of the VDM, this refers to activities supporting an increase in the extent a product satisfies criteria. The criteria may be related to economic value of an enterprise (e.g. competitiveness, profit) and/or to customer value (e.g. usability). Campbell and Goold (1988) argue that the creation of value is influenced by the management style of an organisation. This may be seen as an alignment of criteria actually applied to value judgement in business activities (e.g. designing) to overall value criteria proposed in a company (e.g. ethics, performance, quality). Continuous development and the creation of new business models (Larreche, 2000), continuous reconfiguration of business opportunities (Ramirez, 1999), inventiveness, versatility (Hamel and Prahalad, 1989), and knowledge (Teece, 1998) are seen as resources to generate economic value. In terms of the VDM, these represent activities that may increase the extent a product or service satisfies value criteria. However, this is only the case if the criteria applied for the determination of economic value somehow relate to the activities (e.g. continuous development related to the innovation value criteria).

Exchange value was outlined explicitly in Section 8.2.

Expectancy value is characterised in literature by an expected benefit that someone holds in mind in terms of consequences that may occur following action (Levitt, 1981; Feather, 1982). In terms of the VDM, value may be determined based on criteria referring to an expected benefit. As an example, a person considering spending money in a bank fund may expect value based on the criteria of "more than five percent return on investment". This value criterion can be seen as referring to an expected benefit because at the time of spending the money, there is no proof of value or benefit.

Human values are discussed in literature from different perspectives: Feather (1975) points to value systems as the way humans organise values into hierarchies of importance. From the VDM perspective, value is the output of a value determination process, and as such values per se are not seen as organised in value systems. However, the VDM suggests that humans organise criteria applied in value determination in personal criteria systems. In other words, what is organised in hierarchies of importance is not value per se, but the criteria applied for value determination. This distinction provides a means for consistent explanations on human values, value of entities, and value as an activity, with all three working according to the same mechanisms involved. Griseri (1998) points out that in practice, it may be difficult to identify what values someone really holds. From a VDM perspective, humans determine value based on criteria they "hold". However, the VDM supports considerations that it may be difficult to identifying the values of someone (Griseri, 1998), because of the variables involved in value determination (Chapter 7): As a cognitive activity, value determination (A_{vd}) is situated and dependent on an agent's knowledge. Thus, an agent's situation (S), knowledge (K), interpretation of an entity (A_{ei}), and criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement (A_{cj}) are involved in value determination, which may be seen as an explanation as to why it is difficult to identify the values that someone “holds”. Holden (1999) identifies categories of human values (e.g. aesthetic, economic, political). From a VDM perspective, these categories can be interpreted as categories of criteria for value determination. As such, the categories may be seen as value categories in the specific case where corresponding criteria are applied in value determination.

Product value in literature (Burns and Woodruff, 1992; Fowler, 1990; Hamilton, 1996) is characterised by a benefit to a stakeholder based on a product (Section 3.6). However, as outlined in Section 8.4, there are differences between benefit and value: a benefit refers to an advantage or profit, while value refers to a value statement; a benefit with value to one agent may be of no value to another, although it is the same benefit; and an entity providing a benefit by no means must be an entity of value. Product value according to the VDM is seen as an output of value determination in the interpretation of a product. Value is not seen as dependent on benefit. It is only in the specific case where the value criteria are related to a benefit, that a beneficial product may also be valuable.

Process value: Amit and Zott (2001) conclude that the main questions regarding process value is about what activities a firm should perform ,and how and what configuration of the activities would enable it to add value to the product and to compete in industry. From a VDM perspective, a process and/or activity may be seen as a value entity of which value may be determined. However, value criteria are required to determine the value of a process and/or activities. These criteria may relate to a product or to other economic aspects, such as competition. In other words, the key question regarding process value and value chain from a VDM perspective is not what activities to perform, but rather what criteria to apply. Ashworth and Hogg (2000) suggest strategies and techniques (e.g. cost planning, life cycle costing) to “add value”. Such strategies and techniques may be seen as supporting a value focus during design and construction processes as long as value is determined based on the related criteria, e.g. cost. Gage (1969), for example, applies another value criterion in focusing on process value in terms of the elimination of waste.

Relationship value: Ramirez (1993) concludes that value is developed as a consequence of an interactive relationship between organisations and stakeholders. A view supported by Crosby (1990) and Gummerson (1999) states that value comes as a result of interactions between customers, suppliers, and various stakeholders. From a VDM perspective, value may be determined on a relationship as the value entity. Depending on the criteria applied in value determination, e.g. revenue increase, the relationship may be of value. This is in line with the three dimensions of relationship value identified by Wilson and Jantrania (1993): the behavioural dimension is understood as culture, social bonding, and trust; the economic dimension as concurrent engineering, cost reduction, investment quality, and value engineering; and the strategic dimension as business goals, core competencies, strategic fit, and time to market. According to the VDM, these dimensions may be interpreted in terms of criteria that can be applied to determine the value of a relationship.

Shareholder value: Ashworth and James (2001) recommend investor community management, value creation strategy development, and performance management to deliver shareholder value. All of them may be seen as opportunities to generate value from a shareholder perspective as long as shareholders apply value determination related criteria. Doley (2000) concludes that shareholder value has a focus on growth opportunities and competitive advantage, and argues that this is in contrast to maximising profitability. From a VDM perspective, focus on growth, competition, and/or profitability represent criteria which may be applied during value determination by a shareholder.

Overall, it can be concluded that the VDM provides consistent explanations on key value types in literature.

8.7. Summary

Value-related phenomena explored in Chapter 8 provide explanations on: how to add value (Section 8.1); on exchange and perceived values (Section 8.2 and 8.3); the relationship of value to benefit and need (Sections 8.4 and 8.5); and how the VDM provides explanations on the variety of value types identified in literature (Section 8.6). Insights gained from the exploration may be summarised as follows:

- In the context of how to add value it should be noted that a change to an agent's knowledge is fundamental to changes to an agent's value statement. Changes to an agent's: situation; interpretation; and criteria prioritisation; selection; and/or judgement provide means for a change to an agent's value statement.

- Exchange value refers to the extent an exchange of entities satisfies an agent's criteria.

- Value is the output of a cognitive process and consequently is not perceived, i.e. in the ability to see, hear, or become aware of something through the senses. What may be perceived in value determination is an entity in an agent's external world as interpreted by the agent in determining value.

- Value is not dependent on benefit, although a benefit may serve as input knowledge to value determination.

- Value is not dependent on need, although the concepts of value and need have characteristics in common.

- The VDM provides consistent explanations on the variety of value types identified in literature. A key question in the context of value determination across value types is on the value criteria to be applied.

Value axioms were identified in Chapter 6, a model of value determination was provided in Chapter 7, and an exploration of key phenomena related to value was outlined in Chapter 8. These chapters contribute to an overall theory of value in design as provided in the following chapter.

9. A theory of value in design

In Section 4.3, it was concluded that a theory provides a means to formalise value in design and elements of such a theory were outlined in Chapters 6-7. Answers were provided to research questions on the characteristics of value (Chapter 6), key elements and mechanisms involved in value determination (Chapter 7), and value-related phenomena (Chapter 8). This chapter introduces an overall theory of value in design (TVD). The TVD is composed of the different elements and constructs presented in the previous three chapters.

A brief introduction is given on theory building (Section 9.1). The TVD is then described (Section 9.2) followed by a review of key elements and constructs illustrating their relationship to each other (Section 9.3).

9.1. Theory building

Regarding the term *theory*, academic practitioners have not succeeded in reaching a consensus with regard to its objective and mission; they have not even agreed about core concepts (Alexander, 1992). Therefore, this section is not intended to provide a definition of theory. However, there are characteristics of design (Section 4.1) and value theories (Section 4.2) that can be interpreted as requirements for a theory of value in the context of design (Sections 4.3). According to these requirements, a theory of value in the context of design should:

- provide novel insights of value in design and a value definition;
- describe value in design in terms of constructs, construct relationships, mechanisms, and variables involved;
- provide a perspective of value in design;
- support explanations on conceptual issues and substantive problems;

- support explanations on issues related to the philosophical and scientific value discussion, on instances of the value phenomenon in design, on value creation and analysis, and on measures;
- integrate or relate to other theories and consider relevant literature;
- have a defined scope;
- be built upon axioms and/or generalised characteristics;
- be testable;
- be evolutionary; and
- provide a means to improve design artefact, process, practice, and/or research performance.

Overall, the term *theory* as applied in this thesis refers to a vehicle for delivering explanations on characteristics and mechanisms of a phenomenon under consideration (Smithers, 1990).

The process of developing and testing theories in science involves the development and use of terms and concepts that can be operationalised well enough to make them effective in forming explanations. It is an ongoing process, with no notion of absolute truth or correctness involved. The development of scientific theories is essentially a social process, but one in which the common aim is shared by all involved. This aim is to develop a particular kind of understanding of the way a phenomenon works that can be expressed in terms of scientific theories (Hull, 1988).

An important role in design theory building is seen in the terms and concepts used to form a theory: they must be defined, making it possible in practice to identify and classify, unambiguously, particular examples and states of the phenomenon covered by theory. Literature (Smithers, 1999; Vaishnavi and Kuecher, 2004) points to the need of a distinction between theories, models, descriptions, and methods. Models refer to particular instances of a phenomenon because they are models of something. Models can be built using empirical understanding and knowledge, or they can be constructed from theories. The empirical understanding that forms the basis for all theory construction and model building comes from the attempts to describe what we observe. The terms, concepts, analogies, and metaphors that we use in forming such descriptions are the grounds for the theoretical constructs that we seek to operationalise on the way to forming theories. Methods in design (statements about ways of designing) are not models or theories. Methods specify actions and an organisation to be adopted. In principle, they should be derived from a model of the particular kind of the design process involved (Smithers, 1999).

Theory constructs and model building are based on empirical knowledge. The definition of knowledge is a matter of ongoing debate among philosophers. According to the classical definition, described but not ultimately endorsed by Plato, knowledge is seen as a "true opinion", and in order for there to be knowledge, a statement must be justified and accepted (Moser, 2002). Knowledge acquisition, i.e. the process in which knowledge is received, is based on the cognitive processes of perception, reasoning, and learning (Persidis and Duffy, 1991). As an integral part of these processes, existing knowledge is applied and numerous factors are involved: derivative desires, experiences, inborn qualities, outcome foci, physical needs, self esteem needs, etc. For theories on design cognition, designing is defined by what people do when they design. This assumption, that any theory of a design process must be a cognitive theory, is so widespread that it is often not even made explicit (Smithers, 1999).

There are, however, methodological problems with any attempt to develop a design cognition theory: Designing is a particularly sophisticated kind of behaviour, drawing on numerous human cognitive capacities (Friedman, 1999). Theories of design as cognition must therefore be properly connected to the general theory on human cognition. We currently have very little of such a theory. Consequently, the terms and concepts used to present theories of design as cognition are limited in their support on the construction of explanations on human design behaviour. Another problem with a design cognition theory is that it needs to deal with all the variations and differences we see in the act of designing as influenced by particular education, training, and previous experiences of the people involved. Explanations or models derived from theories of design as cognition must be presented in terms of human behaviour, i.e. in abstract terms. Thus, a problem with such theories is that any attempt to develop methods of design must specify design behaviour (Smithers, 1999).

Overall, there is no direct answer on how to build a theory of value in the context of design. However, value and design theory requirements put restrictions on what can be recognised as a theory of value in the context of design and there are factors supporting theory building, such as the distinction among theory, model, description and method. Further, there are constraints in the development of theories on design cognition in particular: the lack of a general theory on human cognition and therefore limitations in the support of explanations; limitations in capturing the variances and differences of human behaviour; and the need to provide explanations in terms of human behaviour.

9.2. Theory description

The TVD is based on a systematic qualitative research methodology (Section 5.3) emphasising the generation of theory from data in the process of conducting research.

The scope of the theory is limited to the definition of design applied in this thesis (Section 1.2) as the human activity of conceiving, planning, and bringing to reality physical products that serve human beings in the accomplishment of individual and collective purposes (Buchanan, 2005). This view of design supports the product, process, and human views of design and covers value of an entity, as an activity, and an ethic/moral principle.

The key elements of the TVD are illustrated in Figure 9-1.

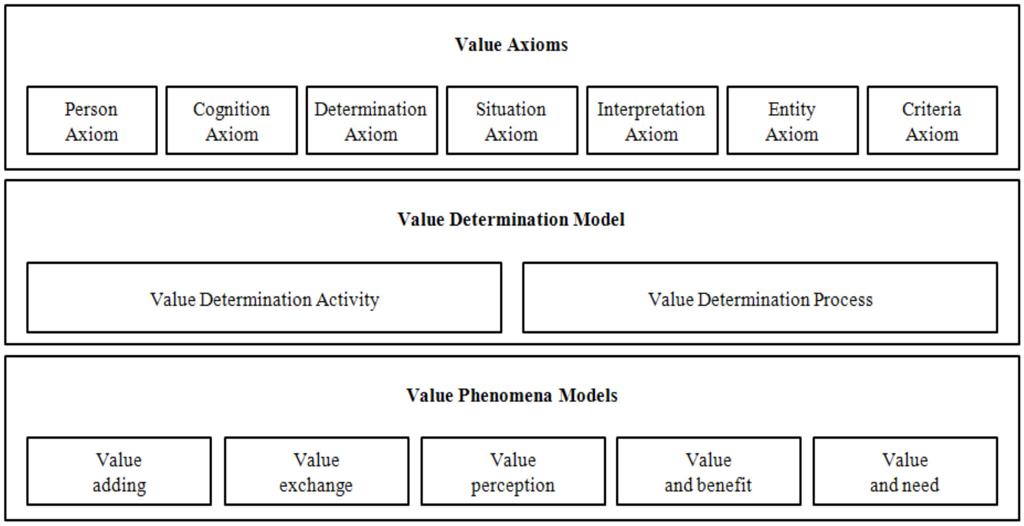

Figure 9-1: Key elements of the TVD

The theory is developed from a fundamental understanding of the nature of value in terms of the value axioms outlined in Chapter 6. The models of value determination outlined in Chapter 7 illustrate a value determination process in terms of three cognitive activities. Based on the value axioms and the value determination models, value phenomena were explored in Chapter 8. The key findings from these chapters are consolidated here as the theory of value in design.

<u>The value axioms</u>

The TVD is based on value axioms. The value axioms are derived from a review of value interpretations across disciplines. The axioms provide insights on the generic characteristics of the value phenomenon:

- The *person axiom* (Axiom 1) indicates that value is connected to people. This is because people determine the value of entities, value as an activity, and hold values in the sense of ethic/moral principles. Consequently, the TVD reflects people in terms of agents representing human beings involved in value determination in the context of design.

- The *cognition axiom* (Axiom 2) argues that value is an output of a cognitive process. This is independent if value is approached as an inherent or attributed property of entities, as an activity, or as an ethic/moral principle. There is always a cognitive process involved in value determination and consequently in value determination in the context of design.

- The *determination axiom* (Axiom 3) argues that value requires a determination process. That is, people express value in terms of statements such as “A is of value”. To formalise a value statement requires a cognitive process aimed towards a value statement. While this process may be conscious or unconscious, without such a process a value statement cannot be derived.

- The *situation axiom* (Axiom 4) argues that value is subject to situatedness. Based on the theory of situated cognition (Clancey, 197; Gero, 2002), this axiom claims that every agent’s thought and action are adapted to the environment and are situated because of what agents perceive, how they conceive of their activity, and what they physically develop together. For example, what an agent brings to a design situation comes from the agent’s desires, experiences, the implicit theories on how the physical world behaves, inborn qualities, outcome foci, and needs. It is this background that distinguishes the design agent’s thoughts and actions from one another when they witness or are subject to a given situation. Consequently, value as the output of a cognitive process is a matter of a given situation.

- The *interpretation axiom* (Axiom 5) argues that value is based on interpretation, i.e. value determination is on interpreted entities rather than on entities in the external world. This is because human beings cannot bypass the interpretation process. From this, it is concluded that value determination on entities in the external world (e.g. a design product) and entities in an agent’s internal world (e.g. a design idea) in essence works according to the same principles, i.e. on interpreted entities.

- The *entity axiom* (Axiom 6) argues that value is related to entities. In other words, value needs to be of "something". This axiom is based on an empirical study of value literature against entities involved (Appendix D). The entities may be physical or non-physical in nature. Typical entities in design may be seen in the design artefact, process, design per se, and/or design management as entities "valued" by agents.

- The *criteria axiom* (Axiom 7) argues that value is connected to criteria. This axiom is based on an empirical study of value literature against criteria involved (Appendix D) analogous to Axiom 6. Value definitions incorporate criteria ranging from economic criteria such as "low price" and "cost of production", to human criteria such as "desirability" and "level of importance".

<u>The value determination model</u>

Value determination is modelled based on the generic design activity concept (Sim and Duffy, 2003). The value determination models illustrate cognitive activities of value determination on a knowledge level in two different degrees of detail:

- The *value determination activity* is outlined in terms of a knowledge processing activity with an interpreted entity as input knowledge (I_{kvd}), a goal to determine value (G_{vd}), and a value statement as output knowledge (O_{kvd}).

- The *value determination model* (VDM) illustrates the value determination activity in more detail in that the model outlines the three cognitive activities involved: criteria prioritisation (A_{cp}), criteria selection (A_{cs}), and criteria judgement (A_{cj}).

The cognitive activities involved in the value determination process may be described as follows:

The *criteria prioritisation activity* (A_{cp}) is an ongoing cognitive activity shifting an agent's criteria on a personal criteria priority list, adding new criteria to the list, and removing criteria as appropriate. As a means to integrate value-related concepts, input knowledge (I_{kcp}) refers to an agent's knowledge both broadly, including tacit and explicit knowledge, and particularly, including desires, experiences, the implicit theories on how the physical world behaves, inborn qualities, outcome foci, and needs (R18). The goal (G_{cp}) of criteria prioritisation is to have "up-to-date" personal criteria. Output knowledge (O_{kcp}) refers to an up-to-date list of criteria at the moment in time when criteria are required for value determination, i.e. output knowledge from this activity is input knowledge to criteria selection (A_{cp}). Overall, what is introduced here is a personal criteria system (rather than a personal value system), i.e. a personal and ongoing system of criteria and their priorities as a means to reflect an agent's individual criteria preferences in value determination. As such, personal criteria systems provide a means to represent all criteria applied in value determination. No distinction is required here between criteria related to or not related to "human values", except that human values-related criteria may be relatively persistent in their priority in a personal criteria system. For example, someone holding the human value criterion of social justice may over time change the priority of this criterion only in the event of, e.g. a war.

- The *criteria selection activity* (A_{cs}) is a cognitive activity selecting criteria for value determination in the context of an entity. Input knowledge (I_{kcs}) refers to general knowledge and knowledge of the entity under consideration. The goal (G_{cs}) of the activity may be described in terms of a selected criterion or a set of criteria for value determination in the context of a specific entity. The output knowledge (O_{kcs}) of this activity is a criterion or a set of criteria that serve as the input knowledge for criteria judgement (A_{cj}) on a particular entity.

- The *criteria judgement activity* (A_{cj}) is a cognitive activity judging to what extent criteria are satisfied through the interpreted entity, i.e. the entity under consideration. Input knowledge (I_{kcj}) refers to knowledge on the criteria to be applied, i.e. the output knowledge of criteria selection (O_{kcs}) and an agent's general knowledge. The goal (G_{cj}) of criteria judgement is a judgement on the extent criteria are satisfied. Output knowledge (O_{kcj}) refers to knowledge on the overall extent individual criteria are satisfied through the interpreted entity. This knowledge is expressed in terms of a value statement and provides a knowledge contribution to the agent. Thus, in formulating a value judgement a formal process of evaluation applies. This formal process can be described as a set of criteria that must be satisfied in order for a judgment to be made. This "extent of criteria satisfaction" is expressed in terms of a value statement as the output knowledge of value determination.

From the VDM it is concluded:

***Value* refers to a judgement on the extent**
an interpreted entity satisfies value criteria.

<u>The exploration of value phenomena</u>

As outlined in Chapters 2 and 3, there are inconsistencies and knowledge gaps in current literature on the phenomena of added value, exchange of value, perceived value, and the relationship of value to benefit and need. The value axioms and the VDM provide a means to explain the phenomena as follows:

- The *phenomenon of added value* is explained in terms of the variables involved in value determinations as a means to manipulate a value statement. It is fundamental that the value determination activity (A_{vd}) as a cognitive activity is situated and dependent on an agent's knowledge. Thus, an agent's situation (S), knowledge (K), interpretation of an entity (A_{ei}), and criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement (A_{cj}) are the key variables in value determination. However, changes in these variables require management and control towards an increase in the extent an entity satisfies criteria, i.e. the issue of value adding and adding value. In criteria selection (A_{CS}), agents establish a cognitive link between the interpreted entity and criteria in that they select criteria in the context of the entity. In other words, agents cognitively add criteria to the entity under consideration. The selected criteria are the input knowledge to criteria judgement (A_{CJ}) and the basis for the value statement. In this context, adding value may be interpreted as the activity of adding criteria to an entity increasing the degree of satisfaction and/or replacing added criteria with more satisfactory ones. Based on this interpretation of adding value, it is recommended to introduce the terminology of adding and added criteria as the appropriate terminology in value research rather than adding and added value.

- The *phenomenon of exchange value* refers to an agent's specific situation where more than one entity are involved and the focus of value determination is on the entities' exchange rather on the entities' value per se. Based on the VDM, it is argued that an agent determines the value of each entity, which results in value statements. The value statements become the input knowledge to the determination of value on the "exchange" of the entities. In other words, the "exchange" becomes the value entity under consideration. Based on the value statements as the input knowledge and the agent's overall knowledge, the agent determines value on the exchange according to the activities of the VDM. It should be mentioned that in the determination of the exchange value, other criteria may be applied than in the determination of the value of the entities under consideration. Thus, exchange value refers to the extent an "exchange of entities" satisfies an agent's criteria. What is exchanged here is not value, but rather entities cognitively linked to a value statement.

- The *phenomenon of perceived value* is explained here in terms of perceived entities rather than perceived value. This is because value as the output of a cognitive process in terms of a value statement cannot be perceived in the sense of the ability to see, hear, or become aware of something through the senses. However, what may be perceived in value determination is an entity in an agent's external world. That is, an entity in the external world may be interpreted in value determination and this entity may be perceived through the senses. Consequently, it is recommended to introduce the terminology of *determined value* and *perceived entity* rather than *perceived value* in value research. It should be mentioned that perceived value is also applied in value research based on the idea of "receiving" and "providing" value analogous to physical products. However, value as the output of a cognitive process cannot be received or provided, i.e. one cannot "transfer" value. Even if there would be consensus on the interpreted entity, criteria priority, selection, and judgement by agents involved in value determination, by no means is value transferred from a conceptual point of view.

- The *phenomenon of a value/benefit relationship* is based on the underlying assumption in literature that a benefit ascribed to an entity makes the entity "valuable". However, based on the VDM there are fundamental differences between benefit and value: a benefit refers to an advantage or profit, while value refers to a value statement, i.e. to the extent an entity satisfies criteria; a benefit of high value to one agent may be of no value to another, i.e. a benefit may be the input knowledge to value determination as the entity under investigation; an entity providing a benefit by no means must be an entity of value; it is only in the specific case where criteria in value determination are related to the benefit (e.g. an advantage) that a "beneficial" entity may be of value to an agent.

- The *phenomenon of a value/need relationship* is based on the underlying assumption that, e.g. a product must fulfil a user's need in order to have value (Fowler, 1990). The characteristics of need may be interpreted as: context dependent; a driver of human motivation; a matter of change; person specific or general; satisfaction related; and subjective or objective as outlined in

Section 8.5. Thus, need has characteristics in common with value in that value is context dependent, a matter of change, related to satisfaction, person specific, and subjective. However, there are also distinctions in that value: is related to motivation only in the specific case where criteria in value determination are related to motivation; cannot be satisfied like need (e.g. value would not disappear like hunger after eating); and is not objective. In the VDM, need is considered in terms of an agent's knowledge. However, knowledge on need may be processed differently: as a driver of motivation, knowledge on need may initiate a value determination activity; need may change priorities and criteria in an agent's personal criteria system; and need may provide criteria for value determination. Thus, it is concluded that value is not dependent on need, although the concepts have characteristics in common.

The descriptive model of the TVD, the description of the value axioms, the value determination model, and the value phenomena models all provide insights on value from a more descriptive perspective, but are limited in providing a comprehensive perspective of the constructs involved and their relationships. This perspective is provided in the following chapter.

9.3. Construct relationships

Based on the investigation on theory characteristics (Section 10.4), a theory may be described in terms of construct relationships (Vaishnavi, 2004). The term *construct* is used in this thesis to refer to an idea containing various conceptual elements (Clancey, 1997). In the philosophy of science, a construct may be interpreted as an "ideal" object, i.e. one the existence of which may be said to be dependent upon a subject of mind (Bunge, 1974). Describing the TVD in terms of construct relationships provides a means for a comprehensive overview on the concepts involved. These concepts and their relationships are based on the VDM outlined in Chapter 6,

From a construct relationship perspective, the TVD may be illustrated as follows:

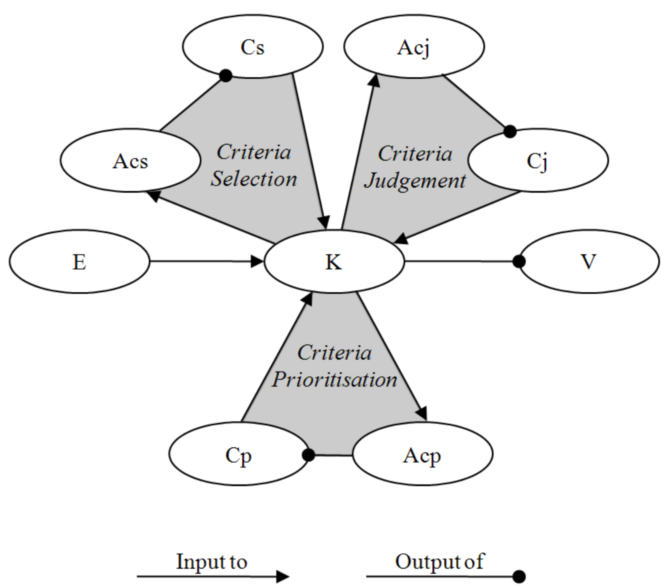

Figure 9-2: Construct relationships of the TVD

The TVD provides a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. In particular, the TVD:

- Describes value in terms of a value statement (V) as the output of a cognitive value determination process. The input knowledge to the process is knowledge of an interpreted entity (E). The process involves the cognitive activities of criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement (A_{cj}).

- Introduces a generic process model for value determination on entities in an agent's external and internal worlds based on interpreted entities (E), as agents cannot bypass the interpretation of entities.

- Applies the term knowledge (K) in a broad sense in terms of tacit and explicit knowledge, including expert knowledge, but to the same extent that desires, experiences, implicit theories on how the physical world behaves, inborn qualities, outcome foci, and needs are knowledge resources for value determination.

- Introduces a personal criteria system consisting of an agent's knowledge (K), criteria prioritisation activity (A_{cp}), and a set of prioritised criteria (C_p). The system is seen as an ongoing cognitive process prioritising criteria, introducing new criteria, and removing criteria from the prioritised set (C_p) as appropriate.

- Introduces a criteria selection activity (A_{cs}), selecting criteria from the prioritised criteria (C_p) and from the agent's general knowledge (K) in the context of knowledge of an interpreted entity (E). Criteria selection (A_{cs}) "adds" criteria to an entity, establishing a cognitive link between the interpreted entity (E) and criteria (C_s) selectively used for value determination.

- Introduces a criteria judgement activity (Acj), judging the extent an interpreted entity (E) satisfies selected criteria. In criteria judgement (Acj), a formal process of evaluation applies. Within criteria judgement, measurable or non-measurable criteria may be applied and the extent to which an entity satisfies the criteria will be judged, leading to judged criteria (Cj) from which a value statement is derived (V). This value judgement is cognitively linked to the entity (E), in that the criteria applied are entity specific.

The value axioms are related to the TVD as illustrated:

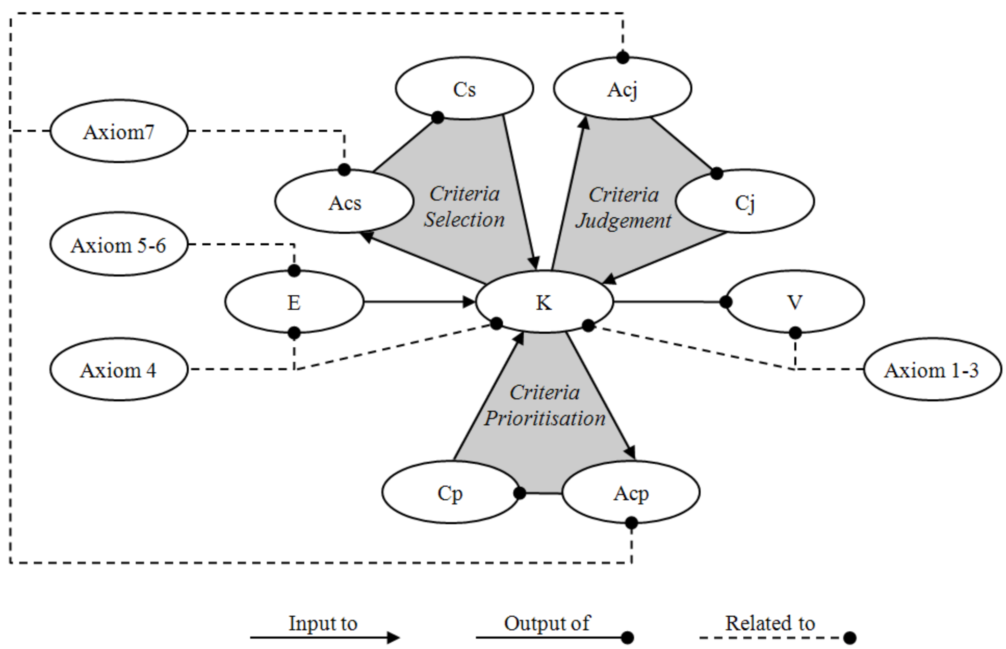

Figure 9-3: Relationship of axioms to TVD constructs

- The person (Axiom 1), cognition (Axiom 2), and determination (Axiom 3) axioms are related to the TVD in that a value statement (V) is the output of an agent's cognitive value determination process based on an agent's individual knowledge (K).

- The situation axiom (Axiom 4) is related to the TVD in that the cognitive process of value determination is based on an interpreted entity (E) and an agent's knowledge (K) and, as with every human thought, is adapted to the environment where it is situated.

- The interpretation (Axiom 5) and entity (Axiom 6) axioms are related to the TVD in that value is determined on an interpreted entity (E).

- The criteria axiom (Axiom 7) is related to the TVD in that the cognitive activities involved (A_{cp}, A_{cs}, A_{cj}) apply criteria aiming to formalise a value statement. In particular, a cognitive link between the interpreted entity (E) and selected criteria for value determination (C_s) is established in the criteria selection activity (A_{cs}).

The VDM is related to the TVD as illustrated in Figure 9-4.

- In value determination, an interpreted entity (E) as input knowledge (I_{kvd}) is processed to a value statement (V) as output knowledge (O_{kvd}).The process is based on knowledge of an agent (K) in the sense of tacit and explicit knowledge, including expert knowledge, but to the same extent desires, experiences, implicit theories on how the physical world behaves, inborn qualities, outcome foci, and need. The goal of value determination is to determine value. However, before value can be determined, there is a need to prioritise, select, and/or judge criteria. This gives rise to the sub-goal of criteria prioritisation (G_{cp}), selection (G_{cs}), and judgement (G_{cj}) whereby the goals can be seen as part of an agent's knowledge (K).

- The criteria prioritisation activity (A_{cp}) is seen as an ongoing cognitive activity prioritising criteria, introducing new criteria, and removing criteria from a prioritised set of criteria as appropriate. Criteria prioritisation (A_{cp}) processes input knowledge (I_{kcp}) of an agent to output knowledge (O_{kcp}) in terms of a prioritised set of criteria (C_p). The prioritised set of criteria becomes part of an agent's knowledge and can serve as input knowledge for the criteria selection activity (A_{cs}).

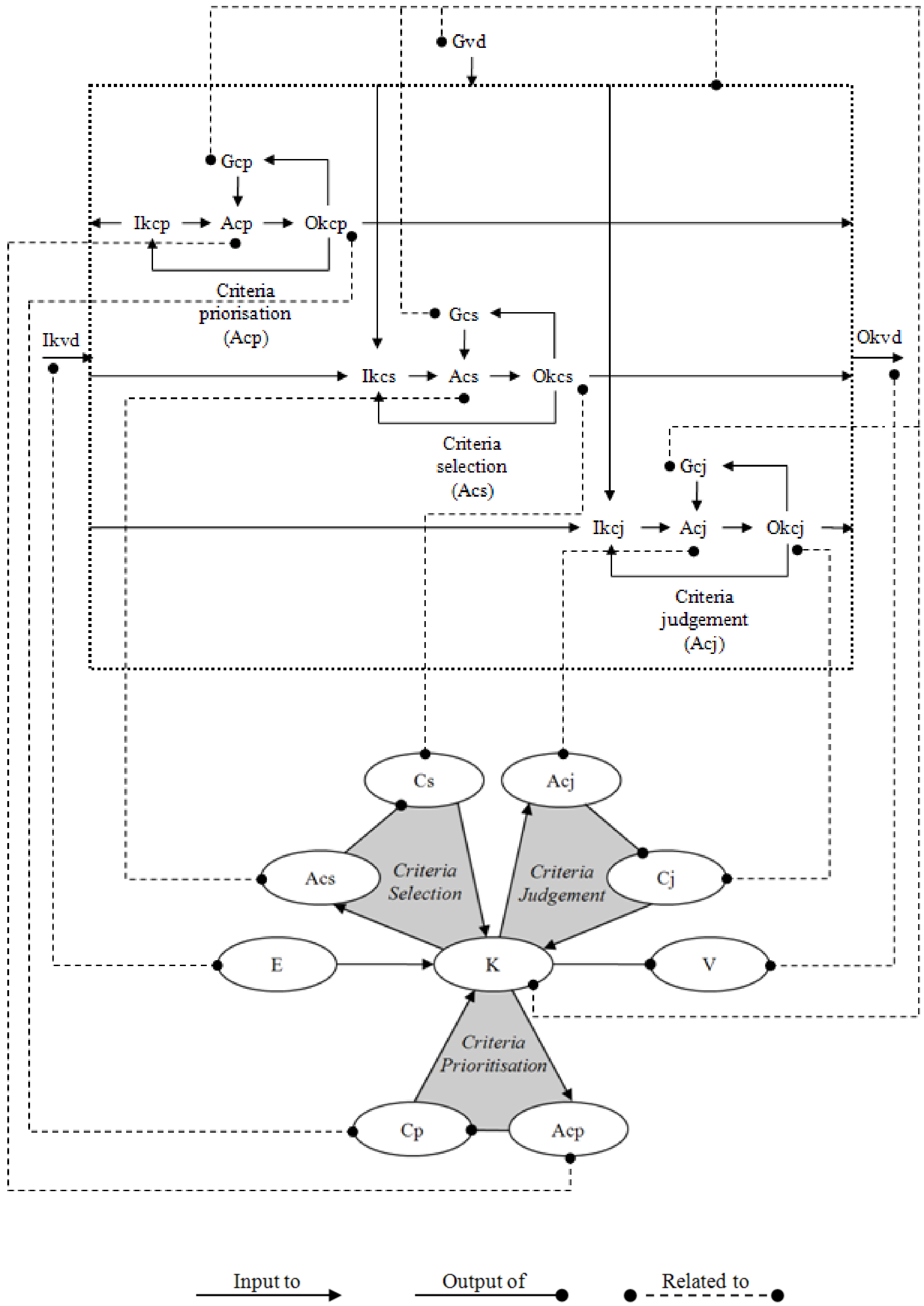

Figure 9-4: Relationship of VDM to TVD constructs

- The criteria selection activity (Acs) processes input knowledge (Ikcs), including knowledge of prioritised sets of criteria, to output knowledge (Okcs) in terms of selected criteria (C_s). The selected criteria (C_s) become part of an agent's knowledge and can serve as input knowledge for the criteria judgement activity (A_{cj}).

- The criteria judgement activity (A_{cj}) processes input knowledge (I_{kcj}), including selected criteria, to output knowledge (O_{kcj}) in terms of judged criteria (C_j) i.e. a value statement. The judged criteria or value statement becomes part of an agent's knowledge and can serve as input knowledge for further value determination activities.

Value phenomena are related to the TVD as illustrated:

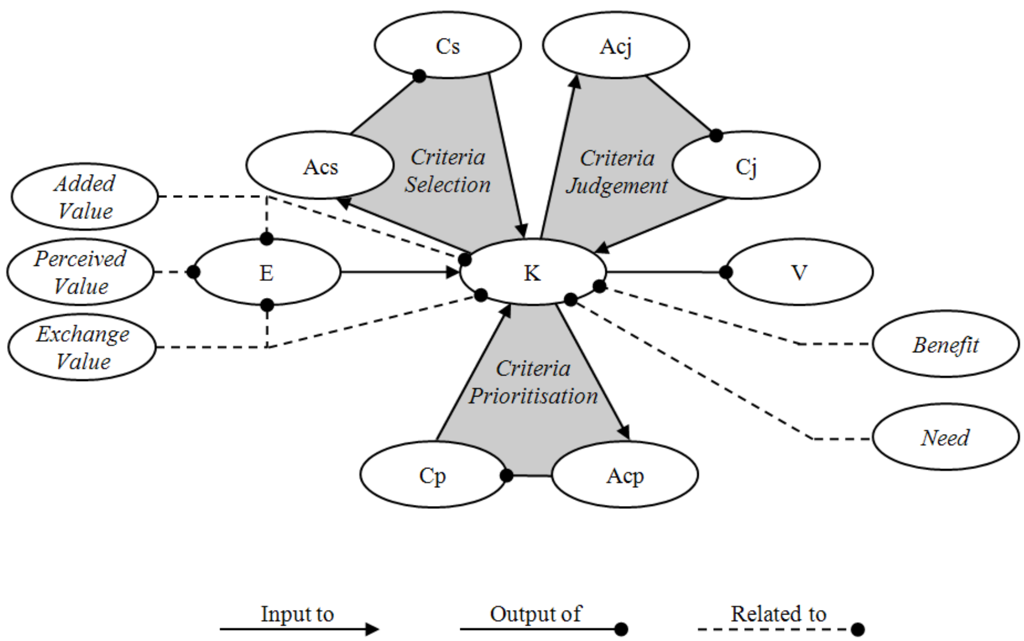

Figure 9-5: Relationship of value phenomena to TVD constructs

- An agent's knowledge (K), interpretation of an entity (E), criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement (A_{cj}) are the key variables of value determination. These variables provide opportunities to increase value in terms of increasing the degree an entity satisfies the criteria applied for determining value. The TVD is related to added value in terms of: a change in an entity leading to a change in the entity's interpretation (E); and a change in the agent's knowledge (K) leading to a different entity interpretation (E), criteria prioritisation (A_{cp}), selection (A_{cs}), and/or judgement (A_{cj}).

- In determining the value of exchange, value is determined on the entities involved according to the value determination process; the value statements (V) become part of an agent's knowledge (K). Based on this knowledge, value is the determination of the "exchange", i.e. "exchange" becomes the value entity (E) and the value of the exchange is determined according to the value determination process.

- Value as the output of a cognitive process cannot be perceived. What may be perceived through the senses in value determination is an entity in an agent's external world. The entity may be interpreted (E) and becomes the input knowledge to value determination. Therefore, it is suggested to apply the terminology of determined value and perceived entity, rather than perceived value.

- It is only in the specific case where criteria in value determination are related to the benefit that a "beneficial" entity may be of value to an agent. Benefit is considered in the TVD as part of an agent's knowledge, i.e. as a resource for value determination.

- Knowledge on need may: be processed as a driver of motivation initiating a value determination activity; change priorities and criteria in an agent's personal criteria system; and provide criteria for value determination as outlined above. In the TVD, need is considered as part of an agent's knowledge, i.e. a resource for value determination.

9.4. Summary

This chapter presented a theory of value in the context of design from descriptive and construct relationship perspectives. The theory is composed of a number of key elements and constructs, i.e. value axioms, the value determination model, explorations on value phenomena, and their relationships. Overall, the theory provides a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. The following chapters present an evaluation of the proposed theory.

10. Evaluation

A theory of value in the context of design was proposed in Chapter 9. The theory was developed according to a research methodology outlined in Chapter 5. This chapter presents the evaluation of the TVD.

The chapter starts with outlining the overall evaluation approach and highlights the rationale of choice in Section 10.1. The chapter then outlines a protocol analysis of key elements of the TVD in Section 10.2, open-interviews to elicit the perspective of designers on the TVD in Section 10.3, and an analysis of the TVD against requirements for a theory of value in the context of design in Section 10.4.

10.1. Approach

Critical realism does not commit to a single type of research, but rather endorses a variety of research methods chosen according to the aim of the research work.

Considering evaluation alternatives leads to considerations of the relative strengths and weaknesses of qualitative and quantitative methods. Qualitative methods support the study of selected issues in depth. To be unconstrained by predetermined categories of analysis contributes to the depth and openness of qualitative enquiry. On the other hand, quantitative methods require the use of standardised measures so that the varying perspectives and experiences of people can be fit into a limited number of predetermined categories in which numbers can be assigned. The advantage of quantitative evaluation approaches is that it is possible to measure the reaction of many people to a limited set of questions, thus facilitating comparison and statistical aggregation of the data. By contrast, qualitative methods typically produce detailed information about a much smaller number of people and cases. This increases understanding of cases and situations studied (Patton, 1990). Given the aim to investigate validity of the findings proposed in the TVD and given the underlying paradigm of critical realism, it was determined that qualitative methods provided a means for theory testing in that qualitative methods permit the study of selected issues in depth and contribute to openness. However, Patton (1990) argues that a credible qualitative study requires addressing the issue of methods used to support validity.

There are a number of techniques and methods that can be used to investigate the validity of findings, e.g. triangulation, rival explanations, and negative cases (Patton 1990). By combining multiple methods, researchers can overcome the intrinsic bias that comes from single-method, single-observer, and single-theory studies (Denzin, 1970). Yin (2003) identifies four types of triangulation used in the assessment of qualitative research: data, investigator, theory, and methodological triangulation. The research work reported in this thesis utilises methodological triangulation in terms of a protocol analysis and open-interviews to determine the validity of key elements of the TVD. Investigator triangulation is applied in terms of open-interviews with three designers from different disciplines. Data triangulation is applied in identifying requirements for a theory of value in the context of design based on data from design and value theories.

Qualitative inquiry typically focuses in depth on relatively small samples, selected purposefully. Quantitative methods typically depend on larger samples selected randomly. Purposeful sampling relies in selecting information-rich cases, i.e. those from which one can gain insights on issues relevant to the purpose of the research (Patton, 1990). The purpose for sampling is the validation of the proposed theory of value in the context of design. For this purpose, a protocol of a design session and open-interviews with designers represent information-rich cases, i.e. typical case sampling strategy.

Sample size depends on purpose and resources. The credibility of small but purposeful samples is often judged on the basis of a recommended sample size of probability sampling. Purposeful sampling, however, needs to be judged on the basis of the purpose and rationale of each study and the sampling strategy used to achieve the study's purpose. The sample should be judged in context. Random probability samples cannot accomplish what in-depth, purposeful samples accomplish, and vice versa (Patton, 1990). Given the purpose to determine the validity of the TVD, it is argued that the three techniques of a design protocol analysis, three open-interviews with designers on key elements of the proposed theory, and an evaluation against requirements from design and value literature on a theory of value together provide a sampling strategy to support this purpose.

The following sections outline the protocol analysis, the open-interviews with designers, and the evaluation of the proposed TVD against theory requirements from design and value theory.

10.2. Protocol analysis

It was proposed in the VDM that value determination is based on a cognitive value determination process with an interpreted entity as the input and a value statement as the output, whereby criteria prioritisation, selection, and judgement (i.e. a personal criteria system) are involved (Section 7.6). There is a need to substantiate the elements of the formalism proposed in the context of design activities by conducting cognitive study.

This section outlines the protocol analysis as applied in the work in terms of the experimental data used (Section 10.2.1), segmentation and coding applied (Section 10.2.2), and design activities (Section 10.2.3), entities (Section 10.2.4), and criteria (10.2.5) identified in the context of value determination.

10.2.1. Experimental data

A transcript of an audio/video recording of a single designer at work has been used for the analysis of the value determination activity in the context of design as a means for investigations on the validity of the VDM. This corresponds to the scope of the TVD as a theory of value in the context of design. The transcript was established by Kok (2000) in the context of research work on learning in design.

The designer recorded was a senior ship designer with more than ten years of working experience in a company that provides consultancy services in the design and supervision of high-speed naval craft and warship construction. The protocol took about 2 hours 45 minutes. The verbalisation and drawing activities of the senior ship designer were recorded using a digital video camera recorder. AutoCAD was used to record all of the drawings pertaining to the design tasks.

In the protocol, the designer was working on the general arrangement of a 60-metre offshore patrol vessel. The vessel had to be armed with weapon systems controlled by a sophisticated fire control system with various surveillance capabilities. At the time of the recording, there was a vessel of similar length under construction. The designer was able to take advantage of the experience gained in the design and construction of the current vessel as he performed the design task of completing the general arrangement, i.e. the general layout of the vessel.

10.2.2. Segmentation and codes

As already outlined in Section 5.2.1, protocols are segmented and categorised depending on the purpose of the analysis. The purpose of the protocol analysis provided in this thesis is to investigate the validity of value determination in the context of design activities. Kok (2000) identified key words or phrases uttered by the designer suggesting the nature of the activity and hence aid in their identification. The following table presents the codes for design activities identified in the design episode:

Design activity	Activity code
Analysing	A1
Approximating	A2
Associating	A3
Constraining	A4
Deciding	A5

Design activity	Activity code
Decomposing	A6
Determining	A7
Defining	A8
Evaluating	A9
Exploring	A10
Gathering	A11
Generating	A12
Identifying	A13
Prioritizing	A14
Resolving	A15
Searching	A16
Selecting	A17
Standardising	A18
Structuring	A19
Synthesising	A20

Table 10-1: Design activity codes

The segmentation of the protocol based on design activities according to Kok (2000) provides a basis for the identification of value determination. In analysing design activities against value determination, entities (E), criteria (C) and value statements (V) are identified. The following table presents the value entities identified in the design episode and the codes applied:

Value entity	Entity code
Design process (e.g. starting point)	E1
Design resource (e.g. supplier)	E2
Design concept	E3
Design parameter	E4
Design risk	E5

Table 10-2: Value entity codes

The following table presents the value criteria identified in the design episode and the codes applied:

Value criterion	Criterion code
Long shore range	C1
Good sea keeping conditions	C2
Unknown	C3
Country of manufacture	C4
Customer acceptance	C5
Ratio $/KW	C6
Clearance and/or space	C7

Value criterion	Criterion code
Absolute or relative position	C8
Practicability	C9
Suitability	C10
Reversing capability	C11
Redundancy	C12
Stability	C13
Balance	C14
Easy and/or quick	C15
Progress	C16
Information	C17
Fluctuation in form	C18
Force	C19
Lifecycle	C20
Satisfaction	C21
Comfort	C22
Acoustic	C23
Size	C24
Motion	C25
Customary	C26
Time	C27

Table 10-3: Value criteria codes

A value statement may be explicit (V1) or implicit (V2). That is, a designer may or may not communicate a value statement to the designer's external world. Table 10-4 provides examples of explicit and implicit value statements.

Seg. Nr. (Time)	Transcript	Value entity	Value criterion	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
36	But the included angle between buttock and the propeller **shaft is 8 degrees. In this present configuration that seems very reasonable.**	concept	angle is 8 degree	A5, A10	E3		C9	C9	V1

Seg. Nr. (Time)	Transcript	Value entity	Value criterion	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
3	The vessel has a range of 2,000 nm at 14 knots. These vessels were chosen as the most suitable for the conditions in the area. **Shore boats were wanted with long range and good sea-keeping characteristics.**	concept	long range and good sea-keeping characteristics	A1, A5	E3		C1, C2	C1, C2	V2

Table 10-4: Explicit and implicit value statements

In segment Nr. 36, the designer decided (A5) that an angle of 8 degrees "seems very reasonable", i.e. the design concept (E3) was considered as valuable based on the criterion of "an 8 degree angle" (C9). The designer's conclusion of "that seems very reasonable" (V1) was interpreted as an explicit value statement. While analysing (A1) in segment Nr. 3, the "range of 2000 nm at 14 knots" was decided (A5) to be the most suitable range for sea-keeping conditions in a specific area. Customers wanted, "shore boats with long range and good sea-keeping characteristics", i.e. the design concept (E3), was considered as valuable if it satisfied to a certain extent "long range" (C1) and "good sea-keeping characteristics" (C2). Value was interpreted as judged on the basis of C1 und C2; however, a value statement (V2) was not made explicitly by the designer. Overall, from the 102 value statements identified throughout the design episode, 79% are implicit value statements (V2) and 21% are explicit (V1).

The following section provides an analysis of value determination related to design activities.

10.2.3. Value-related design activities

The analysis of value determination related to design activities reveals that throughout the design episode, value is primarily determined in the contexts of decision making (40%), prioritising (13%), evaluating (8%), determining (7%), identifying (7%), defining (6%), exploring (5%), analysing (3%) and gathering (3%), as illustrated[14].

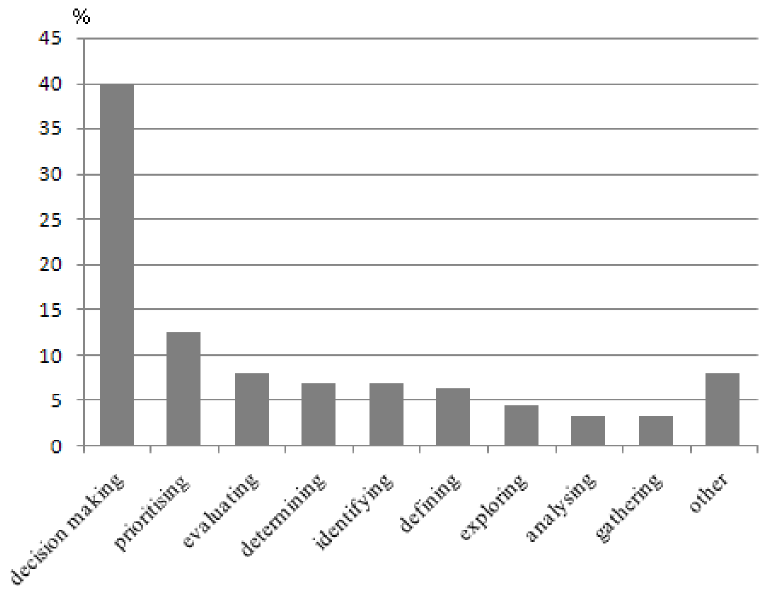

Figure 10-1: Percentage of value determinations related to design activities

8% of the value determination activities are related to "other" design activities. These are approximating, associating, constructing, decomposing, generating, resolving, searching, selecting, standardising, structuring and synthesizing. These design activities are not further considered in the value determination context because they are not frequently (i.e. once) related to value determination.

[14] It should be noted that the results in the Figures 10-1 to 10-5 are based on one design protocol and therefore non-statistical in nature.

Activity	Seg. Nr.	Transcript	Value determination
deciding (A5)	9	There are a lot of home-made systems that suit the particular requirements. **Therefore, we have to look overseas for different suppliers with perhaps some US connections. This will make the selection in certain situations more acceptable to the US government.**	The designer makes a decision (A5) to "look overseas for suppliers with US connections". Value is determined on suppliers (E2) based on the value criteria (C5) to be acceptable for the US government. The implicit value statement (V1) is that suppliers with US connections satisfy the value criteria to a certain extent.
prioritising (A14)	45	**And what we need to do is perhaps draw a section through the vessel in way of the gearbox just to confirm** that the dead-rise angle at this position of the vessel won't cause the gearbox to penetrate the hull.	The designer sets a priority (A14) on the next design step. Value is determined on the next design step (E1) based on the value criteria (C17) to provide the opportunity to confirm the dead-rise angle. The implicit value statement (V1) is that to draw a section through the vessel satisfies the value criteria to a certain extent.
evaluating (A9)	57	And we could wind up with a situation where, based on stiffener position, we might be lucky enough to clear the gearbox. But the reality is that ships are not built to the same high precision that engineering machine shops would work to. **There are bound to be fluctuations in the form and the nominal clearance of 40 mm won't be considered to be anywhere sufficient.**	The designer evaluates (A9) the design concept. The nominal clearance (E4) does not satisfy the criterion (C19) to be more than 40 mm as required because of fluctuation in form, i.e. the nominal clearance is not of value to the designer. The value statement is an explicit statement (V2) expressed as "won't be considered to be anywhere sufficient".
determining (A7)	54	Right. **What we've determined is that the gearbox is too close to the hull.** So, that means that the shaft angle will have to increase.	The designer determines (A7) that the gearbox is too close to the hull. Value is determined on the gear box position (E1) against a certain distance from the hull (C5). The value statement is explicit (V2) in that the designer states that "the gearbox is too close to the whole", i.e. the gear box position is not of value.
identifying (A13)	19	But **there are maintenance considerations that we'll have to consider.** The operatives will need to move about the engine spaces to conduct maintenance both in and out of the vessels. We have to be able to get them in and out of the engine space.	The designer identifies (A13) maintenance considerations to be considered, i.e. to consider maintenance (C9) of value in the context of the overall design concept (E3).

Activity	Seg. Nr.	Transcript	Value determination
defining (A8)	81	So we have a corresponding flange on our stub shaft. It could be a forged stub shaft and if that's the case the flange could be that much thicker. **Let's arbitrarily put it as 25 mm. That should be comfortable**. If it is a forging, the flange will have a root radius. This could be up to a 15mm radius, maybe a bit more. [Rotate this rectangle 5 and move there.]	In defining (A8), the designer puts in the 25 mm thickness (E4), satisfying the value criteria (C22) "to feel comfortable". The value statement is explicitly expressed (V2) in terms of "that should be comfortable".
exploring (A10)	104	That means that **if the accommodations move further aft, they will come up against the engine, which would be a greater noise source** but perhaps of intermittent nature. **Maybe something we can live with.** Let's do this to see how the rest of the layout turns out.	The designer in exploring (A10) the accommodation position determines its value (E4) against noise "we can live with" (C23). The value statement is explicitly expressed (V2) in terms of "maybe something we can live with".
analysing (A1)	16	Notwithstanding these requirements, **we have to satisfy sensible routes for the installation and ready removal of equipment that are likely to be replaced or serviced**. This adds another driver to where the equipment may or may not be situated.	In analysing (A1) the design concept, the designer identifies the need to satisfy sensible routes for the instalment and removal of equipment. To satisfy sensible routes (C7) is determined as valuable in the context of the overall design concept (E3). The value statement is explicit (V2) in terms of "we have to satisfy sensible routes".
gathering (A11)	12	We have been **advised that the $/kW price of a 4-engine application is prohibitive and that we should concentrate our efforts on the 6-engine application.**	In gathering information (A11), the designer states they have been advised to concentrate on a 6-engine application. The value determination is on the 6-engine application (E1) based on the criterion of the $/kW relation (C6). The value statement is implicit (V1) in that the 6-engine application is "advised" and therefore taken as valuable.

Table 10-5: Design activities frequently related to value determination

An analysis of the absolute number of value determination activities and design activities reveals that within the design episode[15], decision making is about four times more frequently applied than other design activities. In consequence, value determination is frequently related to decision making (Figure 10-2).

[15] The protocol analysis is available in Appendix E.

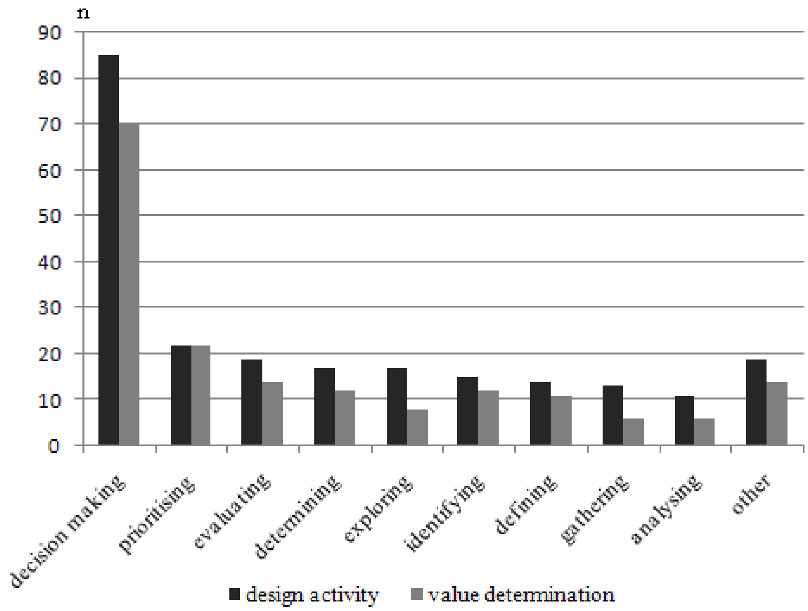

Figure 10-2: Number of value determinations related to design activities

An analysis of the ratio between design activities and value determination reveals that 100% of prioritising is related to value determination (Figure 10-3).

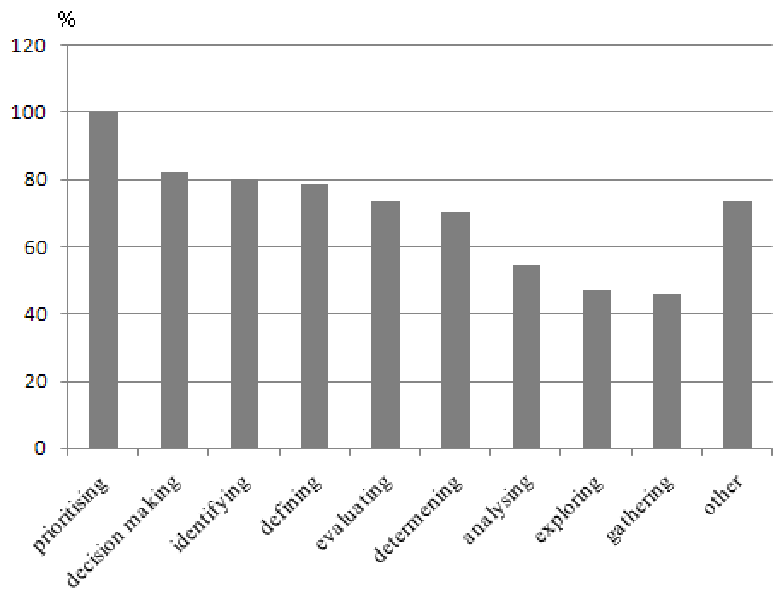

Figure 10-3: Relative percentage of value determinations to design activities

This section provided an analysis of value determination against related design activities. The following section provides an analysis of value entities involved in value determination.

10.2.4. Value entities in design

Analysing value determination against entities reveals that value is determined on the design process (46%) in the context of decision making on the next design step, on the design concept (27%) and on parameters (23%), followed by resources (3%), and risks (1%), as illustrated.

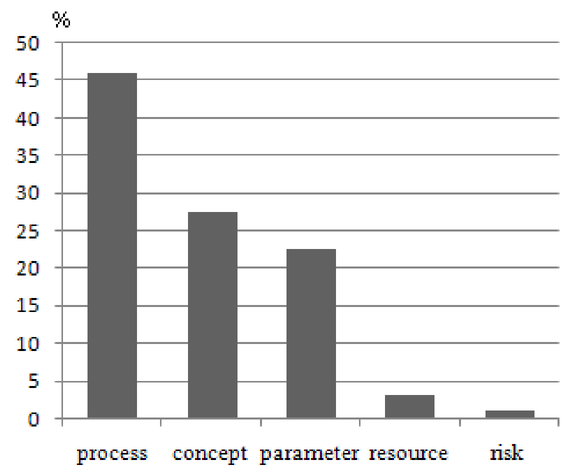

Figure 10-4: Percentage of value entities identified in the design episode

Examples of value entities identified in the design episode are provided.

Value entity	Segment Nr.	Transcript	Value entity
process (E1)	32	**And then from a redundancy consideration, we would like to think** about how to put the engines in separate compartments and divide the two compartments with a water-tight bulkhead.	In deciding the next design step, the designer applies the criteria (C13) “consider redundancy” as value criteria regarding the next step (E1). In other words, the next design step is of value to the designer if the design step considers redundancy.

Value entity	Segment Nr.	Transcript	Value entity
concept (E3)	12	We have been **advised that the $/kW price of a 4-engine application is prohibitive and that we should concentrate our efforts on the 6-engine application.**	In gathering information (A11), the designer states they have been advised to concentrate on a 6-engine application. The value determination is on the 6-engine application (E3) based on the criterion of the $/kW relation (C6).
parameter (E4)	113	Right now the requirements with regard to collision bulkheads are such that the **bulkheads should be placed not less than 94% of ship's length and not greater than 97%. Something of that nature.**	Value determination is on the bulkhead position, i.e. on the parameter of the bulkhead position (E4) to be placed not less than 94% of ship's length and not greater than 97% (C8).
resource (E2)	9	There are a lot of home-made systems that suit the particular requirements. **Therefore, we have to look overseas for different suppliers with perhaps some US connections. This will make the selection in certain situations more acceptable to the US government.**	The designer makes a decision (A5) to "look overseas for suppliers with US connections". Value is determined on suppliers (E2) based on the value criteria (C5) to be acceptable for the US government.
risk (E5)	95	**We've got to be careful that in the process of moving we do not move it through the bulkhead at the other end.** That is some 92 mm in the figure. Move the engine and the gearbox 120 mm.	In evaluating the design concept (A5), the designer identifies the risk "to move through the bulkhead". The designer makes a decision (A9) "to be careful" (E5), which may be of value to the designer in the sense of "not to move through the bulkhead at the other end" (C7).

Table 10-6: Value entities identified in the design episode

This section provided an analysis of value determination against value entities applied throughout the design episode. The following section provides an analysis of value criteria.

10.2.5. Value criteria in design

In analysing value determination against value criteria applied, it appears that in 27% of the value determination activities, the criteria is not communicated in the transcript. This result may be interpreted from different perspectives: consciousness and/or unconsciousness; contradiction to the VDM existing in the empirical data; and/or to what extent the result may be a function of the method applied to identify value criteria.

- From the perspective of consciousness and/or unconsciousness, an interpretation may be that designers tend to apply value criteria in an unconscious manner and/or apply certain criteria in consciousness but do not state criteria explicitly in the design protocol.

- From a human values perspective it may be argued that designers apply value criteria related to human values, i.e. deeply held enduring beliefs but do not express these criteria explicitly in the context of design activities. This interpretation may be seen as supported by the fact that the remaining 73% of value criteria articulated in the context of design activities (with only one exception in terms of "personal satisfaction"), related to design expert knowledge, e.g. clearance, information, position etc.

- From a method perspective it should be noted that the criteria have been identified in the context of design activities and then classified in groups of criteria, i.e. unknown, clearance, information, position, practicability, and other. Thus, criteria not related to the design activities investigated were not identified. With respect to the classification of the criteria, e.g. as unknown, related to clearance, information, etc. it should be noted that this classification was based on the researcher's interpretations of the design protocol text and segments. Thus, criteria applied across segments were not identified.

Despite the 27% of design activities with no value criteria identified, in 73% of the value determination activities, the criteria applied can be identified and grouped into six different classes of criteria. That is, in 15% of the value determination activities, the criteria is related to clearance, in 15% to expected information, in 11% to absolute or relative positions, in 8% to practicability, and in 24% to other criteria in terms of acoustics, balance, customer acceptance, comfort, motion, personal satisfaction, progress, and stability.

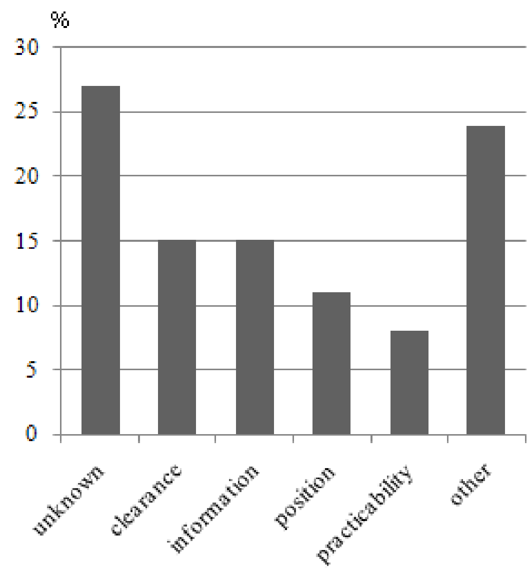

Figure 10-5: Percentage of value criteria identified in the design episode

Examples of value criteria frequently used in the design episode are provided.

Value entity	Segment Nr.	Transcript	Value criteria
unknown (C3)	44	We have the envelope of the engine plus gearbox. **What we must check now, is whether the bottom of the gearbox is going to be within the hull envelope.**	The designer makes a decision (A5) on the next design step (E1) in terms of "what we must check now". The criteria (C3) applied in value determination on the next design step remains unknown.
clearance (C7)	16	Notwithstanding these requirements, **we have to satisfy sensible routes for the installation and ready removal of equipment that are likely to be replaced or serviced.** This adds another driver to where the equipment may or may not be situated.	In analysing (A1) the design concept, the designer identifies the need to satisfy sensible routes for the instalment and removal of equipment. Satisfying sensible routes (C7) includes considerations on clearance and space and is determined as valuable in the context of the overall design concept (E3).

Value entity	Segment Nr.	Transcript	Value criteria
information (C17)	78	**All we're trying to do at this stage is get some approximate idea of space envelope.** How much room do we need to allow for the machinery? Once we have decided that we can then move on to other aspects of the arrangement to see how we can best fit in those needs.	The designer makes a decision (A5) on the next design step (E1) in terms of "all we're trying to do at this stage is to get some approximate idea of space envelope", i.e. value is determined on this next design step based on the criteria to "gain information" (C17).
position (C8)	34	Where else can we consider putting the engines? In this category, **the engines should be placed in such a manner that the propulsion shaft angle with respect to the buttock lines of the vessel in which the shaft line is arranged is 6 to 12 degrees maximum.**	The designer makes the decision (A5) that the shaft line is "arranged 6 to 12 degrees maximum". The engine position (E4) is valued in terms of "such a manner that the propulsion shaft angle is arranged 6 to 12 degrees maximum (C8), i.e. based on a position.
practicability (C9)	23	These prospects are shown on the screen for your inspection. As you can see, **the ability to put 4 engines in a row is just grossly impractical.** There is no room for the ship's structure. The engines would have to go in at heights which would make them difficult to maintain and access. It would raise the CG and impact the overall stability of the vessel. **So, at a glance we can see that this is not a sensible approach.**	The designer makes a decision (A5) that "4 engines in a row is just grossly impractical". The design concept (E3) is valued in terms of "grossly impractical" (C9), i.e. this concept is not of value to the designer based on practical considerations.

Table 10-7: Value criteria identified in the design episode

This section provided an analysis of value criteria applied in value determination throughout the design episode. The following section provides a summary on the investigations on validity of value determination in the context of designing and highlights the insights gained from the protocol analysis.

10.3. Open-interviews

The previous section provided a protocol analysis as a means to investigate the validity of the VDM in the context of design activities. Although the TVD has been developed in a continuous process of observation, empirical generalization, and theory proposition, there may still be aspects relevant to the theory that have not been observed. Therefore, open-interviews with designers are provided in this section to elicit the perspective of practicing designers on the TVD, i.e. to investigate the validity of the constructs of the TVD against current practice.

10.3.1. Interview design

Qualitative interviewing begins with the assumption that the perspective of others is meaningful, comprehensible and able to be made explicit. There are three basic approaches to collecting qualitative data through open-ended interviews (Zhang, 1999):

- The informal conversational interview relies on the spontaneous generation of questions in the natural flow of a conversation. This is typical for an interview that occurs as part of ongoing participant field observations.

- The standardised open-ended interview consists of a set of carefully worded questions and is arranged with the intention of taking each respondent through the same sequence and asking the same questions with essentially the same words.

- The interview guide approach involves outlining a set of issues that are to be explored with each respondent before interviewing begins.

The interview guide approach was selected to investigate the validity of the TVD because the issues to be raised in the interview are known in terms of, i.e. the value axioms, the VDM and the value phenomena models. An interview guide is prepared in order to make sure that the same issues are considered from the individual designers. The interviewer remains free to build a conversation within the area of value in design, to word questions spontaneously, and to establish a conversational style – but with focus on particular issues. The advantage of the interview guide is that it helps the interviewer carefully decide how best to use the limited time available in the interview situation. The guide also helps make interviewing a number of different people more systematic and comprehensive by defining in advance the issues to be explored. Lofland (1971) provides a number of examples of interview guides that have been used in the conduction of sociological research.

Interview guides can be developed in more or less detail, depending on the extent to which it is possible to specify important issues in advance and to which it is felt that a particular sequence of questions is important to ask in the same way or in the same order for all respondents. The interview guide to investigate the validity of the TVD consists of the key elements of the TVD as outlined in Figure 9-1 and related propositions as the issues on which validity is determined during the interview.

A number of decisions must be made in planning an interview: what questions to ask, how much detail to solicit, how long to make the interview, and how to word the actual questions. These are all decisions that will affect the quality of interview responses. There are basically six kinds of questions that can be asked of people: behaviour/experience, opinion, feeling, knowledge, sensory, and background questions (Patton, 1990). Opinion questions aim to understand the cognitive and interpretative processes of people. Answers to these questions tell the interviewer what people “think” about certain issues. These questions typically carry an implication of respondent rationality and decision making. Opinion questions were used primary throughout the interviews. The questions were asked in present tense to gain insights on the respondents’ current understanding of the value phenomenon. The sequence of the questions was arranged from general to specific, i.e. from general characteristics of value to questions on the value determination process and on value-related phenomena.

Table 10-8 provides the interview guide applied to investigate validity of the key elements of the TVD:

Question	TVD issue	TVD element
What is the value of what you see? Showing images of: face-vase-illusion, single crane, mobile crane, multiple cranes on one building	Value is subject to situatedness.	Situatedness Axiom
	Value is based on interpretation.	Interpretation Axiom
	Value is related to entities.	Entity Axiom
	Value is connected to criteria.	Criterion Axiom
What do you think about the concept of value determination illustrated in the VDM? What are the major criteria you apply for value determination?	Value determination involves a personal criteria system.	Criteria Prioritisation
	Value determination is based on selected criteria.	Criteria Selection
	Value refers to the degree an entity satisfies criteria.	Criteria Judgement
How do you think about the TVD's explanations on value adding?	Variables involved in value determination are a situation, knowledge, interpretation of an entity, and criteria prioritisation, selection and/or judgement.	Value adding phenomena
How do you think about the TVD's explanations on value exchange?	Exchange value refers to the extent an "exchange of entities" satisfies an agent's criteria.	Value exchange phenomena

Table 10-8: Interview guide

Three open-interviews were conducted with senior designers each having more than 20 years of design experience. Each of the designers was personally interviewed in a one hour interview session in December, 2008. All of the designers were employed at a market-leading company designing and manufacturing building cranes. However, the designers belonged to different engineering design departments: low-price products; premium products; and a cross functional department with focus on electronic engineering across the product lines. To avoid bias, the designers did not have information on the interview content and related research work prior to the interviews.

The validity of the person and cognition axioms is not explicitly investigated in that these axioms are seen as inherent to the method of interviewing where people formulate value statements as the output of a cognitive process. It was not possible due to demand and time constraints of the employees to investigate the validity of the relationship of value to benefit and need. The following section provides the results from the interviews.

10.3.2. Interview results

This section provides the result of the three interviews explored. The following table presents the issues raised during the interviews in a chronological order, key elements of the interviewee response, and an interpretation of the response from the author's perspective[16].

Question	Response	Interpretation
What is the value of what you see? (showing face-vase image)	"That depends on what the image represents"	In the attempt to determine value, the interviewee points to the dependence of a value statement on an interpreted entity.
	"Where, in the illustration? With only two faces, relatively little can be revealed" "Value develops only in context…"	In the attempt to determine value, the interviewee attempts to identify the value entity and considers the entity's context. This suggests that an entity and its context are relevant to a value statement, which may be seen as part of entity's interpretation.

[16] The transcript of the interviews is available in Appendix F.

Question	Response	Interpretation
	"Where, in the illustration? With only two faces, relatively little can be revealed" "Value of a vase…a place to keep flowers" "It depends... vase... no value there within… I think rather materially"	The value statement changes depending on the interpretation of the face-vase illusion as either "two faces" or "a vase". Without an identified entity, value cannot be logically determined. Even if there is consensus on the entity (a vase) the value statement is dependent on the interviewee, i.e. on the person determining value. This may be interpreted as supporting value as the output of a cognitive process and dependent on the interpretation of entities.
What is the value of what you see? (showing a single crane image)	"To lift and move loads" "Moving loads from A to B" "first the material itself and in the technology and development behind it"	The different value statements on the same value entity support the TVD in terms of personal criteria prioritisation and/or selection. The key word "first" may be interpreted as an indicator for a personal criteria prioritisation.
What is the value of what you see? (showing multiple cranes on one building)	"Different... illustrates the application"	The context of the value entity has changed in that a number of cranes are working together. A change in the context results in the identification of a different value entity, i.e. the application of the product.
	"Organised movement of the loads from A to B"	Value of the application of the product is expressed in terms of "organised movement". In other words, value of the application is judged based on the criteria of organised movement. Thus, a product's function serves as the criteria to determine value of the product's application.
What do you think about the concept of value determination illustrated in the VDM? (exploring entity interpretation and personal criteria systems)	"By all means I confirm that. That is also something that should be desired. It is not always desired. But, that is a very, very strong enrichment in the entire (product development) process. However, there are "only one or two criteria for product acceptance and the profit that you can achieve with the product" "Yes that's obvious. Of course one needs that" "In principle that corresponds"	The interviewee argues that personal criteria systems are relevant to the design process in terms of searching for and finding alternative solutions based on individual criteria. However, in terms of evaluating the results, there are only one or two criteria, e.g. profit.

Question	Response	Interpretation
What do you think about the concept of value determination illustrated in the VDM? (exploring knowledge, criteria selection, and criteria judgement)	"This approach is also part of the task that one has. If we speak about two different tasks, a development engineer and a structural analyst, then there are quite different views on how a part appears" "The development engineer would say we'll make it (the product) … and there are different wall thicknesses in order to develop the (adequate) force curve. The development engineer would say there is no way you can make it because we need far too many raw materials"	The interviewee suggests that value determination is dependent on knowledge, but criteria selection may also be dependent on the design task to be performed, i.e. on individual goals related to design departments. This may be interpreted as a matter of the situatedness of value determination, in that designers select criteria dependent on the task to be done.
What are the major criteria you apply for value determination?	"There are only objective criteria (rather criteria based on ethic/moral principles): that is the marketability of the product together with the profit" "We depend on the calculation with the mechanics" "…for us, as developers… there are various personal criteria; they are our own for the development…"; "…the manufacturing…"; "…marketing has requests"; "…cost accounting has requests"	The designers support the application of criteria in value determination, highlighting different criteria from different departments.
How do you think about the TVD's explanations on adding value?	"...if my customers don't know certain things about my crane, then they can't even consider it valuable, right" "Yes, I can absolutely confirm that. The most important for the customer is that the main functions always work without disruption" "I don't see a contradiction"	The designers support the TVD's explanations on adding value.
How do you think about the TVD's explanations on value exchange?	"Yes, that's right" "Typically, yes"	The designers support the TVD's explanations on value exchange.

Table 10-9: Interview summary

The first part of the interview has a focus on value perception in terms of the perception of value entities. Three different images were presented to the three interviewees independent of each other: a face-vase image, a single crane image and an image of multiple cranes working on one building. The images are illustrated in Figure 10-6.

(9-6 a) (9-6 b) (9-6 c)

Figure 10-6: Pictures applied in exploration of value perception

The interviewees were asked to formalise the value of what they saw in each image. In the context of the face-vase image in Figure 9-6a the interviewees asked for clarification of the entity to be considered, or applied their individual interpretation of the image in terms of either two faces or a vase as the value entity. Without clarification on the value entity, the interviewees were not able to formalise value supporting the argument that value is dependent on interpreted entities. Asked about value in the context of Figure 9-6 b, two agents answered in terms of “moving loads from A to B”, what may be seen as a function of the crane. However, one interviewee valued the crane in terms of the crane’s material, technology, and development effort to build the crane. This supports the argument that people apply individual criteria for value determination. Asked about value in the context of Figure 9-6 c, the interviewees valued the application of the cranes, e.g. in terms of an “organised movement” of cranes. In other words, a change in the value entity’s context (e.g. from a single crane to multiple cranes on one building) changed the entity valued from the crane to “the application of cranes”. This is a supplement to the TVD, which so far only considered changes in an agent’s situation. However, changing a value entity's context provides an additional opportunity to change a value statement.

Overall, the interviewees support the situated characteristic of value referring to different criteria applied, dependent on the design task to be done. The dependence of a value statement on interpreted entities is supported in terms of different statements made in the context of the different entities valued. According to the interview results, an entity and its context are relevant to formalising a value statement. The criterion axiom is supported in that the designers formalise their major value criteria for value determination. The personal criteria systems are seen as relevant in the design process, but in evaluating a solution, only a small number of criteria may be applicable (e.g. profit). The interviewees support the relevance of knowledge in value determination and criteria selection dependent on the design task to be done. The TVD's explanation on added value is supported in terms of knowledge required on criteria and no contradictions were found. The TVD's explanations on value exchange are supported in general terms.

The interview does not support the VDM in terms of the cognitive processes modelled nor do they identify contradictions. However, while the cognitive processes modelled in the VDM provide a means to derive results (e.g. value statements) corresponding to practice, by no means does this suggest that the cognitive processes in reality are those modelled in the VDM. Furthermore, it should be noted that the interpretation of the interview is based on three independent interview results with respect to the issues raised in the interview guide (Table 10-8). However, the interpretation of the interview data is not verified further e.g. based on a discussion of the results with designers.

While Sections 10.2 and 10.3 provided an investigation on the validity of key elements of the TVD, the following section provides an evaluation of the overall TVD against requirements for a theory of value in the context of design.

10.4. Requirements

This section provides an evaluation of the TVD against theory requirements. The requirements were identified from the perspectives of design (Section 4.1) and value (Section 4.2) theory. A summary of the requirements was provided in Table 4-3 where an identification code (R1 to R14) for each requirement was introduced. The following paragraphs provide an analysis of the TVD against the requirements identified.

R1 – The TVD should provide novel insights: The TVD provides novel insights on value axioms (Chapter 6), on the variables and mechanisms involved in value determination (Chapter 7), and on value-related phenomena (Chapter 8). Furthermore, it provides explanations of philosophical and scientific value issues (Table 10-10), and on instances related to value in design (Table 10-11).

R2 – The TVD should provide clarity in value definitions: Value is defined in the TVD. Value refers to a judgement on the extent an interpreted entity satisfies an agent's criteria (Section 7.4).

R3 – The TVD should provide clarity in construct relationships, mechanisms, and variables involved: The TVD identifies the construct relationships and mechanisms involved in value in the context of design. Value is described in terms of a value statement (V), as the output of a cognitive value determination process. Input knowledge to the process is knowledge of an interpreted entity (E). The process involves the cognitive activities of criteria prioritisation (A_{cp}), selection (A_{cs}), and judgement (A_{cj}). The TVD introduces a personal criteria system consisting of an agent's knowledge (K), a criteria prioritisation activity (A_{cp}), and a set of prioritised criteria (C_p). The system is seen as an ongoing cognitive process prioritising criteria, introducing new criteria, and removing criteria from the prioritised set (C_p) as appropriate. A criteria selection activity (A_{cs}) is introduced, selecting criteria from the prioritised criteria (C_p) and from the agent's general knowledge (K) in the context of knowledge of an interpreted entity (E). Criteria selection (A_{cs}) "adds" criteria to an entity, establishing a cognitive link between the interpreted entity (E) and criteria (C_s) selectively used for value determination. The TVD introduces a criteria judgement activity (A_{cj}), evaluating the extent an interpreted entity (E) satisfies selected criteria. In criteria judgement (A_{cj}), a formal process of evaluation applies. Within criteria judgment, measurable or non-measurable criteria may be applied and the extent to which an entity satisfies the criteria will be judged, leading to judged criteria (C_j), from which a value statement is derived (V). This value judgement is cognitively linked to the entity (E), in that the criteria applied are entity specific. The variables involved in the phenomenon of value in the context of design are highlighted in Section 8.1 in terms of the interpretation of an entity (E), the situation of an agent (S), the knowledge of an agent (K), the activity of entity interpretation (A_{ei}), the activity of criteria prioritisation (A_{cp}), the activity of criteria selection (A_{cs}), and the activity of criteria judgement (A_{cj}).

R4 – The TVD should provide a perspective of value in the context of design: The phenomenon of value is explained in the TVD from the perspective of a cognitive process of value determination in the context of design. The perspective of the cognitive process of value determination provides a basis common to different value approaches, e.g. value as a characteristic an entity has in itself (Atkin, 1990), as a characteristic an entity is said to possess only when an entity is in relation to some other entity (Sparks et al, 2001), and as a belief (Rokeach, 1973) with a cognitive process involved for value determination (Lamont, 1956). The perspective of value provided in the TVD is a perspective of value in the context of design and based on considerations given to value interpretations in design (Section 2.2), product and process value management in design (Sections 2.3-0), economic value of design (Section 2.5), human values in design (Section 0), design theory characteristics (Section 4.1), a research methodology for research on value in a design context (Chapter 5), an analysis of value determination in the context of design activities, i.e. protocol analysis (Section 10.2), open-interviews with designers (Section 10.3) and a requirements analysis against design and value theory requirements (Section 10.4).

R5 - The TVD should support explanations on conceptual issues and substantive problems: The phenomenon of value in the context of design is conceptualised in the TVD and provides explanations on the cognitive process of value determination (Chapter 7). The TVD addresses substantive problems in providing explanations on the generic characteristics of value (Chapter 6) and on the key elements and mechanisms involved in value determination (Chapter 7).

R6 – The TVD should support explanations on issues related to the philosophical and scientific value discussion: The following table provides an overview on key issues addressed in value theory identified in the context of the literature review provided in Chapters 2 and 3. Explanations of these issues are provided from the TVD perspective. The issues are classified in terms of their primary (but not unique) relationships to axiology, economics, psychology, and sociology.

Classification	Issue	Explanations
Axiological or philosophical discussion of value	"right" vs. "wrong"	The axiological or philosophical discussion of value is related to ethics and moral theory. Seni (2007) highlights that these theories rest on the concepts of good and bad, right and wrong, and just and unjust (Section 3.1). In terms of the TVD, the good and bad, the right and wrong, and the just and unjust can be considered in the context of the personal criteria system as key elements in the value determination process (Section 7.5). It can be argued that what is of value in terms of, e.g. right and wrong, is judged on the basis of personal criteria selected from the personal criteria system in the context of a certain situation.
	intrinsic vs. extrinsic	In terms of intrinsic and extrinsic values, the TVD argues that value is the output of a cognitive value determination process. In formulating a value statement, a person selects criteria from the personal criteria system. In selecting the criteria, a person must consider knowledge of the interpreted entity. In other words, a person in selecting criteria establishes a cognitive link between an interpreted entity and the set of criteria required to formulate a value statement (Section 7.4). Thus, from a TVD perspective, value does not reside in an object, i.e. is not intrinsic. It is based on the

Classification	Issue	Explanations
		interpretation of an object and the output of a cognitive process, which may be interpreted as an "extrinsic" view of value.
	"end value" vs. instrumental	"End" or "instrumental" values can be interpreted from a TVD perspective in terms of a value statement based on specific criteria applied for value determination. Criteria may be related to "end" or "instrumental" values in that, e.g. someone may be valued against "honesty" seen as an "end value", based on the criteria of "saying the truth". Or, someone may be valued against "generosity" seen as an instrumental value, based on the criteria of an "amount of money spent for social purposes".
	value judgement	Literature on value provides different perspectives on judgement (Section 3.1): human beings using knowledge to judge need satisfaction (Seni, 2007); judgement on "good and bad" (Lamont, 1956); value referring to a preferential judgement; and values referring to criteria by which preferential judgements are made (Holbrook, 1994). Judgement in the TVD refers to the cognitive activity of judging to what extent an interpreted entity satisfies criteria. This activity is based on an agent's knowledge (Section 7.4). In other words, the judgement is on the degree of satisfaction of the criteria applied for value determination. The criteria may be related to need (Section 8.5), to "good and bad", to preference, and/or to values in the sense of ethic/moral principles, but not necessarily are.
	value axioms	Axioms in the context of value theory refer to rules that are universal in their unrestricted applicability throughout the value domain. Kraus (1973), e.g. proposes the axiom of when something has value, then the more there is of it the greater the value. From a TVD perspective, this may be true in a specific case depending on the criteria applied for value determination. For example, if a certain amount of money is seen as valuable, more money may be seen as having a greater value. However, this is a specific case and not a rule applicable throughout the value domain. The TVD is based on value axioms in terms of the person, cognition, determination, situation, interpretation, entity, and criteria axioms (Chapter

Classification	Issue	Explanations
		6).
Economics	value in exchange	In the pricing theory, the value of a good is considered in terms of value in exchange. The value of a good in a given economy is seen as the value that society determines it should have and this value is the same as its price (Seni, 2007). From a TVD perspective, value in exchange refers to a specific situation where value is determined on the extent an exchange of entities satisfies an agent's criteria (Section 8.2). From this it can be concluded that value may be determined in the context of exchange and/or based on criteria "typically" applied in economy, e.g. price, but not necessarily is.
	value vs. labour	According to Ricardo and Marx, value is equal to labour, where labour is the quantity of labour that goes into making a good (Section 3.2). From a TVD perspective, the value of a good can be determined based on criteria related to labour, e.g. complexity, hours, quality, but not necessarily is.
	value vs. cost	Value theories related to engineering and technologies consider the value of an artefact in terms of the cost of producing or acquiring and using the artefact that allows performing the functions of one's needs, given available resources, options, and circumstances (Seni, 2007). From a TVD perspective, the "cost of producing or acquiring and using an artefact that allows performing a function of one's needs" can be interpreted as a value criterion applicable in value determination. However, it should be noted that the TVD separates value from need (Section 8.5), i.e. value is not necessarily related to need.
	value vs. function	Value theories argue that value does not reside in the form or substance of an artefact neither in attitude, beliefs, desires, nor pleasures for a user. Value is seen in the performance of functions through a user-artefact interaction (Bunge, 2006). From a TVD perspective, the value of an artefact can be determined based on criteria related to performance, but not necessarily is.
	social value	Value theories in economics (Section 3.2) can be considered from the perspective of the social value created by members of an economy. In this context, the exchange value of goods can be considered in terms of: the worth of the product's

Classification	Issue	Explanations
		function minus product price; the price minus the cost of production; and the total value to the society, i.e. the worth of the product's function to the customers minus the cost of producing these functions (Seni, 2007). From a TVD perspective, the different perspectives of social value are related to different criteria applied for value determination.
Psychology	value vs. need	Value theories argue that behaviour is triggered by motivations that are in turn determined by needs. This concept interprets value in terms of individual needs (Seni, 2007). According to the TVD, value is not dependent on need (Section 8.5). However, motivation may be related to criteria applied in value determination, i.e. it may have an influence on the cognitive activity of criteria prioritisation, selection, and judgement. In the context of the TVD, motivation may also be interpreted as related to an agent's knowledge in that knowledge may influence motivation.
	value vs. behaviour	Value theories suggest a relationship of value to decision making and goals (Section 3.3). From a TVD perspective, personal goals are seen as part of an agent's knowledge. Consequently, personal goals may influence criteria prioritisation, selection, and judgement. In the context of designing and design activities, the value determination activity is related to decision making as outlined in Section 10.2.3. However, it should be noted that from a TVD perspective, a determined value may have an influence on decision making, but not necessarily.
	value vs. benefit	Value theories suggest a relationship of value to benefit. Rescher (1982), e.g. argues that a person subscribes to a value because the person sees its realisation as beneficial. In the context of the TVD, the relationship of value to benefit is investigated in Section 8.4. It was concluded that a benefit may be related to value in that a benefit may serve as input knowledge to value determination.
	value vs. emotion and desire	Value theories consider emotion or desire as the basis for value (Section 3.3). From a TVD perspective, emotion and desire can be seen as related to an agent's knowledge, i.e. they may influence entity interpretation, criteria

Classification	Issue	Explanations
		prioritisation, selection, and judgement. As such, emotion and desire can be seen as part of the knowledge "basis" for value determination.
Sociology	value as criteria	One of the basic value concepts in sociology is "value as a criterion", i.e. value as a standard for evaluation (Section 3.4). According to the TVD, value is seen as the output of a cognitive process. In other words, a distinction is made between value and the criteria applied for value determination.
	value vs. norms	Value theories in sociology consider needs as prerequisites for the development of values. In this concept, needs give rise to values and values are related on a social level to norms (Section 3.4). In the TVD, needs are seen as part of an agent's knowledge, i.e. as a resource to determine value. Based on an agent's knowledge, the agent's personal criteria system may change in terms of criteria considered and prioritised. An agent may apply criteria "common" to cultural norms.
	value attitude	Damasio (2003) argues that animals, from which humans are one species, manifest instincts of value, i.e. have positive and negative attitudes expressing wants and desires. Value determination in the TVD is based on an agent's knowledge. The term knowledge is applied in a broad sense to basic physical needs, derivative desires, experiences, expert knowledge, implicit theories on how the physical world behaves, inborn qualities, outcome foci, and self-esteem needs (Section 6.3). Thus, value attitude from a TVD perspective can be explained in terms of an agent's priority on value criteria based on an agent's knowledge.
	value systems	Value literature proposes value systems on group and individual levels. On a group level, terms like social, cultural, or organisational value systems are used to denote the ordering of the values held by a particular group of people; on an individual level, values are seen as being ordered by importance relative to one another (Section 3.4). According to the TVD, value is determined on the basis of personal criteria systems rather than personal value systems. Social, cultural, or organisational "value systems" may be seen as criteria systems on a group level and may become

Classification	Issue	Explanations
		part of an agent's knowledge.
	value evolution	From a value theory perspective, values are not seen as something that humans are born with. They are learned and developed through interaction with other humans, and through the experience of decision making situations (Section 3.4). According to the TVD, value is determined based on criteria. Thus, it is suggested that what is learned by an agent are criteria to be applied for value determination. The criteria are part of an agent's knowledge and may be learned and developed through interaction with other humans, and through the experience of value determination situations.

Table 10-10: Explanations on philosophical and scientific value issues

From the explanations provided in Table 10-10, it can be concluded that the TVD provides a consistent basis for explanations on value-related issues across disciplines including axiology, economics, psychology, and sociology.

R7 – The TVD should support explanations on instances of the value phenomenon in the context of design: Table 10-11 provides an overview on instances[17] of the value phenomenon in the context of design identified in Chapter 2 in terms of value interpretations (Section 2.2), product and process value management (Section 2.3 and 0), economic value of design (Section 2.5) and human values in design (Section 0). The explanations on the instances are provided in context of the knowledge gaps identified (Section 2.7).

[17] The term *instance* is applied in the sense of an occurrence of the value phenomenon.

Instance	Context	Explanation
Value interpretations in design	When does value in design "appear"?	From the work reported in this thesis it can be concluded that value is determined in the context of design activities (Section 10.2.3). In the design episode investigated, value is determined primarily in the context of prioritising and decision making (Figure 10-3). This may be seen as an indicator that value in design "appears" in the context of cognitive decision making processes.
	What is the appropriate metric of value in design?	Value refers to a judgement on the extent an interpreted entity satisfies an agent's criteria (Section 7.4). As such, there may be no "appropriate metric" for value in design. Criteria applied for value determination depend on an agent's knowledge, interpretation, and situation.
	How to add value in design?	Value refers to a judgement on the extent an interpreted entity satisfies an agent's criteria (Section 7.4). Added value can be interpreted as an increase in the extent an entity satisfies criteria (Section 8.1). In the context of adding value, consideration needs to be given to criteria selection and judgement. In criteria selection, agents select specific criteria in the context of the interpreted entity. In doing so, agents establish a cognitive link between the interpreted entity and criteria, i.e. agents add criteria cognitively to the entity. The selected criteria are then the input to criteria judgement and consequently the basis for the value statement. In this context, adding value may then be interpreted as the activity of adding criteria increasing the degree of satisfaction and/or replacing added criteria with more satisfactory ones (Section 8.1). So, value cannot be added directly in design. However, a basis for adding value in design may be seen in the knowledge on the criteria applied for value determination.
Value management in design	What is the relationship of value to benefit and cost?	According to the TVD, value is related to benefit in that a benefit may serve as the input knowledge to value determination (Section 8.4). Cost can be seen as a value criterion applied in value determination (Section 7.4).
	What are the key elements and mechanisms involved in	The VDM outlines the mechanisms involved in the value determination process (Section 7.6) and as such, mechanisms involved in design process value. The key elements involved in the value determination process may be seen as key

Instance	Context	Explanation
	design process value?	elements involved in design process value in terms of: an interpretation of an entity, a situation of an agent, knowledge of an agent, and the activities of criteria prioritisation, selection and judgement. It should be noted that in the determination of design process value, the design process per se becomes the value entity.
Economic value of design	What are the key elements and mechanisms involved in the economic value of design?	Based on the VDM, economic value may be interpreted as the output of a value determination process based on economic criteria (e.g. cost, margin, time-to-market). The VDM outlines the mechanisms involved in the value determination process (Section 7.6). The key elements of the VDM may be seen as key elements involved in the economic value of design in terms of: an interpretation of an entity, a situation of an agent, knowledge of an agent, and the activities of criteria prioritisation, selection, and judgement. It should be noted that in the determination of the economic value of design, design per se becomes the value entity.
Human values in design	What are underlying key elements and mechanisms involved in human values in design?	The TVD integrates human values in terms of personal criteria systems applied in the value determination process (Section 7.5). So, from a TVD perspective, design theories that consider human values in terms of e.g. technology that accounts for human values, ethics, and/or satisfaction indices aim to focus design on criteria applied in value determination. The key elements and mechanisms outlined in the VDM (Section 7.6) and in particular the personal criteria system (Section 7.5) may be seen as underlying key elements and mechanisms involved in human values in design.
	What is the relationship of human values in design to activities, beliefs, criteria, goals, and situations?	Based on the TVD, value is determined in the context of design activities (Section 10.2.3) and a personal criteria system is applied (Section 7.5). In the VDM, beliefs in the sense of ethic/moral principles and goals are interpreted as part of an agent's knowledge (Section 7.3), where they may be related to priorities in personal criteria systems. Criteria are central to the VDM, i.e. to the value determination process in terms of personal criteria systems, and the activities of criteria prioritisation, selection, and judgement (Chapter 7). From a TVD perspective, value is the output of a cognitive process and consequently subject to

Instance	Context	Explanation
		situatedness (Section 6.3).
	What is the relationship of human values to other value types?	The TVD integrates human values in terms of personal criteria systems applied in the value determination process (Section 7.5). From this perspective, the distinction made in value literature between “human values” and “value” refers to the distinction between criteria held in personal criteria systems for value determination (human values), and the output of the cognitive process of value determination (value). This is what separates “human values” from other value types like brand, customer, economic, exchange, expectancy, product, relationship, and shareholder values.
	How is value related to strategic goals?	Based on the TVD, value is different from goals. On the one hand, a company may define goals and then value the contribution of entities based on criteria related to these goals. On the other hand, goals may become part of an agent’s knowledge and consequently criteria related to goals may be applied for value determination.

Table 10-11: Explanations on instances of value in the context of design

From Table 10-11 it can be concluded that the TVD provides a consistent basis for explanations on instances of the value phenomenon in the context of design.

R8 - The TVD should support explanations on value creation, analysis, and measures: Explanations related to value creation are provided in Section 8.1 in the context of added value. Value refers to a judgement on the extent an interpreted entity satisfies an agent’s criteria (Section 7.4). Added value can be interpreted as an increase in the extent an entity satisfies criteria (Section 8.1). Regarding adding value, consideration needs to be given to criteria selection and judgement. In criteria selection, agents select specific criteria in the context of the interpreted entity. In doing so, agents establish a cognitive link between the interpreted entity and criteria, i.e. agents add criteria cognitively to the entity. The selected criteria are then the input to criteria judgement and consequently the basis for the value statement. In this context, adding value may then be interpreted as the activity of adding criteria increasing the degree of satisfaction and/or replacing added criteria with more satisfactory ones (Section 8.1). So, value as an output of a cognitive process cannot be directly "created". From a TVD perspective it may be suggested that value analysis should focus on the analysis of the variables involved in value determination, i.e. on the interpretations of the entity considered for value determination, on the agent's knowledge, and on criteria prioritisation, selection, and judgement. Measures in value theory (e.g. cost, function, performance) from a TVD perspective refer to criteria applied in value determination. What may be measured in the context of value is the extent an interpreted entity satisfies an agent's criteria.

R9 – The TVD should integrate or relate to other theories and consider relevant literature: The TVD integrates the generic design activity concept (Sim and Duffy, 2003) in Section 7.2 and the approach of Gero (2002) on situatedness in Section 6.3. The TVD is related to design theory in the context of design definitions, value interpretations in design, product and process value management, economic and human values (Chapter 2), and design theory characteristics (Section 4.1). The TVD is related to value theory in the contexts of axiology, economics, psychology, sociology (Chapter 3), and value theory characteristics (Section 4.2).

R10 - The TVD should have a defined scope: The TVD is a theory of value in the context of design. From a value perspective, the TVD covers value of an entity, as an activity, and human values based on a model of the value determination process (Section 7.6). From a design perspective, the TVD covers design as an activity, as an artefact, and human factors in design based on a protocol analysis of value determination in the context of design activities (Section 10.2) and open-interviews with designers (Section 10.3) with consideration given to value in the context of design artefacts and value determination based on personal criteria systems (Table 10-8). From a theory perspective, the TVD covers value and design theory based on an analysis of the TVD against theory requirements derived from value and design theory characteristics (Section 10.4).

R11 – The TVD should be built upon axioms and/or generalised characteristics: The TVD is built upon the axioms outlined in Chapter 6. The value axioms can be seen as rules basic to the theory of value and consequently basic to the theory of value in design.

R12 – The TVD should be testable: The TVD is based on a model of a cognitive process of value determination (Chapter 7). A model of a cognitive process cannot be tested directly. Consequently, key elements of the TVD are tested in terms of a protocol analysis (Section 10.2), open-interviews (Section 10.3), and a requirements analysis (Section 10.4).

R13 – The TVD should be evolutionary: The development of the TVD is based on a world view of critical realism (Section 5.1.3). In the world view adopted, there is no claim for a totally comprehensive understanding of a certain problem or for a "complete" perspective. Thus, the TVD is seen as evolutionary in the sense that application of the theory may lead to new insights and consequently to evolutionary modifications.

R14 – The TVD should provide a means to improve design artefact, process, practice, and/or research performance: In Section 2.7 it was concluded that current literature on value in design lacks a more fundamental formalism of value. The TVD provides such formalism to support the development of more comprehensive explanations on value and consequently on value in design. Thus, the TVD can be seen as a means to improve research performance in supporting the development of explanations on the nature of value and on value-related phenomena. Consequently, design artefacts, processes, and practices may be improved.

Overall, the TVD satisfies the requirements for a theory of value in the context of design as summarised in Section 4.3.

10.5. Summary

The previous sections provided an evaluation and a degree of validation of the TVD in terms of: a protocol analysis on value determination in the context of design activities (Section 10.2); open-interviews on the TVD (Section 10.3); and an evaluation of the TVD against theory requirements (Section 10.4). This section provides a summary of the results:

- The protocol analysis (Section 10.2) identifies value determination in the context of design activities. In the design episode investigated, value was primarily determined in the contexts of prioritising, decision making, identifying, defining, evaluating, determining, analysing, and gathering (Figure 10-3). Value entities identified for value determination are the design process, concepts, parameters, resources, and risks. Major criteria applied throughout the design episode are clearance, information, position, and practicability. However, in 27% of the value determination activities, the criteria could not be derived from the transcript. This may be interpreted as an indicator that designers tend to apply value criteria in an unconscious manner and consequently do not state value criteria in the design protocol; or, from a human values perspective, that designers apply value criteria related to human values, i.e. deeply held enduring beliefs, but do not express these criteria explicitly in the context of design activities. Overall, the results of the protocol analysis support the proposed VDM, i.e. they provide a degree of validation in that value determination was identified in the context of designing. However, the relationships between value determination and design activities and between the value criteria and entities identified may be dependent on the individual designer and the design episode, i.e. they cannot be generalised.

- The results of the open-interviews (Section 10.3) provide a degree of validation of the following elements of the theory: the situatedness, interpretation, entity, and criteria axioms; the key elements of value determination in terms of knowledge, criteria, and value statements involved; and the TVD's explanations of value adding and exchange. The TVD evolved based on the open-interview results, in that changing a value entity's context provides an additional opportunity to change a value statement. With respect to the VDM, the interviews do not provide any contradictions, but at the same time do not provide support on the cognitive activities modelled within the VDM.

- The results of the requirements analysis (Section 10.4) highlight the capability of the TVD to satisfy theory requirements derived from design and value theory. Overall the TVD provides: novel insights on the value phenomenon; clarity in value definition; clarity in construct relationships, mechanisms, and variables involved; a perspective of value in the context of design; support on conceptual issues and substantive problems; explanations on philosophical and scientific value issues; explanations on instances of value in design; and explanations on value creation, analysis, and measures. The TVD: integrates and relates to existing theories; has a defined scope; is built on axioms; is testable and evolutionary; and provides a means to improve design artefact, process, practice, and/or research performance.

11. Discussion

The aim of the research reported in this thesis was to develop a theory of value in the context of design as a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. This includes: a set of value axioms presented in Chapter 6; a model of value determination illustrated in Chapter 7; and value-related phenomena explored in Chapter 8. The overall value formalism was presented in terms of the theory of value in design (TVD) in Chapter 9, and an evaluation of the work was presented in Chapter 10.

This chapter presents a discussion of the work reported in this thesis in terms of the pros and cons of: the aim and objectives (Section 11.1); the research methodology (Section 11.2); the overall TVD (Section 11.3); the value axioms (Section 11.4); the model of value determination (Section 11.5); and the explanations on value-related phenomena (Section 11.6). Future research is recommended (Section 11.7), and a summary of the discussion is provided (Section 11.8).

11.1. The aim and objectives

The TVD provides a means to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design, i.e. corresponding to the aim of the research work reported in this thesis (Section 1.3).

Within the research reported in this thesis, a current state of knowledge on value in design and on value theory in general was established (Chapters 2 and 3). Shortcomings of current work were summarised (Section 3.7). Requirements for a theory of value in the context of design were identified (Section 4.3), and derived from design (Section 4.1) and value (Section4.2) theory characteristics. The TVD was evaluated against the requirements (Section10.4). The key characteristics of the value phenomenon were identified in terms of value axioms (Chapter 6), and a model of value determination was established as a means to provide explanations on the underlying key elements and mechanisms involved (Chapter 7). The theory was described and concept relationships within the theory were considered (Chapter 9). The research work was evaluated (Chapter 10). The pros and cons of the work were considered and implications for future work were provided (Chapter 11). As such, the work reported in this thesis corresponds to the aim and the objectives outlined in Section 1.3. However, it should be noted that the selection of data sources was subject to the time that could be assigned for conducting the research presented in this thesis. In particular, further investigations on value in the context of design are recommended under the consideration of additional value literature across disciplines.

Overall, the pros and cons of the work presented were considered to be:

Pros

- ✓ A current state of knowledge on value was established.
- ✓ Requirements for a theory of value in the context of design were identified and the TVD was evaluated against those requirements.
- ✓ Key characteristics of the value phenomenon were identified and explanations on the underlying processes and mechanisms were given.
- ✓ Value was formalised in terms of the theory of value in design and concept relationships were considered.
- ✓ The research work was evaluated, strengths and weaknesses were considered, and implications for future work were provided.

Cons

- o The selection of data sources was subject to the time that could be assigned for conducting the research presented in this thesis. Further research on value in the context of design is recommended under the consideration of additional value literature across disciplines as a means to gain further insights on the internal and external validity of the TVD.

11.2. The research methodology

Research can be understood as a systematic enquiry whose goal is to create new knowledge (Chapter 5). A research methodology provides a means that conclusions of the research effort are based on and conducted with as much rigour, relevance, significance, integrity and independence as possible. Research should be conducted based on the most valid and reliable procedures, methods, and techniques, and the process should be unbiased as possible.

The nature of value in the context of design resulted in a research methodology based on a paradigm of critical realism (Chapter 5). Within the world view adopted and from an ontology perspective it is considered possible to conceptualise reality and to make theories in order to describe it. From an epistemology perspective, emphasis is on “how and why” particular phenomena come into being. From a methodology perspective, emphasis is on causal mechanisms and how they work. Empirical inquiry entails examining the range of possible mechanisms at play and analysing which are to be studied and which are felt to have a relevant impact. This world view resulted in a “search” for knowledge in a continuous process of observation, empirical generalization, and theory proposition. The value phenomenon was investigated from different perspectives where triangulation was applied to data, methods, and observers.

The data triangulation of the work includes data from: an investigation on value in industry (Hug, 2003); value theories in design, axiology, economics, psychology, and sociology; and design practice in terms of a design session protocol. Such data triangulation ensures that data from different sources is used not only in the sense of practice and empirical data, but also in the sense of data from different disciplines, which is considered as supportive in building a fundamental theory of value. Data triangulation was applied in the context of developed value axioms based on an analysis of value interpretations in design (Section 2.2) and value interpretations in axiology, economics, psychology, and sociology (Sections 3.1-3.4). Value definitions were analysed against characteristics in common (Appendix D); the results were investigated in the context of further value theories in design, axiology, economics, psychology, and sociology; and value axioms were formalised in a continuous research process. This supports that: the axioms describe common characteristics of value across disciplines; the characteristics are plausible in the context of value theories; and relevant literature is considered. Data triangulation was also applied in deriving requirements for the TVD from literature on design theory (Section 4.1) and value theories (Section 4.2).

Method triangulation in the context of the TVD was applied based on literature reviews (Chapters 2 and 3), a protocol analysis (Section 10.2), and open-interviews (Section 10.3) - methods that have been shown to be valid and provide a degree of reliability (Ericson and Simon, 1984; Gero and McNeill, 1998, Ridley, 2008). Method triangulation provides a means of assessing a degree of convergence as well as elaborating the divergence between results. It was applied to key elements of the VDM in investigations on the validity of value determination in a design protocol analysis (Section 10.2) and in open-interviews with designers (Section 10.3). In the open-interviews, observer triangulation was applied in terms of interviewing designers from different departments to reduce bias in the research process.

Overall, the pros and cons of the research methodology were considered to be:

Pros

- ✓ The critical realism world view matches the nature of the phenomenon of value in the context of design in that it captures central aspects of natural and social sciences. From an ontology perspective, it is considered possible to conceptualise reality and to make theories in order to describe it, but there is no claim for a "complete" perspective of a certain problem. From an epistemology perspective, emphasis is on "how and why" particular phenomena come into being.
- ✓ Data triangulation ensures that the theory of value in design was not based on one data source only, but rather on data across axiology, economics,

psychology, and sociology which were considered as supportive in building a fundamental theory of value.

- ✓ Method triangulation as applied to key elements of the VDM provided a means of assessing a degree of convergence as well as elaborating the divergence between the results.
- ✓ Observer triangulation as applied in the context of open-interviews to the VDM was applied to reduce bias in the research process.

Cons

- o Only one design protocol was analysed against value determination as described in the VDM, i.e. further protocol analysis may provide further insights on value determination in design

11.3. The theory of value in design

The TVD presented in Chapter 9 is aimed to support the development of more comprehensive explanations on the value phenomenon and consequently on value in the context of design. The theory is considered novel because it provides previously undefined value axioms, explanations on value determination, and new insights on value-related phenomena.

The TVD has a degree of generality in that: the value axioms provide general statements on the nature of value; the VDM provides a general representation of the value determination process; and the explanations on related phenomena are based on the VDM where general terminology is applied. The TVD supports consistent explanations on value-related phenomena in axiology, economics, psychology, and sociology (Section 10.4) and, from a design perspective, explanations on value as the value of an entity, an activity, and human values. The validity of the VDM was investigated in a design protocol analysis and in open-interviews with designers. The overall TVD was evaluated against requirements for a theory of value in the context of design. The generality of the theory beyond this is not tested and the interpretations of the interview data were not verified. The TVD was tested in the context of design based on a design protocol analysis and open-interviews with designers, i.e. it was not tested in the context of other individuals and social groups, within or across different cultures, which can be seen as a limitation in generality. Future work is recommended in this area.

The TVD is based upon value axioms, which can be seen as statements about value as a basis for building the theory. The identification of value axioms was based on an analysis of value characteristics in common across disciplines. The axioms serve as a means for the development of a value determination model that is based on knowledge processing activities. The VDM provides interpretations of cognitive activities involved in value determination. Based on the value axioms and the VDM, explanations on value-related phenomena were derived. The coherence of the TVD was then investigated in terms of the relationship between key elements of the TVD: an interpreted entity, an agent's knowledge, value determination activities, and a value statement. The coherence was further investigated in terms of the relationship of the TVD to value axioms, the VDM, and the explanations on value-related phenomena (Section 9.3), with no contradictions found (Section 9.3).

The TVD was evaluated against design and value theory requirements (Section 10.4). In literature, there is no pre-defined set of requirements for a theory of value in the context of design. Characteristics of design theory (Section4.1) and value theories (Section 4.2) were derived from literature and interpreted as requirements for the TVD (Section 4.3). The TVD satisfies the requirements for a theory of value in design in that the TVD: provides novel insights on value in the context of design, a value definition, and a perspective of value in the context of design; describes value in the context of design in terms of construct and construct relationships; supports explanations on conceptual and substantive problems, on issues related to the philosophical and scientific value discussion, on instances of value in design, and on value creation, analysis, and measurement; integrates other theories; has a defined scope; is built up-on axioms; is testable; is evolutionary; and the TVD can be seen as a means to improve research performance.

It should be noted that the TVD is a theory of value in the context of design, i.e. provides a means to develop explanations on value in design. Although explanations on instances of value in design were considered (Section10.4), this area provides potential for future research on: value criteria to be applied in design; value adding; value analysis; value management, economic value of design; and human values in design (Section 11.7.2).

Overall, the pros and cons of the theory of value in design were considered to be:

Pros

- ✓ The TVD is considered novel because it provides previously undefined value axioms, explanations on value determination, and new insights on value-related phenomena.
- ✓ The TVD has a degree of generality in that it supports consistent explanations on value-related phenomena across disciplines.
- ✓ The coherence of the TVD was investigated in terms of the relationship of value axioms, the value determination model, and the explanations on value-related phenomena to the TVD's constructs.
- ✓ The TVD satisfies theory requirements.

Cons

- o The interpretations of the interview data were not verified further and the results of the open-interviews may consequently provide a biased perspective. A verification of the interpretations with designers and/or the triangulation of data interpretation may provide means to gain insights on the validity of the results.
- o The validity of the TVD was not investigated with individuals, social groups other than designers, or multiple stakeholders. Generality is consequently limited to the context of design. Further investigations on the TVD with other individuals or social groups may support the generality of the TVD.

11.4. The value axioms

The value axioms identified in Chapter 6 were aimed to provide an initial basis for building the TVD. The axioms focus on generic key elements that are inherent to the value phenomenon across disciplines.

The value axioms are general statements on the nature of value in that they are not specialised nor limited to a range of subjects or applications such as value types. The application of the axioms within a particular context does not change the axiom. The axioms were derived from literature across disciplines including axiology, economics, psychology, and sociology as areas with major contributions to value research providing support on the general characteristics of the axioms. The validity of the axioms was investigated in the context of a protocol analysis and open-interviews. However, their generality beyond this was not tested. Regarding comprehensiveness, the value axioms were derived from literature on design, axiology, economics, psychology, and sociology as the areas providing key contributions to value research.

A set of axioms should be consistent, i.e. it should not be possible to deduce contradictory statements from them. The value axioms state that value is the output of a cognitive process requiring determination, is subject to situatedness and interpretation, and is entity, criteria, and person related. The axiom's relationship to the VDM was investigated (Section 9.3) with no contradictions identified, providing support on the consistency of the set of axioms against the VDM.

A set of axioms should be complete, i.e. any true statement within the system described by the axiom can be deduced from them (Classic Encyclopaedia, 2008). The value axioms provide a means to build the TVD through deductive research, i.e. to deduce specific conclusions from theory. The process of theory building resulted in additional insights and conclusions related to the value axioms. In the open-interview, for example, one of the designers argued that for value determination, the interpretation of the entity and the entity's context may be relevant. While the interpretation of the entity was considered before the interview, the entity's context was not and thus, provided a new insight on the variables involved in value determination. As the theory develops, additional axioms may be identified and/or existing axioms may require changes.

Overall, the pros and cons of the value axioms were considered to be:

Pros

- ✓ The axioms were derived from literature across disciplines including axiology, economics, psychology, and sociology as the disciplines with major contributions to value research, providing support on the general nature of the axioms identified.
- ✓ The axioms were investigated in open-interviews with designers with no contradictory statements identified providing support on comprehensiveness and validity.
- ✓ The axiom's relationship to the VDM was investigated providing support on consistency.

Cons

- o The axioms were deduced from literature and the set of axioms can be seen as complete within the scope of this thesis, but not in a general sense. Further research is recommended on value axioms to provide further insights on the value phenomenon.

11.5. The model of value determination

The VDM was outlined in Chapter 7 and was intended to provide a representation of the cognitive process of value determination. Key elements of the VDM received a degree of validity in open-interviews with designers where no contradictory statements were identified and in a protocol analysis where value determination was identified in the context of design activities.

The modelling formalism focused on cognitive activities based on knowledge processing towards a value statement. Regarding generality, the activities were characterised by their inputs, outputs, and goals, and based on a modelling formalism similar to IDEF0. The general applicability of IDEF0 supports coherence on the commonality of the VDM. The VDM received a degree of validity in open-interviews with designers and no contradictory statements were identified on the key elements of the VDM.

Regarding comprehensiveness, some critical issues have to be raised. One is that even if the output of the value determination model is correct in terms of corresponding to practice, the way the human mind actually acts may be different to the process proposed by the model. Another issue regarding the VDM is the question of whether people use several ways to perform any particular "intelligent" function. If we assume they do, then the model of value determination represents (at best) only one proposition. Another issue was raised by Miller (1994), who questioned consciousness in cognitive science and concluded that we do not know a lot about consciousness and unconsciousness. One may argue that the process of value determination may be the same in both consciousness and unconsciousness, and a differentiation is not required. However, because we do not know a lot about consciousness and unconsciousness, we cannot draw this conclusion. At a minimum, we may expect that the VDM represents a propositional model of value determination under the condition of consciousness.

Knowledge represents a key resource for value determination. The behaviour of this resource was not investigated as part of this research. That is, the areas of desires, experiences, implicit theories on how the physical world behaves, inborn qualities, and outcome foci in relation to the value determination process were not investigated. Further research is recommended on the value determination process in the context of these areas to support comprehensiveness of explanations on value in design.

Value determination was considered in the VDM from a single-agent perspective. However, in the context of design, value may be determined in situations with multiple agents involved, e.g. in the context of a dialogue between a customer and a designer. Although multi-agent environments were considered in the context of this thesis (Reber and Duffy, 2005), the VDM was not tested against multi-agent environments. Further investigations on multi-agent environments based on the VDM may provide a means to support generality of the VDM.

Overall, the pros and cons of the model of value determination were considered to be:

Pros

- ✓ The VDM received a degree of validity in open-interviews with designers and in a protocol analysis.
- ✓ The VDM was based on a modelling standard similar to the broadly accepted modelling standard IDEF0 providing support on coherence on commonality of the VDM.

Cons

- o The way the human mind actually acts may be different compared to the process proposed in the VDM. The VDM may represent only one proposition.
- o Knowledge as a key resource for value determination was not further investigated in terms of, e.g. desires, experiences, inborn qualities, and outcome foci. Further research is recommended on knowledge as a key resource of value determination to support comprehensiveness on explanations on the value phenomenon.
    - o The validity of the VDM was not investigated against multi-agent environments. Further investigations are recommended in this field to support generality of the VDM.

11.6. The exploration of value-related phenomena

In Chapter 8, explanations were provided on value-related phenomena, i.e. on added, exchanged, and perceived values, and on the relationship of value to benefit and need as key phenomena inherent to the value discussion throughout literature.

With respect to generality, explanations on added value were provided in terms of the variables involved in value determination: an interpreted entity, an agent's knowledge, and criteria prioritisation, selection, and judgement. Exchange value was explained in terms of a specific situation where two entities are involved and value is determined on the "exchange" of entities. The explanations provided regarding added and exchange values were based on the value determination process outlined in the VDM. General rather than specific terminology was applied, and the explanations were not limited to specific instances. The concept of perceived value was then explored, and based on the VDM it was suggested to introduce a more precise terminology in value research in terms of perceived entity rather than perceived value. It was argued that an entity may be perceived for value determination in terms of the human senses. The explanations were general in that the concept of perceived entities was not limited to a specific instance. Explanations on the relationship of value to benefit and need were then provided and it was concluded that value does not automatically come along with a benefit ascribed to an entity. Need was looked at as a resource for value determination, i.e. part of an agent's knowledge. The explanations were not limited to specific instances. Thus, the explanations on value phenomena are general in terminology applied and the explanations are not limited to specific instances.
Regarding comprehensiveness, the analysis of value interpretations outlined in Chapter 2 identified the concepts of added, exchanged, and perceived values and the relationship of value to benefit and need as those frequently applied in value theory. In the process of theory evaluation, further value-related phenomena were investigated as part of the requirements analysis on the TVD (Section 10.4), with explanations given on philosophical and scientific value issues (Table 10-10), and on particular instances of value in design (Table 10-11). Thus, concepts frequently

applied in value theory were identified and explored in detail (Chapter 8), while other concepts were briefly explained (Section 10.4) and recommended for future work. It may be concluded that the value-related phenomena considered in this thesis are representative phenomena in axiology, economics, psychology, and sociology and therefore provide a basis for further research on value in design.

The value-related phenomena of added, exchange, and perceived value were considered in the context of open-interviews with designers with not contradictory statement found. However, the relationship of value to benefit and need was not investigated in the open-interviews.

Overall, the pros and cons of the exploration of value-related phenomena were considered to be:

Pros

- ✓ The explanations on value-related phenomena are general in the sense that they do not refer to specific instances of the phenomenon under consideration.
- ✓ Value phenomena frequently applied in value theory were investigated, i.e. added, exchanged, and perceived values, value and benefit, and value and need.

Cons

- o The relationship of value to benefit and need was not investigated in open-interviews. Such an investigation may provide a means to gain further insights on the relationship and on the validity of the explanations provided in the TVD.
- o Explanations provided on philosophical and scientific value issues and instances of value in design were not verified further. Based on the TVD, further investigations on these explanations are recommended as a means to gain further insights on the value phenomenon in general and on the validity of the TVD in particular.

11.7. Future work

Throughout the research carried out in this work, a number of insights into the nature of value in the context of design were obtained. These are briefly summarised here as areas for future investigations.

11.7.1. Research methodology

The selection of data sources was subject to the time that could be assigned for conducting the research work presented in this thesis. Value in the context of design was investigated based on design literature and value literature in axiology, economics, psychology, and sociology. However, literature my provide further theories on the value phenomenon than those considered within the work reported in this thesis and thus, provides a means for further investigations on the TVD.

The TVD was not investigated with individuals or social groups other than designers. In consequence generality of the TVD is limited within the context of design. Further investigations on the TVD in the context of other individual and/or social groups within or across cultures are recommended as a means to support generality of the TVD. Research in this field may also provide a means to gain further insights on the relationship of value determination to social norms, ethics and moral principles.

The value axioms were deduced from literature. The set of value axioms can be seen as complete within the scope of this thesis, but not in a general sense. Further investigations in literature may provide a means to identify further value axioms and to gain further insights on the nature of value in general and in the context of design.

Explanations on value-related phenomena were provided in this thesis. Frequently applied phenomena in value literature were explored. In the context of the requirements analysis on the TVD, explanations on philosophical and scientific value issues and on instances of value in the context of design were provided. However, these explanations were not tested. Further research is recommended to verify these explanations as a means to investigate validity of the TVD and to gain further insights on the value phenomenon.

11.7.2. Value in design

Explanations on instances of value in design were provided (Table 10-11). In the context of these explanations, particular areas of future work on value in design are recommended:

- In investigating an appropriate metric of value in design it was concluded that there is no general metric for value in design. Further research work is recommended on criteria to be applied in the context of design.

- In investigating how to add value in design, variables to add value in design were identified and it was concluded that adding value in design refers to different aspects of design, e.g. product and design process values, and economic value of design. Based on the TVD, further research is recommended on adding value in design.

- Product and process value management, from a TVD perspective, should consider key characteristics of value, i.e. value is people-based, the output of a cognitive process, requires determination, is subject to situatedness and interpretation, and is entity and criteria connected. This provides a new perspective for further research on product and process value management.

- In the context of the economic value of design and based on the TVD, it can be concluded that future research on value management in design should have a focus on agents, entities, and economic value criteria involved and on the overall characteristics of value outlined in the value axioms.

- In the context of a relationship between value and the goals of a company, it was concluded that value is different from goals. A company may define goals and then value the contribution of entities based on criteria related to these goals; or goals may become part of an agent's knowledge and consequently may be applied for value determination. This is related to business efforts to align personal and company goals/values. Further research in this area based on the TVD may provide new insights.

- Knowledge was identified as a key resource of value determination. Further research on the relationship of knowledge to value determination is recommended to gain further insights on the relationship of value to desires, experiences, implicit-theories on how the physical world behaves, inborn qualities, and outcome foci.

11.7.3. Multi-agent environment

Value determination was considered in the VDM from a single-agent perspective (Chapter 7). However, in the context of design, value may be determined in situations with multiple agents involved, e.g. in the context of a dialogue between a customer and a designer.

What agents may bring to a multi-agent situation is an individual knowledge processing activity, generating an individual value statement. The value statement is the output of a knowledge processing activity based on an individually interpreted entity. In a multi-agent environment, three activities may be considered in the context of value determination: an individual criteria prioritisation, aimed to provide up-to-date and individually prioritised criteria; an individual criteria selection, aimed to individually select criteria in the context of an individually interpreted entity; and an individual criteria judgement, aimed to individually judge the extent an interpreted entity satisfies criteria (Reber and Duffy, 2005).

It may be argued that three scenarios represent typical multi-agent environments for value determination in the context of design: (1) a team of designers in a design collaboration situation; (2) a designer discussing the value of an entity with a customer; and (3) a salesman selling a product to a customer. In the first scenario it is suggested that even if the members of a design team would have the same expert knowledge, this does not suggest an agreement, e.g. in criteria prioritisation, selection, and judgement because of the individual designers' needs, desires, experience, etc. In the second scenario, the expert knowledge between a designer and a customer may be different, resulting in different value criteria and judgements. In the third scenario, it is suggested that opposing value statements between the salesman and the customer may be required, i.e. if the product satisfies the value criteria of the customer to a greater extent than, e.g. the money to be exchanged against the product, and the money satisfies the salesman's criteria to a greater extent than the product, there may be consensus to sell the product to the customer.

It may be concluded that the value determination model provides a means for consistent explanations in single- and multi-agent environments; this, however, was not tested. Further research work is recommended on value determination scenarios involving a broader range of stakeholders relevant to design, such as design teams, manufacturers, salespeople, buyer, and users. Other issues related to a multi-agent environment may be seen in the context of agents as part of social communities, in the alignment of criteria among agents, of criteria to shareholder value systems, and to business ethics and moral principles.

11.8. Summary

The pros and cons of the work reported in this thesis were discussed in this chapter, which includes the research methodology, methods, and the results. In addition, the future work was identified. This chapter summarises the discussion presented in this chapter.

The critical realism world view applied in the work reported in this thesis matched the nature of the phenomenon of value in the context of design. From an ontology perspective, it was considered to be possible to conceptualise reality and to make theories in order to describe it. There is no claim of a totally comprehensive understanding of a certain problem or for a “complete” perspective on a phenomenon. Data triangulation ensured that the TVD was not based on one data source only but rather on data across axiology, economics, psychology, and sociology, which were considered as supportive in building a fundamental theory of value. Method triangulation applied to key elements of the VDM provided a means of assessing a degree of convergence as well as elaborating the divergence between the results. Observer triangulation was applied in the context of open-interviews to the VDM to reduce bias in the research process. However, only one design protocol was analysed against value determination as described in the VDM. Further protocol analysis may provide further insights on value determination in design.

The TVD provides general statements on the nature of value in terms of value axioms, a general representation of the value determination process, and explanations on value-related phenomena. The coherence of the TVD was considered in terms of construct relationships. The TVD was evaluated against design and value theory requirements. The TVD was tested in the context of design based on a design protocol analysis and open-interviews with designers. However, the theory was not tested in the context of other individuals and social groups within or across disciplines and/or cultures as a means to increase generality. The area is recommended for future work.

The value axioms were derived from literature with major contributions to value research. The axioms were considered in open-interviews with designers with no contradictory statements identified. The set of value axioms can be seen as complete in the context of the research work reported in this thesis. However, this does not suggest completeness on value axioms in general. Further investigations in literature on value axioms may provide new insights and identify new axioms and/or existing axioms may require change.

The investigations on the validity of the VDM were based on: observer triangulation, i.e. open-interviews with three designers; and method triangulation in terms of a protocol analysis and open-interviews. Within the open-interviews, no contradictory statements were identified and additional insights were considered in the VDM. However, the way the human mind actually acts may be different to the process proposed in the VDM.

The explanations on value-related phenomena are general in the sense that the explanations do not refer to specific instances of the phenomenon under consideration. Value phenomena frequently applied in value theory were investigated in depth. However, explanations on value-related issues in the context of theory evaluation (Table 10-10) were not tested and are recommended for future work.

Areas of future work were identified from the perspectives of research methodology, value in design, and multi-agent environments. From a research methodology perspective, further investigations are recommended on: the validity of the TVD in the context of individuals and social groups other than designers; value axioms to gain further insights on the phenomenon; the relationship of knowledge to value determination as a means to gain further insights on the relationship of value to desires, experiences, implicit-theories on how the physical world behaves, inborn qualities, and outcome foci; and philosophical and scientific value issues. From a design perspective further investigations are recommended on: value criteria to be applied in the context of design; how to add value in design in the context of product, process, and economic values; product and process value management under consideration of the characteristics of value; economic value with a focus on agents, entities, and criteria involved; and the alignment of personal and company goals and values. In the context of multi-agent environments, it was suggested that the VDM provides a means for consistent explanations in single- and multi-agent environments; this however, was not tested. Future work was recommended on: value determination scenarios involving a broader range of stakeholders, e.g. design teams, manufacturers, salespeople, buyers and users; and agents as part of social communities considering value criteria among agents, shareholder value systems, business ethics and moral principles.

12. **Conclusion**

This thesis presents a theory of value in design. The work is summarised in Figure 12-1. Practical experience in value analysis and investigations in value literature provided the basis for the development of the theory. Based on the literature, the need for a more fundamental formalism of value in the context of design was identified, the research problem was formalised, and a research methodology was developed. The requirements for a theory of value in design were derived from design and value theory characteristics. The nature of value was investigated based on literature and value axioms were derived. A model of value determination was proposed based on the value axioms and further literature investigations. The axioms, the value determination model, and further literature investigations provided the basis for explanations on value-related phenomena. The validity of the axioms, the value determination model, and the explanations on value-related phenomena was investigated through open-interviews and a protocol analysis. The theory of value in design was then proposed based on the axioms, the value determination model, and the explanations on value-related phenomena. The theory was evaluated against the theory requirements and the internal validity was investigated in terms of construct relationships. The pros and cons of the work and future directions were identified. The conclusions of this work are detailed as follows.

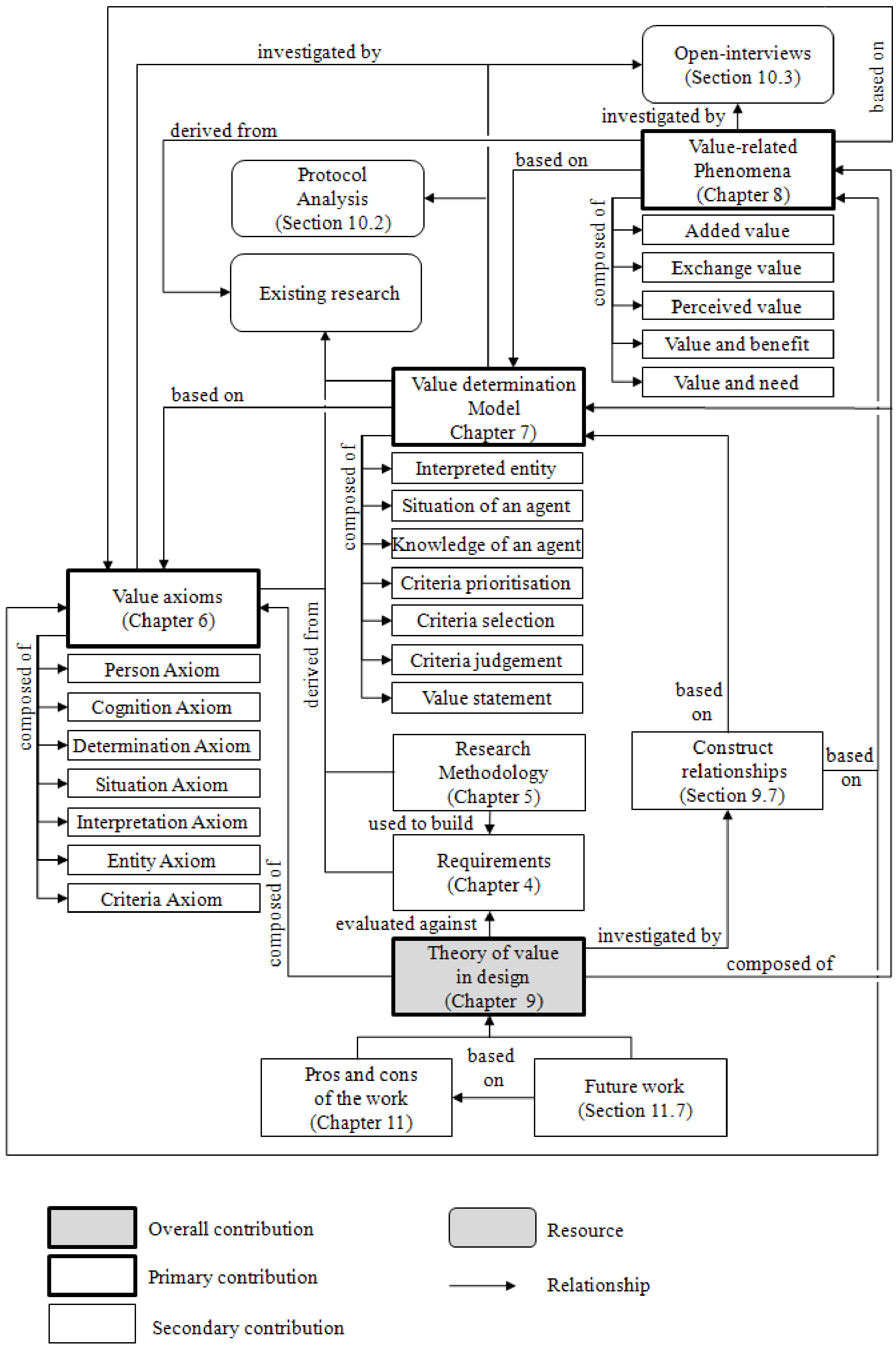

Figure 12-1: Summary of work

12.1. The review of value theories

Value in design is investigated in literature primarily from the perspectives of product and process value management, economic value of design, and human values in design. Product value management has a focus on product value analysis with consideration given to a product's function, benefit, cost, performance, and quality. Process value management has a focus on the design process value with consideration given to the design process performance and support that may be provided based on design techniques. Design management points to the need to manage the economic value of design with consideration given to: design as a means to increase margins and return on invests; reduced time to market; and design as a resource of competitive advantage and new business opportunities. Human values in design are considered in different contexts ranging from design that accounts for human values, design with respect to ethics and sustainability, and satisfaction indices related to human values and to cross cultural assessments of leading values in design-oriented companies. Although different perspectives of value in design have been investigated, the nature of value in design was not revealed.

Value theories can be classified in axiology referring to general or philosophical theories of value as well as to scientific theories including economics, psychology, and sociology. Axiology is related to ethics and moral theories. These theories rest in the concepts of good and bad, right and wrong, and just and unjust. Axiology has a focus on general conceptual questions on value in terms of the objectivity of value, the intrinsic versus extrinsic nature of value, the beliefs in value, value judgement, and general rules basic to the theory of value. Value theories in economics focus on the creation, exchange, and consumption of goods of value in a society. The main classical theories of economic value can be seen in the pricing and labour theories. In the pricing theory, the value of goods is considered in terms of value in use or the utility of a good, and its value in exchange. The labour theory of value relies on the idea that value is equal to labour, where labour is the quantity of labour that goes into the creation of a good. Value theories are related to engineering and technology, based on the idea that artefacts meet the needs and ends of a user through some mechanism or causal system. Value theories in psychology focus on how humans value with respect to their needs, how their behaviour is directed as meeting needs, and on need-based. The basic idea is that behaviour is triggered by motivations that are in turn determined by needs, whereby needs and wants are organised by priority. Value and behaviour are discussed in psychology in the context of people's benefits, emotions, goals, and situations. Value theories in sociology have a focus on how collective values emerge and develop, how they relate to cultural and social norms, and how they are embodied in society. Two basic concepts applied in sociology are the concepts of value as a criterion and as a conception of the desirable. Value theories in sociology make a distinction of holding a value, making evaluations, ascribing a value to someone else, and ascribing an evaluation to someone else. Value theories in sociology consider a relationship of value to needs, beliefs, and value systems, and consider value to be learned and developed in interaction with other humans. A review of value interpretations reveals that value is interpreted as the value of an entity, as an activity, and as an ethic/moral principle. A review of value types reveals that literature has a focus on brand, customer, economic, exchange, expectancy, human, product, process, relationship, and shareholder values. Although the different perspectives of value have been investigated, the nature of value was not revealed.

12.2. The requirements for a theory of value in design

The requirements for a theory of value in design were derived from design and value theory characteristics. These characteristics can be seen as restrictions on what can be recognised as a theory of value in design. A theory of value in design is required to: provide novel insights and a value definition; describe the phenomenon in terms of constructs, construct relationships, mechanisms and variables involved; provide a perspective of the phenomenon (in that it cannot capture all of the phenomenon); support explanations on conceptual issues and substantive problems, on issues related to the philosophical and scientific value discussion, on instances of value in design, and on value creation, analysis, and measures; integrate or relate to other theories and consider relevant literature; have a defined scope; be built upon axioms and/or generalised characteristics; be testable; be evolutionary and provide a means to improve design artefact, process, practice, and/or research performance.

12.3. The research methodology for theory building

While value and design are linked to social science in terms of human values and cognitive processes, a theory of value in the context of design should have the characteristics of science, namely rationality, objectivity, and universalism. Critical realism captures central aspects of social and natural sciences and consequently provides a research methodology within which the research of value in the context of design can be conducted.

From the ontology perspective of critical realism, reality exists and it is possible to conceptualise it and make theories in order to describe it, whereby critical realism does not claim a totally comprehensive understanding of a certain phenomenon or a "complete" perspective. Instead, critical realism regards knowledge as fallible in the sense that a scientific insight of a phenomenon is a partial insight of certain aspects, deliberately chosen and due to change. From an epistemological perspective, critical realism aims to explain the relationship between experiences, events, and mechanisms. The focus is on "how and why" a phenomenon came into being and to its specific characteristics. Emphasis is on the explanations of the constitution of empirical phenomenon. Within critical realism, different kinds of reasoning are required: inductive, deductive, abductive and retroductive. The research work reported in this thesis is based on a retroductive reasoning process that links the empirical from induction (e.g. the value axioms), with the theoretical from deduction (e.g. the value determination model) into a continually evolving process.

In critical realism, investigating conditions within social science is based on premises and a characteristic such as "openness", i.e. closure does not exist. Understanding and analysis is theory-laden and concept-dependent but they don't determine the outcome. The context influences the phenomenon we study. Thus, value theories, design and value theory characteristics, a protocol analysis from a design episode, and open-interviews with designers all impact the study of the theory of value in design.

Abstract research, synthesis, and concrete research were applied in this thesis as three types of critical realism research: abstract research and synthesis was applied in the context of the identification of value axioms and based on the analysis of value interpretations across disciplines; and concrete research was applied in the context of the development of the value determination model and the overall theory of value in design with theoretical analysis involved in terms of a literature review on value theories and empirical analysis in terms of, e.g. open-interviews with designers. According to Sayer (1992), this can be seen as a preferable way to understand a concrete problem.

12.4. The theory of value in design

The theory of value in design presented in this thesis is composed of the value axioms, the value determination model, and the explanations on value-related phenomena. The following sections highlight the related findings.

12.4.1. The value axioms

Seven value axioms were derived from value literature with the overall objective to provide a basis for building the theory of value in design. The validity of the value axioms was investigated in open-interviews with designers with no contradictory statements identified. The value axioms reveal that value: is connected to people (Axiom 1); is an output of a cognitive process (Axiom 2); requires a determination process (Axiom 3); is a matter of a given situation (Axiom 4); is determined by the interpretations of entities (Axiom 5); and is related to entities (Axiom 6) and to criteria (Axiom 7). In other words, value is characterised as the output of a cognitive process, subject to situatedness and interpretation, and related to people, entities, and criteria.

12.4.2. The value determination model

A model of value determination is required to provide explanations on the cognitive activities involved. Since cognitive science lacks well-established theoretical understanding of the cognitive capabilities used during design (Smithers, 1999), there was a need for a knowledge level model of the value determination process. A rational choice was made to adapt the generic design activity concept (Sim and Duffy, 2003) to apply a design activity formalism at the knowledge level. Based on this formalism, the value axioms, and further literature investigations the model of value determination (VDM) was proposed.

Value determination as a cognitive process is situated and dependent on an agent's knowledge. The value determination process can be formalised in terms of a knowledge processing activity generating a value statement as the output from knowledge of an interpreted entity as the input, under the direction of the overall goal of determining value. The variables involved in the value determination process are: an entity interpreted by an agent; a situation of an agent; knowledge of an agent; a criteria prioritisation activity aimed to provide up-to-date and prioritised criteria; a criteria selection activity aimed to make a selective use of criteria in the context of an interpreted entity; and a criteria judgement activity aimed to judge the extent an interpreted entity satisfies criteria. The output of the value determination process is a value statement.

The criteria prioritisation activity can be interpreted in terms of a personal criteria system, i.e. an ongoing cognitive activity shifting criteria on a personal priority list, adding new criteria to the list, and removing criteria from the list as appropriate. In criteria selection, agents make a selective use of criteria based on input knowledge of the interpreted entity and on up-to-date and prioritised criteria. In selecting criteria, agents cognitively connect criteria to the interpretation of an entity under investigation. In criteria judgement, agents judge the extent the interpreted entity satisfies the criteria selected in the criteria selection activity. The “extent of criteria satisfaction” is expressed in terms of a value statement as the output knowledge of value determination. Thus, value refers to a judgement on the extent an interpreted entity satisfies an agent’s criteria.

The activities in value determination make use of tacit and explicit knowledge. This includes expert knowledge as well as basic physical needs, derivative desires, experiences, implicit theories on how the physical world behaves, inborn qualities, outcome foci, and self-esteem needs. This interpretation of knowledge in the context of value determination provides a perspective of needs, desires, experience, etc. as knowledge resources and enables the integration of value-related theories (e.g. hierarchy of needs) into the value determination model.

12.4.3. The value-related phenomena

Based on literature, added value, exchange and perceived values, and the relationship of value to benefit and need were identified as key value-related phenomena. The value axioms, the value determination model, and further literature investigations provided a means to gain insights on these phenomena.

Added value: A change to an agent’s knowledge is fundamental to changes to an agent’s value statement. Changing an agent’s situation, interpretation, and criteria prioritisation, selection, and judgement provide a means for a change in value statements. Although these changes provide an opportunity to influence value statements, by no means is there a guarantee for a value statement change. This is because an agent: may not consider a change as relevant and ignore the change; may consider a change as relevant but not change criteria priority, selection, and judgement; or may change the value criteria but judge the extent of criteria satisfaction as before. In other words, a change that may occur in the value statement lacks management towards an increase in the extent an entity satisfies criteria. This, however, may be seen as related to the terminology of value adding and added value as frequently used in literature. With respect to added value it was found that in criteria selection (A_{CS}), agents select specific criteria in the context of the interpreted entity. In doing so, agents establish a cognitive link between the interpreted entity and criteria, i.e. agents add criteria cognitively to the entity. The selected criteria are the input to criteria judgement (A_{CJ}) and consequently the basis for the value statement. In other words, the selective use of criteria makes a value statement entity specific. In this context, adding value may then be interpreted as the activity of adding criteria to an entity increasing the degree of satisfaction and/or replacing added criteria with more satisfactory ones.

Exchange value refers to a specific situation where two entities are involved but the focus of value determination is on the entity's "exchange" rather than on the entity's value statements per se. An agent in the situation to judge value on the exchange of entities (e.g. money against a product) determines the value of these entities, which results in entity specific value statements. The value statements become the input knowledge to value determination on the "exchange" of entities. However, the entity specific value statements may not be of relevance to the value determination on the exchange of the entities. For value determination on the "exchange", other criteria may be applied then for value determination on the entities involved. In a situation where, e.g. the exchange of a product against money is considered, an agent may come to the conclusion that the product satisfies the agent's criteria to a higher extent than the money. However, in determining value on the exchange of the product against money, the agent may apply a criterion such as "saving money to reduce risk" and come to the conclusion that the value of the entity's exchange is low. Overall, exchange value refers to the extent an "exchange of entities" satisfies an agent's criteria. What is exchanged here is not value as such, but rather entities linked to value statements.

Perceived value: Value as the output of a cognitive process is not perceived in the sense of the ability to see, hear, or become aware of something through the senses. However, what may be perceived in value determination is an entity in the agent's external world. That is, an interpreted entity is the input knowledge to value determination and this entity may be perceived through the senses. Consequently, it was suggested that the terminology of determined value and perceived entity should be used rather than perceived value. It should also be noted that value cannot be received or provided, i.e. one cannot "transfer" value. Even if there would be a consensus by the agents involved in value determination on the interpreted entity and criteria priority, selection, and judgement, by no means is value transferred from a conceptual point of view.

Value and benefit: There are fundamental differences between value and benefit. A benefit refers to an advantage or profit, while value refers to a value statement, i.e. to the extent an entity satisfies criteria. A benefit with high value to one an agent may be of no value to another, although it is the same benefit. That is, a benefit may be the input knowledge to value determination and judged on the extent the benefit satisfies value determination criteria. An entity providing a benefit by no means must be an entity of value; it is only in the specific case where criteria in value determination are related to the benefit (e.g. an advantage) that a "beneficial" entity may be of value to an agent.

Value and need: Value is not dependent on need although the concepts have some characteristics in common: they are context dependent, a matter of change, related to satisfaction, and subjective. However, there are also distinctions in that value: is related to motivation only in the specific case where criteria in value determination are related to motivation; cannot be satisfied like needs; and is not objective. Need is considered in the VDM in terms of an agent's knowledge where knowledge on need may, as a driver of motivation, trigger a value determination activity, change priorities and criteria in an agent's personal criteria system, and provide criteria for value determination.

12.5. Pros and cons of the work

The theory of value in design received a degree of validity in three open-interviews with designers, a protocol analysis of the VDM, investigations on the TVD's construct relationships, and an analysis of the TVD against theory requirements.

Open-interviews: Three open-interviews were conducted with senior designers for the purpose of eliciting the perspective of practicing designers on key elements of the TVD. The dependence of a value statement on interpreted entities was supported in terms of different statements made in the context of the different entities valued, and in that no value statement could be derived until an entity was identified. The proposed criterion axiom, i.e. value is criteria –connected, was supported in that the designers formalised their major value criteria for value determination. The personal criteria system was seen as relevant in the design process, but the designers suggested that in evaluating a solution, only a small number of criteria may be applicable (e.g. profit). The interviewees supported the relevance of knowledge in value determination and criteria selection dependent on the task to be done. The TVD's explanation on added value was supported regarding knowledge required on criteria. The TVD's explanations on value exchange were supported in general terms. A new insight during the interview was that a change in the value entity's context, e.g. from a single crane to multiple cranes on one building, changed the entity valued from the crane to "the application of cranes". This is a supplement to the TVD, which so far only considered changes in an agent's situation. In other words, changing a value entity's context provides an additional opportunity to change a value statement. Overall, no contradictions were identified in the interviews.

Protocol analysis: Value determination based on the key elements of the VDM was identified in a design protocol analysis in the context of prioritising, decision making, identifying, defining, evaluating, determining, analysing, and gathering. Entities for value determination were identified in terms of the design process, concepts, parameters, resources, and risk. In 73% of the value determination activities, the criteria applied were identified in terms of, e.g. clearance, absolute or relative positions, and practicability. In 27% of the value determination activities, the criteria were not communicated in the transcript. From a consciousness and/or unconsciousness perspective, an interpretation may be that designers tend to apply value criteria in an unconscious manner and/or apply certain criteria in consciousness, but do not state criteria explicitly in the design protocol. From a human values perspective, it may be argued that designers apply value criteria related to deeply held enduring beliefs, but do not express these criteria explicitly in the context of the design activities. Finally, from a method perspective, it should be noted that the criteria have been identified in the context of design activities. Thus, criteria not related to the design activities, e.g. criteria applied across design activities, were not identified.

Construct relationships: In the investigations on construct relationships it was found that the TVD constructs in terms of: an interpreted entity; agents' knowledge; a value statement; and criteria prioritisation, selection, and judgement are consistent to the value axioms, the value determination model, and the explanations on value-related phenomena.

Requirements analysis: The TVD was evaluated by the set of requirements derived from design and value theory characteristics and it was shown that the TVD satisfies these requirements as follows.

- The TVD provides novel insights in terms of the value axioms, the value determination process, and on value-related phenomena.
- Value in the TVD is defined as the output of a cognitive process referring to a judgement on the extent an interpreted entity satisfies an agent's criteria.
- The TVD describes construct relationships, variables, and mechanisms involved in the phenomenon of value in the context of design.
- The TVD provides a perspective of value in design in that the phenomenon is explained as the output of a cognitive value determination process in the context of design.

- The phenomenon of value in the context of design is conceptualised in the TVD.
- The TVD supports explanations on issues related to the philosophical (e.g. intrinsic vs. extrinsic value) and scientific value discussions i.e. on key issues addressed in economics (e.g. exchange value), psychology (e.g. value vs. need), and sociology (e.g. value as criteria), and on instances of value in the context of design (e.g. on value management in design, economic value of design, human values in design).
- The TVD supports explanations on value creation, analysis, and measures in that it is suggested that adding criteria, replacing criteria, and increasing the extent an interpreted entity satisfies criteria provide means to change a value statement. Value as an output of a cognitive process cannot be directly "created". It is suggested that value analysis should focus on analysing the variables involved in value determination, i.e. on the interpretations of the entity considered for value determination, on the agent's knowledge, and on criteria prioritisation, selection, and judgement. Measures in value theory (e.g. cost, function, performance) from a TVD perspective refer to criteria applied for value determination.
- The TVD integrates other theories in terms of the generic design activity concept (Sim and Duffy, 2003) and the approach of Gero (2002) on situatedness.
- The TVD has a defined scope in that the TVD is a theory of value in the context of design. From a design perspective, the scope of the TVD covers design as an artefact, as an activity, and as human factors in design. From a value perspective, the TVD covers value of an entity, as an activity, and as human values.
- The TVD is built upon axioms. The value axioms can be seen as formal general rules basic to the theory of value and consequently basic to the theory of value in design.
- The TVD is based on a model of the cognitive process of value determination. A model of a cognitive process cannot be tested directly.

Consequently, key elements of the TVD were tested in terms of a protocol analysis, open-interviews, and a requirements analysis.

- The TVD is evolutionary in the sense that the application of the theory may lead to new insights and consequently to modification. In the world view adopted, there is no claim for a totally comprehensive understanding of a certain problem or for a "complete" perspective.
- The TVD can be seen as a means to improve research performance in supporting development of explanations on the nature of value and on value-related phenomena. Consequently, design artefacts, processes and practices may be improved.

Overall, the investigations in terms of open-interviews, the protocol analysis, construct relationships, and the requirements analysis provide support on the validity of the theory of value in design. However, the cons of the work were also identified as follows.

- The attempt to establish the current state of knowledge in the context of design was limited in that the selection of data sources was subject to the time that could be assigned for conducting the research presented in this thesis.
- The TVD was not investigated with individuals or social groups other than designers nor in multi-agent environments. Consequently, generality is limited to the context of design and single-agent environments.
- The value axioms were deduced from literature and the set of axioms can be seen as complete within the scope of this thesis, but not in a general sense.
- The way the human mind actually acts may be different compared to the process proposed in the VDM. The VDM may represent only one proposition.
- Knowledge as a key resource for value determination was not further investigated in terms of, e.g. desires, experiences, inborn qualities, and outcome foci.

- Explanations were given, based on the TVD, on issues related to the philosophical and scientific value discussion and instances of value in the context of design. However, these explanations were not verified further.
- Only one design protocol was analysed against value determination.
- The relationship between benefit and need was not investigated in the open-interviews and the interpretations of the interview data were not verified further.

Based on the identified cons and the proposed theory of value in design, future work is identified as outlined in the following section.

12.6. Future work

The four directions of future work are from the perspectives of research methodology, value in design, value in general, and multi-agent environments.

From a research methodology perspective it is recommended to: investigate additional value-related literature as a means to gain further insights on the internal validity of the TVD; investigate the TVD with other individuals and/or social groups other than designers, from within and across cultures as a means to gain further insights on the generality of the TVD; and investigate the explanations on the philosophical and scientific value issues as a means to gain further insights on the external validity of the TVD.

From the perspective of value in design, further research, based on the TVD, is recommended on: value criteria applied in design to gain insights on value metrics; adding value in the contexts of product and design process values and economic value of design as a means to increase design performance; and the alignment of human and company values in the context of design to gain insights on the relationship. Furthermore, research is recommended on the explanations provided in the context of instances of value in design: on value “appearance”, the relationship of value to benefit and cost, the key elements and mechanisms involved in design process value, economic value of design, and human values in design; and on the relationship of human values to activities, beliefs, criteria, goals, situations, and other value types as a means to gain further insights on value in design in general, and the validity of the TVD in particular.

From the perspective of value in general, further research, based on the TVD, is recommended on explanations provided in the contexts of: axiology, i.e. "right vs. wrong", intrinsic vs. extrinsic, "end vs. instrumental", value judgement, value axioms; economics, i.e. value in exchange, value vs. labour, value vs. cost, value vs. function, social value; psychology, i.e. value vs. need, value vs. behaviour, value vs. benefit, value vs. emotion and desire; and sociology, i.e. value as criteria, value vs. norms, value attitude, value systems, value evolution.

From a multi-agent perspective, research is recommended on: the alignment of value criteria in design teams as a means to gain insights on value in design collaborations; value determination scenarios involving stakeholders relevant to design, such as designers, manufacturers, salespeople, buyers, and users as a means to gain insights on value in the context of total design; the relationship of value criteria in shareholder value systems to those applied in design as a means to gain insights on the economic value of design; and value determination in design in the context of business ethics and moral principles as a means to gain insights on human values in design.

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Appendix

Appendix A: Design definitions

Date	Definition	Reference
2005	Design is the human power of conceiving, planning, and bringing to reality all of the products that serve human beings in the accomplishment of their individual and collective purposes.	Buchanan, 2005
1991	Design is considered as a process of goal-directed reasoning where there are many possible solutions and although the process can be supported methodologically, it cannot be logically guaranteed.	Roozenburg and Eekels, 1991
1990	Design is a goal-oriented, constrained, decision-making, exploration and learning activity which operates within a context which depends on the designer's perception of the context.	Gero, 1990
	Design is the creation of a synthesised solution in the form of products, processes or systems that satisfy perceived needs through mapping functional requirements and design parameters.	Suh, 1990
1985	Design is the activity involved with constructing a system. The design tasks, however, extends throughout a system life cycle.	Katz, 1985
1967	Design is a process to create or restructure a situation-specific solution.	Nadler, 1967
1966	Design is relating product with situation to give satisfaction.	Gregory, 1966
	Design is the performing of a very complicated act of faith.	Jones, 1966
1964	Design is a goal-directed problem-solving activity.	Archer, 1964
1963	Mechanical engineering design is the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency.	Feilden, 1963
1962	Engineering design is a purposeful activity directed towards the goal of fulfilling human needs, particularly those which can be met by the technology factors of our culture.	Asimow, 1962
1959	Engineering design is the process of applying various techniques and scientific principles for the purpose of defining a device, a process, or a system in sufficient detail to permit its physical realisation.	Taylor, 1959

Appendix B: Design process models

Model	Description
Archer	Archer defines the design process in six stages: (1) programming, i.e. establishment of issues and proposal of course of action; (2) data collection, i.e. collection, classification and storing of data; (3) analysis, i.e. identification of sub-problems, preparation of design specification, reappraisal of proposed programme and estimation; (4) synthesis, i.e. preparation of outline design proposals; (5) development, development of prototype design, preparation, and execution of validation studies; and (6) communication i.e. preparation of manufacturing documents. The six stages are grouped into three phases, i.e. analytic, creative, and executive (Cross, 2003).
Asimow	"Asimow (1962) shows the process of design in three phases that bear on the solution of the design project, while the part that deals with the solution of subordinate problems is represented as a sequence of operations as every step of the process proceeds" (Evbuomwan, 1996, p. 305). Archer highlights three phase of the design process in terms of (1) feasibility study, (2) preliminary design, and (3) detailed design.
Cross	Cross (1994) presents the design process in six stages within a problem-solutions model: (1) clarification of objective; (2) establishing functions; (3) setting requirements, (4) generating alternatives; (5) evaluating alternatives; and (6) improving details. For each stage a design method is used to support achievement of the objective in each stage. "The model integrates the procedural aspects of design with the structural aspects of the design problems. The procedural aspects are represented by the sequence of methods while the structural aspects are represented by arrows showing the commutative relationship between problem and solution and the hierarchical relationships between problem/sub-problems and between sub-solutions/solutions." (Hall, 1962, p.84)
French	The model by French (1985) is based on the following design activities: (1) the analysis of the problem phase involving the identification of the need to be satisfied; (2) the conceptual phase involving the generation of broad solutions in the form of schemes; (3) the embodiment of schemes involving the development of generated schemes into greater details; and (4) the detailing where the selected scheme is worked into finer details.
Gero	The evolutionary design model by Hybs and Gero (1992) considers the design process as a series of transformations from one state of the design to another state, e.g. transforming function, structure, and behaviour into a design description. The activities in this model are described in terms of: (1) formulation or design brief or specification; (2) analysis; (3) synthesis; (4) production of design description; (5) simulation; (6) real world interaction; (7) evaluation; (8) reformulation; (9) simulated structure performance; and (10) actual product performance.
Harris	The model by Harris (1980) consists of five stages: (1) appreciation of the task, (2) conception, (3) appraisal of concepts, (4) decision, (5) checking, and (6) elaboration.
Hubka	The model by Hubka (1992) represents the design process in four phases i.e. (1) elaboration of assigned problem, (2) conceptual design, (3) layout, and (4) elaboration in the sense of detailing.
Jones	The model by Jones (Jones and Tornelly, 1962) represents the design process in three stages: (1) analysis, (2) synthesis, and (3) evaluation. "The model emphasises the need to establish specifications in a solutions neutral form as well as investigating interactions between design factors. The synthesis stage does exhibit a bottom-up approach in developing the overall design. The idea of evaluating the design by the pre-operation, pre-production and pre-sales team is a later occurrence in this model." (Evbuomaw, 1996, p. 305)

Krick	Krick (1969) describes the design process in five stages: (1) problem formulation; (2) problem analysis; (3) search for alternative solutions; (4) decision; and (5) specification. Problem formulation involves defining the design problem to be solved. Problem analysis involves an analysis of the design problem towards a detailed definition of a specification, constraints and criteria. The search for alternative solutions of performed through inquiry, invention and research. The decision stage involves evaluation, comparison, and screening of alternative solutions. The specification stage involves detailed documentation. (Evbuomanw, 1996).
Marples	The model by Marples (1960) can be seen as an attempt to abstract the design process in terms of case studies carried out. The case studies are used to illustrate design as a sequence of decision leading from an original statement of the requirements to a specification of the details to be manufactured.
Pugh	Pugh (1999) regards total design as the systematic activity necessary from the identification of market (user need), to the selling of the successful product to satisfy that need, i.e. an activity that encompasses product, process, people, and organisation. Pugh's model consists of a design core in terms of (1) market, (2) product specification, (3) conceptual design, (4) detail design, (5) manufacture, and (6) sales.
Pahl and Beitz	Pahl and Beitz (1984) model the design process in four phases: (1) clarification of the tasks, (2) conceptual design, (3) embodiment design, and (4) detail design. Task clarification involves the collection of information about the requirements in a solution neutral form. Conceptual design involves the establishment of function structures, the search for solution principles and their combination into solution concepts. In embodiment design, the designer determines the layout and forms and develops a technical product or system. In detail design the form, dimensions, and surface properties of all individual parts are finally laid now, the material is specified, the technical and economic feasibility is checked, and the production documents are produced.
Ullman	Ullman (1992) proposes a model design phases as part of a model of a product life cycle. The first three phases in a product's life cycle are considered to be of major concern for product design: (1) specification development, (2) conceptual design, and (3) product design. In specification development, the goal is to understand the problem and lay the foundation for the remainder of the design project. At the end of this phase, the scheme for the remainder of the project, together with, e.g. the estimates for time, personnel requirements, and costs are audited during a formal design review. The results from this phase are used in the conceptual design phase where concepts are generated and evaluated. As a result of the knowledge gained in this phase, the design problem may be broken down into more manageable subsystems for individual design efforts. In the product design phase, the importance of the concurrent design of the product and the manufacturing processes is emphasised in that product generation and evaluation form an iterative loop. The three phases are followed by the production, service and product retirement phase.
Watts	Watts (1966) represent the design process in terms of a designer or design team in dynamic relationship with an environment. The design process is described in terms of three processes: (1) analysis, (2) synthesis, and (3) evalution. These processes are performed from a lower i.e., more abstract level to a higher i.e., more concrete level representing the design phases. In moving from the abstract level to the concrete one decision are made. (Evbuomay, 1996)

Appendix C: Value interpretations

An overview of value interpretations is provided. The overview is not intended to provide a summary of all value interpretations in literature, rather to provide an overview on those commonly referred to in axiology, economy, psychology, and sociology literature. However, to increase transparency on the interpretations' contexts, the classification of axiology, business economics, engineering, marketing, psychology, and sociology was applied.

Context	Interpretations	Reference
Axiology	Value theory is seen as a concept concerned with the value or worth of people or things considered in terms of usefulness or economic value. Value theory can involve legal, moral, aesthetic, or quantitative values. Values are at the root of all types of behaviours, including those that are morally, politically, or economically motivated.	Madison, 2008
	Values are "things" of the mind and are related to people's vision of a "good life". Values provide stimuli and constraints on thought and action. Values may be held by a single person and/or a group of people. Values are related to a benefit.	Rescher, 1982
	Humans attribute value to things as an activity.	Lamont, 1956
Business economics	Value is related to an increase in earnings. Value for money is seen as added value.	Ashworth and James, 2001
	Value is relative and not an inherent feature of any object.	Best and De Valence, 1999
	Value is commonly applied to assets, is measured in comparison with other assets of similar function, attractiveness, cost, and/or exchange worth and cannot be assessed in isolation.	
	Value is a measure of the worth of something to its owner or any other person who derives benefit from it, this being the amount at which it can be exchanged.	CABE, 2001
	Value is the relationship of market-perceived price to market-perceived quality.	Daniels, 2000
	The two main drivers of value creation are the continuous development of fundamental capabilities and the creation of new business models.	Larreche, 2000
	Value is defined as a conception, explicit or implicit, of what an individual, group, or organisation regards as desirable.	Harrison, 1998
	Value is quality relative to price.	Gale, 1994
	Value emerges from the inventiveness and versatility of organisations to build competitive advantage.	Hamel and Prahalad, 1989
	Value creation is influenced by the management style of an organisation.	Campbell and Goold, 1988
	Value is the amount buyers are willing to pay for what a firm provides for them.	Porter, 1985
	Value is the amount for which a thing can be exchanged.	Allingham, 1982
	Value of an asset is defined as a function of usefulness and availability.	
Engineering	Value is a fair return or equivalent of goods, services, or money for something exchanged.	SAVE International, 2007
	Value is benefits (what you get) divided by sacrifices (what you	Thomson et al,

Context	Interpretations	Reference
	put in).	2003
	Value is a complex entity made of scarcity, utility, costs of production, worth in use, value in exchange, and made by marginal utility. It is influenced by the conditions of supply and demand.	Ashworth and Hogg, 2000
	Value is the relationship between the contribution of the function to the satisfaction of the need and the cost of the function.	British Standards Institution, 2000
	Value is function plus quality divided by cost.	Dell'Isola, 1997
	Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.	Womack and Jones , 1996
	Value is a functional outcome, a goal, purpose or objective that is served directly through product consumption.	Burns and Woodruff , 1992
	Value is a capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer.	Chase, 1990
	Value is a user's initial impression plus satisfaction in use, divided by first cost plus follow-up cost.	Fowler, 1990
	Value is the level of importance that is placed upon a function, item or solution.	Hamilton, 1990
	Value can be considered as the ratio of function achieved to its lifecycle cost.	
	Value is the relationship between function cost and actual cost.	Miles, 1972
	Value is seen as the maximisation of process efficiency through the identification and elimination of waste at the business process level.	Gage, 1969
	Value is the relationship of product worth to product cost.	Miles, 1966
Marketing	There are different views on enterprise value in terms of an internal view of market and book values, an external view of new products and current output, and an economic view of new opportunities.	Andriessen, 2003
	The value chain can be analysed in terms of the decomposition of a firm into activities to study economic implications of this activity; the main question of the value chain is about what activities a firm should perform and how.	Amit and Zott, 2001
	Value is the relationship of market-perceived price to market-perceived quality.	Daniels, 2000
	Maximum shareholder value is on growth, opportunity, and competitive advantage. A distinction is made to maximum profit seen as short term cost cutting and quick improvements.	Doyle, 2000
	Economic value is on usefulness, monetary worth of things, and services; political value is interested in power; religious value is on unity; in the centre of social value is the love of people; the basic interest of theoretical value is truth.	Holden, 1999
	Enterprise value innovation can take place on three platforms: product, service, and delivery.	Kim and Mauborge, 1999
	Value is generated by the quality element in a long term relationship. Value is co-produced through interaction between the supplier, customer, competitor, and others.	Grönross, 1997
	Value to customer via service can be achieved by a focus on benefits, relationships, and effective operation pricing. The strategies on benefits focus on clear communication and association between attributes and benefits delivered. Relationship strategy is to involve, attract, and maintain a strong	Berry, 1996

Context	Interpretations	Reference
	relationship with customers in a multi-service organisation. Effective operation pricing strategies focus on designing a service system that aligns the cost of the activity with its value to target customers by eliminating some activities entirely or streamlining low-priority elements of the service chain.	
	Value is seen as quality relative to price.	Gale, 1994
	Value refers to a preferential judgement, whilst values are used to refer to the criteria by which such judgements are made.	Holbrook, 1994
	Marketing strategy adds value to enterprise via positioning, advertising, pricing, and brand. Value is related to psychology, cognition, and motivation.	Jones, 1994
	Value in business markets is the perceived worth in monetary units of the set of economic, technical, service, and social benefits received by a customer's firm in exchange for the price paid for the product offering, considering alternatives.	Anderson, Jain, and Chintagunta, 1993
	Value stems from the interaction among the economic actors, i.e. a focus of value creation is seen in the network and role of multiple stakeholders in relationship marketing.	Norman and Ramirez, 1993
	Relationship value has economic, strategic, and behavioural dimensions.	Wilson and Jantrania 1993
	Value can be generated from brands; value of brand equity is seen as a source of value to a customer by enhancing the customer's interpretation of information, confidence in the purchase decision, and use satisfaction and value to enterprise by enhancing efficiency and effectiveness of marketing programs, brand loyalty, and competitive advantage;	Aaker, 1991
	Value comes as a result of interactions and relationship between customers, suppliers and different stakeholders.	Crosby, 1990
	Value refers to the customer's overall assessment of the utility of a product based on perceptions of what is received and what is given.	Zeithalm, 1988
	Value is low price.	
	Value is whatever I want from a product.	
	Value is the quality I get for a price I pay.	
	Value is what I get from what I give.	
	Value is the amount buyers are willing to pay for what a firm provides for them.	Porter, 1985
	Value to enterprise is created via competitive advantage through the management of internal activities.	
	The product is a cluster of value expectations with tangibles and intangibles.	Levitt, 1981
	The core concept of value is the transaction or exchange of, e.g. goods, services, money, time, energy, and feelings.	Kotler, 1972
Psychology	Value educates about good values such as honesty, respect, integrity, etc, and how to use these values to make informed decisions.	Hight and Cooper, 2006
	Needs are one source of information that enter into the determination of values.	Kahle and Goff, 1993
	Value is related to action. However, the link between value and action has received less attention than how action relates to general motivational dispositions such as the needs for achievement, affiliation, and power. Evaluation is seen as an inherent characteristic of human behaviour.	Halisch , Kuhl, and Feather, 1987
	Value is related to expectation and utility. Values organised in hierarchies of importance are seen as value systems. Values are	Feather, 1982

Context	Interpretations	Reference
	influenced by both the properties of the person engaged in valuing and the characteristics of the item valued.	
	Value is what a thing is worth.	Najder, 1975
	Value is a valuable thing or property.	
	Value is an idea which makes us consider given objects, qualities, or events as valuable.	
	Value is an enduring belief that a specific mode of conduct or end state of existence is personally or socially preferable to an opposite or converse mode of conduct or end state of existence.	Rokeach, 1973
	Value appears to mean the esteem in which any object is held. It devotes an effect produced in the mind.	Bailey, 1967
Sociology	Individuals and groups differ in terms of the priorities they assign to the ten basic values, i.e. self-direction, stimulation, hedonism, achievement, power, security, conformity, tradition, and benevolence. Values may serve as standards or criteria.	Schwartz , 2006
	Values are defined as desirable trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or social entity.	Schwartz, 1994
	Values are learned criteria that predispose us to act as we do.	Hutcheon, 1972
	Value(s) include anything of interest to human subjects, all kinds of desires, wants, likes, pleasures, needs, interests, preferences, duties, and many other modalities of selective behaviour.	Pepper, 1958
	Values are considered to be conceptions of the desirable, influencing selective behaviour.	Kluckhohn, 1951

Appendix D: Value definitions analysis

Value definition[18]	Reference	Context	Target	Entity	Criteria
Value is the amount for which a thing can be exchanged.	Allingham, 1982	economy	customer	exchange	the amount for which a thin can be exchanged
Value of an asset is defined as a function of usefulness and availability.		economy	customer (implicit assumption)	asset	function of usefulness and availability
Value in business markets is the perceived worth in monetary units of the set of economic, technical, service and social benefits received by a customer firm in exchange for the price paid for the product offering, considering alternatives.	Anderson, Jain, and Chintagunta, 1993	customer value assessment	customer firm	exchange	function of perceived worth in monetary units and the price paid
Value is a complex entity made of scarcity, utility, costs of production, worth in use, value in exchange and made by marginal utility. It is influenced by the conditions of supply and demand.	Ashworth and Hogg, 2000	adding value in design and construction	enterprise respectively customer (implicit assumption)	product (implicit assumption)	scarcity, utility, costs of production, worth in use, "value" in exchange, marginal utility
Value is related to an increase in earnings. Value for money is seen as added value.	Ashworth and James, 2001	value based management	enterprise	product (implicit assumption)	increase in earning
Value appears to mean the esteem in which any object is held. It devotes an effect produced in the mind.	Bailey, 1967	nature, measures and causes of value	human being (implicit assumption)	object	the "esteem in which an object is held"

[18] The term *definition* as applied here refers to explanations in literature on what value „is“, i.e. does not include descriptions on characteristics of value and value types as included in Appendix C.

Value definition[18]	Reference	Context	Target	Entity	Criteria
Value is commonly applied to assets, is measured in comparison with other assets of similar function, attractiveness, cost and/or exchange worth and cannot be assessed in isolation.	Best and De Valence, 1999	building in value in architecture	human being (implicit assumption)	asset	attractiveness, cost, exchange worth
Value is the relationship between the contribution of the function to the satisfaction of the need and the cost of the function.	British Standards Institution, 2000	quality management systems	customer (implicit assumption	product (implicit assumption)	relationship of contribution of function to satisfaction of need and cost of the function
Value is a functional outcome, a goal, purpose or objective that is served directly through product consumption.	Burns and Woodruff, 1992	delivering value to customer	consumer	product	functional outcome, goal purpose, objective
Value is a measure of the worth of something to its owner or any other person who derives benefit from it, this being the amount at which it can be exchanged.	CABE, 2001	value of urban design	owner or other person	product (implicit assumption)	benefit, amount at which something can be exchanged
Value is a capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer.	Chase, 1990	value creation in product development	customer	product (implicit assumption)	a capability provided at the right time at an appropriate price
Value is the relationship of market-perceived price to market-perceived quality.	Daniels, 2000	customer value management	enterprise	product (implicit assumption)	market-perceived price to market-perceived quality
Value is function plus quality divided by cost.	Dell'Isola, 1997	value engineering	human being (implicit assumption)	product (implicit assumption)	function plus quality divided by cost
Value is defined as worth divided by cost.	Fowler, 1990	value analysis in design	human being (implicit assumption)	product (implicit assumption)	worth divided by cost

Value definition[18]	Reference	Context	Target	Entity	Criteria
Value is user's initial impression plus satisfaction in use, divided by first cost plus follow-up cost.			user	product (implicit assumption)	initial impression plus satisfaction in use, divided by first cost plus follow-up cost
Value is seen as the maximisation of process efficiency through the identification and elimination of waste at the business process level.	Gage, 1969	value analysis	enterprise (implicit assumption)	process	efficiency through elimination of waste
Value is quality relative to price.	Gale, 1994	customer value management	customer (implicit assumption)	product (implicit assumption)	quality relative to price
Value is the level of importance that is placed upon a function, item or solution.	Hamilton, 1996	creating value in engineering	human being (implicit assumption)	function, item, solution	level of importance
Value can be considered as the ratio of function achieved to its lifecycle cost.			human being (implicit assumption)	product (implicit assumption)	ratio between function achieved and its lifecycle cost
Value is defined as a conception, explicit or implicit, of what an individual, group, or organisation regards as desirable.	Harrison, 1998	managerial decision making process	individual, group, organisation	what is regarded as desirable	desirability
Value refers to a preferential judgement.	Holbrook, 1994	nature of customer value	customer (implicit assumption)	entity (implicit assumption)	preference
Values are learned criteria that predispose us to act as we do.	Hutcheon, 1972	conceptual clarification on values	human being (implicit assumption)	behaviour (expressed in terms of "to act what we do")	values as criteria
Values are considered to be conceptions of the desirable, influencing selective behaviour.	Kluckhohn, 1951	values in the theory of action	human being (implicit assumption)	behaviour	values as conceptions of the desirable
Value is the relationship between function cost and actual cost.	Miles, 1972	techniques of value analysis	enterprise (implicit assumption)	product (implicit assumption)	relationship between function cost and actual cost

Value definition[18]	Reference	Context	Target	Entity	Criteria
Value is the relationship of product worth to product cost.	Miles, 1966	evaluating product's function	human being (implicit assumption)	product	relationship worth to cost
Value is what a thing is worth.	Najder, 1975	values and evaluation	human being (implicit assumption)	thing	worth
Value is a valuable thing or property.			enterprise (implicit assumption)	product (implicit assumption)	amount buyers are willing to pay
Value is an idea which makes us considering given objects, qualities or events as valuable.			people	objects, qualities, events	"considered as valuable"
Value is the amount buyers are willing to pay for what a firm provides for them.	Porter, 1985	competitive advantage	consumer	product (implicit assumption)	"willing to pay"
Values are "things" of the mind and are related to people's vision of a "good life". Values provide stimuli and constraints on thought and action. Values might be held by a single person and/or a group of people. Values are related to a benefit.	Rescher, 1982	introduction to value theory	single person and/or group of people	people	benefit
Value is an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence.	Rokeach, 1973	nature of human value	human being	"mode of conduct", "end-state of existence"	personally or socially preferable
Value is a fair return or equivalent of goods, services or money for something exchanged.	SAVE International , 2007	value standard	human being (implicit assumption)	goods, services, money	a fair return or equivalent for something exchanged
Values are defined as desirable trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or social entity.	Schwartz, 1994	universal aspects in the content and structure of values	human being (expressed in terms of a person or social entity)	behaviour (implicit assumption referring to "guiding principles in life)	values as goals

Value definition[18]	Reference	Context	Target	Entity	Criteria
Value is benefits (what you get) divided by sacrifices (what you put in).	Thomson et al, 2003	managing value and quality in design	human being (implicit assumption)	product (implicit assumption)	benefits divided by sacrifices
Value is a capability provided to a customer at the right time at an appropriate price, as defined in each case by the customer.	Womack and Jones, 1996	lean thinking	customer	product or service (implicit assumption)	capability at the right time at an appropriate price
Value is low price.	Zeithalm, 1988	consumer perception	consumer	exchange (implicit assumption)	low price
Value is whatever I want from a product.			consumer	exchange	ratio of what I get for what I give (implicit assumption)
Value is quality I get for a price I pay.			human being	exchange (implicit assumption)	quality I get for a price I pay
Value is what I get from what I give.		consumer perception	consumer	exchange	ratio of what I get for what I give (implicit assumption)

Appendix E: Protocol analysis

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
1 (00:00)	The length corresponds to the length and breadth characteristics of the vessel currently under construction in America for the Royal Bahamas Defence Force.								
2	These vessels are 60 m long with 9 m beam. They are presently propelled by three 1600 KW 16 cylinder Caterpillar diesel engines. These engines, together with the loading and the requirements of the vessel, small guns and 60 crew, propel the vessel at around 24 knots. Each vessel has a range of 2,000 nautical miles at 14 knots.								
3	These vessels were chosen as the most suitable for the conditions in the area. **Shore boats were wanted with long range and good sea-keeping characteristics.**	concept	long range of shore and good sea keeping characte-ristics	A1, A5	E3		C1, C2	C1, C2	V2
4	As this boat is currently under construction, experience has been gained in building this boat.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
5	**This seems a logical starting point** in developing new design performance requirements. These requirements to some extent are: (i) maximum speed of around 38 to 41 knots; (ii) highly sophisticated control systems; (iii) minimal management of the systems, so a lot of the weapon system functionality is to be incorporated in the vessel.	starting point	logical choice	A5, A11	E1	C3		C3	V2
6	As the **vessel** is being built in the US and with US money, **there is a desire to outfit it with as much US-manufactured equipment** as practical versus with equipment purchased elsewhere.	vessel	USA manu-factured equipment is fitted	A1	E3	C4		C4	V2
7	This (desire) poses some difficulty, because the marine market in the States is not been geared to the manufacture of small patrol craft or small warships.								
8	The American fleet is mainly a deep blue water ocean going fleet. Their weapons systems are geared towards much larger crafts.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
9	There are a lot of home-made systems that suit the particular requirements. **Therefore, we have to look overseas for different suppliers with perhaps some US connections. This will make the selection in certain situations more acceptable to the US government.**	supplier	acceptable for the USA govern-ment	A5	E2	C5		C5	V2
10 (00:05)	So, we've done some preliminary power requirements for this vessel and have established there is a need for something in the order of (I don't know the figure at hand, which is X number of megawatts).								
11	This falls into two major areas of selection: either 6 engines, or 4 engines of larger capacity.								
12	We have been **advised that the $/kW price of a 4-engine application is prohibitive and that we should concentrate our efforts on the 6-engine application.**	6 engine design application	$/KW is lower than 4 engine concept	A11	E3	C6		C6	V2
13	**So this in itself is a driver to the design.**	priority on 6 engine application	$/KW is lower than 4 engine concept	A5, A14	E1	C6		C6	V2
14	This adds to the complication of having to accommodate 6 propulsions in a relatively small envelope.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
15 (00:06)	**We can see straightaway this compromises certain aspects of arrangements.** By the time we accommodate propulsions, the auxiliary and perhaps weapons systems, there is little **space left in which to squeeze the logistics requirements** of the vessel, i.e. the stores needed to survive at sea for ten days times the number of people on board.	design concept	space is left for logistic require-ments	A1, A6	E3	C7		C7	V2
16 (00:07)	Notwithstanding these requirements, **we have to satisfy sensible routes for the installation and ready removal of equipment that are likely to be replaced or serviced.** This adds another driver to where the equipment may or may not be situated.	design concept	there are sensible routes for instalment, ready removal equipment etc.	A1, A5, A13	E3	C7		C7	V1
17	**First things first**. We **must look at how we will put the 6 engines in the vessel.**	to look how to put 6 engines in the vessel first	unknown	A5, A14	E1	C8		C8	V2
18	Now, 6 engines of MTU 4000 series, i.e. the engines which are being proposed. There are perhaps one or two ways to put these into the vessel sensibly.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
19	But **there are maintenance considerations that we'll have to consider.** The operatives will need to move about the engine spaces to conduct maintenance both in and out of the vessels. We have to be able to get them in and out of the engine space.	design concept	reflecting mainte-nance	A5, A13	E3	C9		C9	V2
20	How can we get 6 engines and 6 propellers in a row?								
21	We have 6 lines of shafting, i.e. 6 separate shafts. **But the vessel cannot practically accommodate 6 propellers in a row,** let alone six engines.	design concept	six propellers are not in one row	A5, A10	E3	C10		C10	V2
22 (00:09)	Can we put 4 engines in abreast? Each pair of engines drives a single propeller, and we arrange the engines in a staggered format. 4 engines are abreast in one area with the other 2 engines in another area.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
23	These prospects are shown on the screen for your inspection. As you can see, **the ability to put 4 engines in a row is just grossly impractical.** There is no room for the ship's structure. The engines would have to go in at heights which would make them difficult to maintain and access. It would raise the CG and impact the overall stability of the vessel. **So, at a glance we can see that this is not a sensible approach.**	design concept to put 4 engines abreast	practicable	A5, A10	E3	C10		C10	V1
24	So let's look at another consideration. We know from past installations that it is possible to put in a U-drive gearbox, which enables the engine to be placed in reverse arrangement. A stub shaft comes from the engine to the gearbox and then the main propulsion shaft comes out underneath the engine and runs aft to the propellers.								
25	This in itself may be a solution, but we as previously mentioned, we simply cannot accommodate 6 propellers. **The most we can fit in the width of the ship appears to be three at any one time.**	design concept	3 propellers can be accommo-dated in one line	A5, A10	E3		C11	C11	V2
26	The most we can fit in the width of the ship appears to be three at any one time.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
27	We need to fit in some sort of gearbox that enables 2 engines to be connected to one gearbox with a propulsion shaft. We know from commercial catamaran construction in the market place that very narrow hulls have to accommodate a lot of engine installations. We know that there are combined gearboxes that enable so many engines to be joined to one drive train.								
28	What we must do is **communicate with gearbox manufacturers to find out if there is anything suitable for this particular application and for this particular power output.**	Communi-cate	anything suitable for this particular application and power	A5, A11	E1	C11		C11	V2
29	We know that these are typically available for water-jet applications. **What needs to be done is to establish reverse reduction capability for conventional propeller arrangements.** The gearbox manufacturer has come back to us and has made a recommendation but it's only a tentative one, as it happens to be a gearbox suitable for water-jets which don't have reverse requirements; i.e. because for reversing in water-jets, manipulation of the reversing bucket of the jet nozzle provides the reversing capability.	design concept	it provides reversing capabilities	A5, A11	E3	C12		C12	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
30	So for a propeller version, you actually have to have a reverse reduction gearbox. The gearbox manufacturer is looking into a situation to see how adding a reverse capability feature impacts the size of the gearbox.								
31	**So, where do we start to put the engines?** Put the gearbox and forward set of engines in a forward machinery space. **The engines will be close coupled to the gearbox, minimising any space take up.**	starting point	minimum space required	A5, A14	E1	C7		C7	V2
32	**And then from a redundancy consideration, we would like to think** about how to put the engines in separate compartments and divide the two compartments with a water-tight bulkhead.	following design step	conside-ring redun-dancy	A5, A14	E1	C13		C13	V2
33	**One of the major design parameters for the vessel of this size is its damaged stability characteristics.** A requirement in naval vessels in excess of 30 m and up to 90 m waterline length is that it should survive damage of any two adjacent compartments. On the diving bulkheads, there are sets of intact stability requirements.	design concept	should survive damage of any two adjacent compart-ments	A5, A13, A14	E3		C14	C14	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
34	Where else can we consider putting the engines? In this category, **the engines should be placed in such a manner that the propulsion shaft angle with respect to the buttock lines of the vessel in which the shaft line is arranged is 6 to 12 degrees maximum.**	engine position	placed in such a manner that propulsion shaft angle is arranged 6 to 12 degree maximum	A4, A5	E4		C9	C9	V2
35	This basically means that the angle references another arbitrary line. This is the line that represents the buttock lines of the ship in way of the line of the shaft. And what we have to do is check the angle between the two.								
36	But the included angle between buttock and the propeller **shaft is 8 degrees. In this present configuration that seems very reasonable.**	concept	angle is 8 degree	A5, A10	E3		C9	C9	V1
37 (00:18)	This would tell me that it may well be possible to move engines further aft. This would have the impact of increasing the included angle, but then I have to actively consider where these engines in the overall context are in the overall position of the boat.								
38	These engines **can't move much further aft because we may put the boat out of balance.**	to move engine further	boat does not get out of balance	A5	E3		C15	C15	V1

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
39	What is the other consideration? We know from separate consideration that the propeller is of the order of 1.8 m. This is typically derived by calculation to absorb the power of the combined engines. This is taking a typical 3-bladed propeller. We know that there are greater advances and more efficiency to be obtained from a 5- or more-bladed propeller.								
40	**But as an initial consideration, if we work on what we know for the sake of ease and quick calculation, we can conclude that 1.8 m diameter is what is necessary to absorb the power.** We're assuming propeller shaft speed of something on the order of 700 rpm. A particular development of these Vosper hulls is the built-in wedge characteristic at the back end of the boat that provides some lift.	initial considerati on	easy and quick calculation is possible	A1, A5, A14	E1	C16		C16	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
41 (00:20)	And more recently, another innovation is the **vibration attenuation caves which are fitted directly over the propellers. These enable us to fit propellers with a lot less clearance to the hull** than what would ordinarily be, perhaps to avoid vibration being transmitted to the hull. This attenuation panel made from an elastomeric membrane is suspended from a watertight box directly in way of each propeller. With this facility or characteristic we assume a propeller tip clearance of 15% of propeller diameter to work from. What is the dimension from the membrane face to the centreline of the propeller? This gives us a datum point to the aft end of the vessel.	vibration attenuation cave	propeller can be fitted with clearance a lot less to the hull	A5, A15	E3		C7	C7	V2
42 (00:22)	**So we already decided from previous experience that we might use the benefits and experience gained from previous craft.** We know the rudder - it may be a similar size or perhaps slightly different.	benefits and experience from previous crafts	unknown	A5, A8	E1		C8	C8	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
43	We know from a clearance point of view between the rudder and the propeller that **we want to set the propeller as far off as possible and clear of the rudder.** We need to use all the advantages that we had on the previous boat. So what we have to manage to do now is to dictate the position of the propeller centre.	propeller position	position is far of and clear from the rudder	A5, A8	E4		C7, C8	C7, C8	V2
44	We have the envelope of the engine plus gearbox. **What we must check now, is whether the bottom of the gearbox is going to be within the hull envelope.**	next step	unknown	A5, A13, A14	E1	C3		C3	V2
45	**And what we need to do is perhaps draw a section through the vessel in way of the gearbox just to confirm** that the dead-rise angle at this position of the vessel won't cause the gearbox to penetrate the hull.	next step	it provides the opportu-nity to confirm	A6, A13, A14	E1	C17		C17	V2
46	Now, going to plan view.	plan view as next step	unknown	A5, A14	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
47	The engine has been placed in the boat to provide good propeller separation and good separation between engines to satisfy maintenance requirements. So from this we've determined the approximate distance to the shaft centreline to be 2.55 m. So in the section we have, we represent that position. So 2550. **Now I need to determine where the baseline of the ship is.** Now, what I failed to do the last time. 44, 57, copy this from there to there. I should have done it before (drawing section).	to determine the baseline of the ship as next step	unknown	A5, A8, A14	E1	C3		C3	V2
48	Right. So what we have done is to put in a uniform angle of shafting as a starting point. **Put in a 5 degree angle. And it doesn't have to be a round figure. But it makes life easier in remembering figures** when juggling about the screen.	figure	can be remember-red	A5, A8	E4	C10		C10	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
49	The 5 degree angle is borne out of the propeller centreline. And on the face of it there is sufficient clearance of the gearbox sump to the bottom of the vessel at the given frame position. So in manipulating and moving between different views and calculating what the shaft line might be at a given position**, it looks reasonably clear. 5 degrees seems to fit that quite nicely.**	5 degree angle	there is sufficient clearance	A5, A10	E4		C7	C7	V2
50	So take a dimension to check, whether it is 1.708 m. So offset the baseline. Drive shaft centre at frame 37. It is 1.708. This is where the propeller centre or the shaft centre is situated.								
51	Alright. The gearbox has been drawn in cell DVJ971F. I can't remember the name I've put in. I want this and I want that. That's a shame. I only have the plan and end views. That's nonsense.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
52	I haven't drawn the view that I want. I may just have to do that. So I might have to find my drawing. **So I need to find my sub-contractor drawing. I only need to draw the bottom contours of the gearbox. It's only the bottom of the gearbox that is important in checking** the clearance. Where is my sub-contractor drawing? Over there, 36m [Drawing DVL931-E] Select object 48m.	to find sub-contractor drawing	it outlines the bottom contour of the gearbox	A5, A16	E1	C18		C18	V2
53	Insert drawing block. **The subcontractor has not been able to provide us with computerised drawings so it's necessary to draw this out manually.** Ah, certainly there are more ways to provide this information that you need or perhaps scale the drawing provided, but you have to start from somewhere. Some of these I may have to do because having drawn the other view I remember what the dimensions are. Hmm, well, DVLJ931-E. Let's do that block again. Slight point. Change the character of this line. That's better. Come on. OK, bingo. Give me a handle that I can remember. Leave that at the moment.	to draw this out manually	required infor-mation can be gained	A5	E1	C18		C18	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
54	Right. **What we've determined is that the gearbox is too close to the hull.** So, that means that the shaft angle will have to increase.	gearbox position	not too close to hull	A7	E4		C5	C5	V1
55	We can't be certain of the distribution of the bottom structure. But chances are, we have supporting members in the vicinity of the mounting blocks. The distance between the mountings, i.e. the girth distance of the mounting blocks, is 900 mm. **Experience with light-weight high-speed craft tells us we need to have close spacing of the shell in the bottom structure.** There is a good chance that the spacing is 300 mm even if it's allowed to go larger elsewhere.	to have close spacing of the shell in the bottom structure	unknown	A8	E4		C5	C5	V2
56	As shown, this is 900 mm. Assume 300 mm, and make a line perpendicular to the hull. Move that to a possible location. We measure the distance we have. It is something like 140 mm from the distance of the shell line to the underside of the gearbox. There is a possiblity that this longitudinal stiffener in the bottom shell might well be 100 mm deep.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
57	And we could wind up with a situation where, based on stiffener position, we might be lucky enough to clear the gearbox. But the reality is that ships are not built to the same high precision that engineering machine shops would work to. **There are bound to be fluctuations in the form and the nominal clearance of 40 mm won't be considered to be anywhere sufficient.**	nominal clearance	more than 40 mm because of fluctuation in form	A10	E4		C19	C19	V1
58	So we have been tasked to review the shaft angle installation. Increasing the angle by sliding from the propeller will have the effect of raising the gearbox and engine.								
59	But as can be seen in the profile view, **the engine installation height is still quite acceptable.** Hmm, there is plenty of room above the engine for it to be lifted and withdrawn and for any gearbox withdrawal consideration. It allows for good air circulation and the ability to move services in, over, and around it. So maybe 0.1 degrees will give us sufficient clearance. Alright now. That's ensuring that the gearbox is clear of the hull.	engine installation height	there is room above the engine for the ability to be lifted and withdrawn, for the gearbox to be withdrawn, there is good air circulation, and room for service	A5, A10	E4		C7	C7	V1

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
60	**Now, we have to look at the engineering considerations of attaching the engine to the gearbox.** For the forward machinery space, the engine is flexibly coupled to the gearbox. The engine in the aft machinery space will require different considerations.	to look at the engine attachments to the gearbox as next step	unknown	A5, A13	E1	C3		C3	V2
61	Experience from previous vessels built has enabled us to design an arrangement whereby the propulsion engine is in one engine room and the gearbox and the after engine are in another watertight space. The centreline engine is connected to the input side of the gearbox.								
62	Previous vessels we have built have similar configurations, for example, with a U-drive configuration, where an engine is arranged in the aft space and the gearbox is in the forward space. A small stub shaft was run from the engine's flexible coupling through the bulk-head and then stopped at the bulkhead. This led to localised cracking of some tank structures that were connected to the bulkhead.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
63	**This could have been overcome at the initial design stage, had more attention been paid to the stiffness of the structure.** But we were confronted with this problem.	the initial design stage	attention is paid to the stiffness of structure to avoid localised cracking	A13	E3		C14	C14	V2
64	But this is overcome by doing away with the bulkhead bearing and introducing a second pedestal bearing connected to the bottom hull foundation. It would be on the forward side of the bulkhead, replacing the bearing, and it would thus take out of balance forces away from the flexible drive shaft and from the bulkhead. **A pedestal bearing which is originally connected is more able to cope with the force.** This is a lesson learned, and in this new application we'll be looking to do the same thing.	pedestal bearing originally connected	able to cope with the force	A5	E3		C19	C19	V1

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						Prioritised	Selected	Judged	
65	Now at this moment in time we are not too sure how to configure the structure above on the main deck. We know we have to accommodate some weapons systems. We have to accommodate the various combustible and compartment air requirements and the ship's machinery spaces. We also need to lift these engines in and out of the vessel, so perhaps we are driven towards making this engine room a little bit longer than what is necessary in order to accommodate the items of equipment fitted above on the main deck.								
66	So, the shaft that will run from the engine's flexible coupling to the bulkhead is longer than the previous arrangement, but compared to this, the length of the main drive shaft is still small.								

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						Prioritised	Selected	Judged	
67	There will be an advantage in some respect in mounting the engine aft. Because with the rise of the buttock towards the aft end and the installation angle which happens to be parallel with respect to the baseline on this vessel, there will be a converging effect. This means to say that the height of supporting seat will be less and as such, proven to be a lighter assembly. So we arbitrarily suggest that a small drive shaft goes in between. Again, this is dependent on the engine power**. We really have to have this engine in order to make any other judgement.**	to have the engine	on the basis of the engine, other judgments can be made	A5, A13	E3	C26		C26	V2
68	This is the right document. 16V 4000-series rating, 2320 kW. We will know this will be derated to suit ambient air conditions in the theatre of operation. Typically, this would be of the order of 2000 kW as anticipated. Wow, this is 2720 kW or maybe about 2500 kW. Hmm, a more recent engine installation with 3000 kW had a drive shaft diameter of 160 mm. **This is 2500 kW, so we just arbitrarily put 150 mm as a starting point.** More detailed calculations can follow.	2500 as a starting point	unknown	A1, A5	E1		C3	C3	V2

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69	**Now, I assume the Cardan shaft has a total length of 900mm. This is not unrealistic.** The Cardan shaft's flexible drive has a very shallow included angle. At the moment it is 2'30". This is very slight. So let's put something in there. 450. And, no, this going to be 900 [Drafting].	assumption	realistic	A8	E1		C8	C8	V2
70	Right, so we have a situation where we have a gearbox. We have an input coupling from the gearbox and we're going to fit a flexible drive Cardan shaft with it, a flange on the output shaft, a pedestal roller bearing, and a watertight seal to the shaft to maintain the integrity of the engine compartment.								
71	**Now, if we consider that we're going to have a shaft of about 150mm diameter, a corresponding pedestal bearing** for that shaft will have to be evaluated to see whether there is sufficient room for the bearing itself.	to evaluate a corres-ponding pedestal bearing for the shaft	Infor-mation can be gained on sufficient room	A3, A5	E1	C17		C17	V2
72	**Right. Let's just check the flange diameter and existing coupling.** That's 2000. That's not very promising.	flange diameter	unknown	A5, A10	E4	C3		C3	V2

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73	Typically what I'll do there is I'll go to the library and look up the catalogue on Cardan shafts to match torque carrying capacity. So I'm going to grab that document since it is not computerised.								
74 (01:00)	[Looking for the document.] It just so happens that this particular catalogue doesn't have what I'm looking for. **I need to consult yet another catalogue which is in the library.**	next step	required infor-mation can be gained	A16	E1	C17		C17	V2
75 (01:01)	[Looking for another catalogue.] Right, what I do is choose one which has the right torque range. **Previous experience has driven us to use the 190 Series** which has been renamed to the 390 Series. This being a heavy duty application, we go to the 390 Series.	to apply the 190 series	unknown	A17	E1		C3	C3	V2
76	**And what we need to determine is the TN value which is the torque value.** This requires the engine kW rating divided by shaft revolution times a constant factor to give us kNm. So take the torque figure of the engine which was 2720 at 2100. 2720/2100x9.555.	next step to determine the TN value	unknown	A5, A7	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
77	**So, we are looking for something which has something in the region of 12.5 kNm torque capacity range.** Again, experience has shown that something in excess of that capability is typically chosen. The reason, I think you'll find, is for the life cycle of the Cardan shaft. Again, we can draw some conclusion from previous installations to know where to start from. All these characteristics can be refined at a later date.	looking for something in the region of 12,5 kNm	Con-sidering the lifecycle of the cardan shaft	A5, A8	E4		C20	C20	V2
78	**All we're trying to do at this stage is get some approximate idea of space envelope.** How much room do we need to allow for the machinery? Once we have decided that we can then move on to other aspects of the arrangement to see how we can best fit in those needs.	to get some approxi-mate idea of space envelope	once decided, we can move towards other aspects	A5, A14	E1	C17		C17	V2
79	**So I was looking at an arbitrary 900 mm length, and it appears quite satisfactory that I can get it for the Cardan shaft application,** which ranges from 430 mm long up to 1150 mm if required. So my 900 sits comfortably in the middle. And in terms of the torque carrying capacity, it would suggest that the 190-55 series is quite suitable.	looking at arbitrary 900 mm	appears quite satis-factory in the middle	A16	E4		C21	C21	V1

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
80	So let's just list some basic dimensions for this Cardan shaft. It has certain mating flange sizes that we're looking at, and those are given in the table as dimension A. This appears to be a 250 mm diameter flange. And the flange thickness is given as G, which is 18 mm. So we just represent the flanges there.								
81	So we have a corresponding flange on our stub shaft. It could be a forged stub shaft and if that's the case the flange could be that much thicker. **Let's arbitrarily put it as 25 mm. That should be comfortable**. If it is a forging, the flange will have a root radius. This could be up to a 15mm radius, maybe a bit more. [Rotate this rectangle 5 and move there.]	25mm thickness	makes feeling comfort-table	A5, A8	E4		C22	C22	V1
82	Right, so between these we have the Cardan shaft. What are the principal dimensions? M is 130. This represents the knuckle positions. Let's put that as 130 mm and 130 mm. Aah, I don't know what you want to say about this. I've done it wrong. I have chosen the wrong end point on the stub shaft. In fact it should be, instead of basing it on the shrunk-on diameter, the other way around.								

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						Prioritised	Selected	Judged	
83	**What do we have in terms of distance there? 770 mm. But even 770 mm is well within the scope.** So I'll need to make a change there. So what do we need to do to get this…? [Drawing.] These then become the knuckle points. Right, that's on the Cardan shaft.	770 mm parameter	within a certain scope	A5, A8	E4		C9	C9	V1
84	**Right, what is the next thing I need to determine? Pedestal bearings. Wouldn't it be great if there was only one manufacturer?** Dimension to pedestal bearings. [Looking for information.] Found it. Cooper bearing. Alright. Cooper pedestal bearing.	number of manufactur er	number is low	A5, A14	E2	C10		C10	V1
85	And what we are considering is a shaft which is nominally 150 mm diameter. Here it is in Imperial. So we need to look at 150. Cooper roller bearing. It seems to fit a 150 diameter. These seem to fit in a P10 casing.								

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86	This pedestal bearing is a fixed type. I don't know the dimension. So I need dimension L. It is 174. 174 is the width of cartridge that carries the roller bearing. So 174 mm. Have a look to see what we have at the bulkhead. Oops, presently we have 203 mm into which we'll be looking to put this cartridge. Well, for practical considerations then, **we must allow the stub shaft to protrude beyond the bulkhead so that there is clearance all around this pedestal bearing for maintenance and inspection accessibility.**	to allow the stub shaft to protrude beyond the bulkhead	this serves practical conside-rations of mainte-nance accessi-bility	A5, A7	E3		C10	C10	V2
87	**We'll probably allow at least 140.** So, on that basis of a cartridge width of 174, half of which, I can't think, 174 divide by 2 is 87. So 87. So, all this time my Cardan shaft is going to get shorter and shorter in length. So 87 is the cartridge width. [I have a nasty suspicion; this seems to be a ham-fisted way of doing things.]	to allow at least 140 mm	unknown	A5	E4		C3	C3	V2
88	Where is G? 295 mm is about 147.5. So that's on the cartridge. The pedestal foundation, according to the catalogue, has a dimension of 89 mm. Hmm, interesting.								

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						Prioritised	Selected	Judged	
89	L is 174, no, it is not correct. H dimension. Dimension H is 181. Another dimension is T. T is 415. Put a right angle here. Just drawing in the boundaries of the pedestal. [Drawing.] Right. This is the pedestal bearing. **And now we should legislate for some clearance on the other side of the pedestal bearing.**	to legislate for some clearance as next step	unknown	A7, A14	E1	C3		C3	V2
90	Go back to Cardan shaft. Just confirm again what the prospects were for the dimensions here. In Series 740, 780, 710 for dimensions. Hmm, within series 713. So 710. Hmm, the dimension we want to maintain is 710.								
91	**Let's choose the clearance in this cartridge.** 25 mm beyond the cartridge. Let's go for 87. 87+25=112, say 115. Move that item that point from there to there. That should be sufficient.	proposed solution	clearance sufficient	A5, A7	E3	C7		C7	V2
92	Right. Now, what have we laid out? All this effort is to determine whether we have to move the GB up the shaft line and likewise the engine. **So we need to find out what the dimensions are from the knuckle joints of the flexible Cardan shaft**. So it is 411. 411+260=671. So the dimension I don't want to fall below is 710.	find out what the dimensions are from the knuckle joints…	unknown	A5, A7	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
93	So I need to move the engine and the gearbox at least 40 mm up the shaft line.								
94	Now it may just suit me to move it more than that figure. So I look at the gearbox sump to the frame line. The forward end of gearbox sump is some 92 mm further aft from the frame line. In order to be able to fit in a reasonably deep frame and in order to not have to cut away the gearbox sump, it makes sense to move the engine and the gearbox up the shaft line so that it will clear this frame.								
95	**We've got to be careful that in the process of moving we do not move it through the bulkhead at the other end**. That is some 92 mm in the figure. Move the engine and the gearbox 120 mm.	to be careful	in moving we do not move it through the bulkhead	A5, A9	E5		C7	C7	V1
96	So that will add 120 mm to the length of the Cardan shaft. So let's do that then. So we need to extend this line. So 120. Extend from there to there. Move the gearbox and the engine. Move from there to there.								

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97	Now, what haven't we done? I'll do it again. Only this time, we need to put in the elements of the Cardan shaft. Oops, why isn't that happening? Right, the assumed bulkhead position and **the various connections that come off the engine can make clearances quite tight. Check what clearance we have available. 347, which not accessible by a man.**	clearance	accessible by man	A5, A7	E4		C7	C7	V2
98	So what shall we do? Instead of moving the bulkhead, it may be necessary to move the whole configuration further aft rather than further forward. **So just leave that for the time being.**	leave that for the time being	unknown	A5, A9	E1	C3		C3	V2
99	**I think we can feel reasonably confident with the arrangement as it stands now.** Just show the other pedestal bearing. Hmm, use the frame structure to back it up. Whenever possible, try to position shaft supporting equipment close to frame structures, knowing that down the line we have good, good routing for individual equipment.	overall arrange-ment	reasonably confident	A5, A20	E3		C17	C17	V1

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
100 (01:43)	Alright. Now, one thing that's happening in moving the shaft or the gearbox and the engine further up the existing shaft line has been an increase in clearance between the gearbox sump and the bottom of the boat. **We should go back to check to see if it is at the acceptable height.** Still the same point there. We've gained a little but not a lot. So in reality we still have to make some minor changes to the angle of the shaft to ensure clearance at the gearbox sump. So not great gains there.	design process	gain information on acceptable height	A10	E1	C16		C16	V2
101	Now what do we do? Hmm, we still have the opportunity to put generators in the aft position rather than in the forward position.								
102	It's a noise issue here. Generators are likely to be kept running. The operating profile of this vessel is such that it has limited time at sea. It has to spend a lot of time in the harbour. Chances are the harbour facilities may not have the shore supplies. It will be necessary to run generators. The crew is likely to live on board this vessel. This means to say that the generators will be running all the time, which puts a heavy burden on noise control.								

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						Prioritised	Selected	Judged	
103	And to have the generators directly next to accommodation space places is a higher risk of not meeting acoustic performance profiles. **So, subject to the weight balance of the vessel, we might consider putting the generators aft of the main propulsors, thus keeping all of the noise sources further aft.**	generator position	keeping noise source further aft	A9	E4		C23	C23	V2
104	That means that **if the accommodations move further aft, they will come up against the engine, which would be a greater noise source** but perhaps of intermittent nature. **Maybe something we can live with.** Let's do this to see how the rest of the layout turns out.	accommo-dation position	we can live with noise	A5, A9	E4		C23	C23	V1

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105	So, taking advantage of previous vessel arrangements, let's get an idea of the crew numbers we may need to accommodate. Take a look at what we've got at the moment - 2, 4, 6, 8, 10 within bulkhead space. It's quite crowded, and we have to accommodate seven more officers. This could be more reasonably and comfortably arranged for seven officers. It's in the mid-body of ship, which from a comfort point of view will be more acceptable. **There is a tendency to structure comfort with rank of the enlisted personnel.**	to structure comfort with rank	unknown	A7	E3	C3		C3	V2
106	What else do we need to accommodate? We have 28 crew, possibly split between senior and junior rankings. So 28, maybe 12 senior ranking and 16 junior ranking.								
107	**Ah, other documents will have to be looked at to see whether there are more definitive requirements.** Crew numbers, crew makeup. Right, we have 36 crew. 8 officers including commanding officers, one chief officer and six others, plus ten chief petty officers. 18 listings. Lots of these documents.	to look at other documents	more require-ments can be identified	A13	E1	C17		C17	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
108	What do we have within this block? We say we have 8, 10, 12, 16, 20. Hmm, shows some promise. [Block shows officer accommodations.]								
109 (01:51)	**I think we should start to determine where we'll roughly put the propulsion engine.** We should now look to see what the other limitations are for the internal arrangements of the vessel.	to determine roughly where to put the propulsion engine as next step	unknown	A5, A14	E1	C3		C3	V2
110	So say we need a nominal displacement of 550 tonnes. We have a set of hydrostatics from past vessels that we've built. With this we can determine what the design waterline would be.								
111	**The vessel has been designed to ABS,** the high speed rules and requirements of Lloyd's Register Special Service Craft. There are regulations within those documents that dictate positions of collision bulkheads. Once we've looked at those rules and determined where the bulkheads should be, that should give the other extreme of the envelope that we need to use for this vessel.	vessel	designed according to ABS	A8	E2		C17	C17	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
112	Let's consult the hydrostatics of a previous vessel, which I happen to have at hand. Right, a nominal draft of 2.7 m will correspond to a displacement of approximately 550 tonnes. That gives us an indication. A design draft of somewhere around 2.7 m is appropriate.								
113	Right now the requirements with regard to collision bulkheads are such that the **bulkheads should be placed not less than 94% of ship's length and not greater than 97%. Something of that nature.**	bulkhead position	placed between 94% and 97% length	A11	E4		C8	C8	V2
114	**I need to check, as I can't remember.** So more document consultation. Well something to remember. But the likes of this work is such that it isn't sufficient to stick it all in the head.	to check	unknown	A5, A14	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
115	Collision bulkheads in Table 2.42. Consideration will be given to the proposal for positioning the bulkhead slightly further aft of the arrangement. The craft, blah, blah,… The minimum is 0.05 length on waterline. The maximum is 0.08. **And as we're putting as much as practical in this boat, we're always squeezing for more space.** So we'll kick off with 0.05 and see where that sits in relation to transverse framing, as arranged in the previous vessel.	starting point	as much as practical	A5, A11	E1		C9	C9	V2
116	Right, what we need to determine now is based on 2.7 m draft. **We need to see what this represents in terms of waterline length.** This corresponds to 55.4 m x 0.05. This means to say the collision bulkhead from the stem needs to be arranged a minimum of 2.77 m aft of the intersection of waterline with the stem. So just see where 2.77 m comes to. 2.77 m seems to sit quite reasonably close to what we had before. This is 31. So let's take 32 and the distance between is 1000 mm. So that gives us a clue where the frame is. So you got 28. It's true. That's 15. So 1, 2, 3, 4, 5, 6 ,7 ,8 ,9 ,10.	to see what this represents in terms of waterline length	unknown	A5, A7, A14	E1	C17		C17	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
117	**Let's put in the previous craft's bulkhead for a moment so that I know where I am.** And that's 16, 17, 18, 19, 20, 21, 22. That's correct. So that's where the previous craft had the bulkhead. Obviously, there is some advantage if we can retain some of these positions. That'll help out in thinning as we know what space we have. So, that'll be the FP bulkhead position of the previous craft. That looks like 0, 1, 2, 3,... That's the forward perpendicular bulkhead. That's the demand of the requirements.	put the previous craft bulkhead at the moment	if some new information can be derived ("where I am")	A8	E1	C17		C17	V2
118	At best this FP bulkhead could move half a frame, as we're likely to have half frames in the fore end of the boat. It's getting so tight and we can't practically run longitudinal. In any case, we won't be able to add any more structure than what we already have in there because of the shape of the vessel. So there is a possibility that the FP bulkhead could go forward by half a frame. **Now what we can do for part of the requirements is draw in the arrangement from a previous vessel and see how that suits this new configuration.** We can always edit out what we don't need.	to draw in from previous vessel the arrangement	there is new information on how best it suites the new configuration	A5, A20	E1	C17		C17	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
119	OK. So what we've done is import the accommodation characteristics from a previous vessel. **And now we have to consider the features required for the new vessel.** Now, we know we have a sophisticated gun on the main deck. Oh dear, this vessel is a warship. It's got to be capable of delivering the weapons systems. [Extracts some info.] What's known as hard kill factors? [Checks document.]	now to consider features required	unknown	A5, A14	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
120	All right. Point defence missile system. Nominated is RAM, R-A-M, Rolling Airframe Short range surface to air missile system. In short, RAM is comprised of Mark 49 Guided Missile Launching System, Mark 42. Block One Guided Missile RAM Pack, 11 RAM version. Surface to surface missile system. 8 Harpoon Missiles. Block 1 G Missile with Grade B shock resilient canister. Medium calibre gun system chosen. Oto Melara 76/62 super rapid CIWS (Close in Weapon System), Phalanx. Block 1 Bay. Minor calibre guns - 2 each of M60, GPMG M60, M60, M60. Not too sure if that's a 0.5" or 62 calibre. And that comes as a requirement for small arms, which includes those 2 machine guns, 16 assault rifles and 8 automatic pistols. They are not so much of a worry space-wise. **So those are the large items that have to be considered.**	to consider an item	item has a certain size	A5, A13	E3		C24	C24	V2
121	Soft kill considerations will take up a bit of space. Those are decoy launchers and anti-missile decoy launchers. And, Super barricade 4 launchers. **All these need their space envelope both for installation and for their effective use.**	equipment arrange-ment	equipment does fit into space envelope for installation and effective use	A5, A13	E3		C7	C7	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
122	The initial problem seems to be that the point defence system and close-in weapons systems chosen are very similar in their roles. And each requires a large area of target acquisition. And as one of the other requirements of the vessel, it should be kept small so that its optical reflection is limited. One does not want to build superstructures or tiers of structure in an effort to mount all of these systems at different levels, so that they don't interfere with each other. **Somewhere along the line there has got to be a compromise. So, what's going to give? I don't know.**	to compro-mise	unknown	A5, A13	E1		C3	C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
123	First of all, let's see about putting in the Oto Melara Gun. So search the library cells for that gun, Oto 76. [Searching the database.] One thing that is known about this particular gun is that there is an under-deck carousel. This carries the ammunition such that there's a need for clearance in order to load ammunition onto it. And a minimum of 4 m in terms of compartment space would be required as we know from the experience of a previous installation. **Right. Based on the existing bulkhead positions, the forward-most compartment was 5 m long. So that would appear to be more than sufficient.**	length of compart-ments	unknown	A4, A14	E4		C22	C22	V1
124	**That would unfortunately place the gun quite a long way forward, which from a ship-motion point of view would not be quite clever.** Now it isn't a man-operated gun, but it still does not want to be in a severe environment. These guns are gyro stabilised and they do not want to be constantly engaged in correcting for trim variation, just to maintain a target trajectory.	to place the gun forward	adequate from a ship motion point of view	A5, A10	E3		C25	C25	V1

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
125	**It may be better for us to consider how what we do now has an effect on accommodation, and how best to organise this accommodation.** Let's just see what else we have. What we'll do is introduce another layout to this arrangement to include another deck. [Key strokes.]	to consider accommo-dation as a next step	unknown	A9, A14	E1	C3		C3	V2
126 (02:14)	Right, now Harpoons. Let's get the missile, the Harpoon Missile Plan. We know that the height of the missile installation is such that it's possible to walk under the level of the lowest canisters.								
127	**So we can arrange to maintain the ship's side walkway to get around the missile installation**.	missile installation	walkway can be arranged	A5	E3		C7	C7	V2
128	So we just normally barricade 900 mm on the ship's side. [Key strokes.] Oh, why am I not getting the offset? Why am I not getting the offset? **We'll try the copy command then**. Just a nominal… Oops. Just the nominal starting position.	try the copy command	unknown	A8, A14	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
129	So now we have to include… I have to have 8 missiles. This is 4. **So, it is customary to have missiles pointing in opposite directions,** so the other bank of four faces the opposite direction. At least then when they take off, they won't have to go around the house and come all the way back again. Half will go one way; the other half will go the other way.	to have missiles pointing in opposite directions	customary	A8	E3		C26	C26	V1
130	Oops. Hmm. Let do a rotate and copy. I did, come on. Rotate. Hmm, because I've got the object snap on it went to the other end of the line to rotate. It didn't accept mirror. Ok, that'll just get them somewhere on the boat. I have to accommodate them somewhere.								
131	**This is not the best position to situate the missiles** because there is the requirement for the engine removal hatches. This means to say the missile arrangement alignment may be disturbed each time an engine is withdrawn. What's more, because the engine removal hatch is likely to be bolted, the rigidity of the connection to the main deck is in question.	position	in line with engine removal require-ment	A10	E4		C8	C8	V1

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
132	As the engine removal hatch saddles the full width of the ship, there **doesn't seem to be any clear way to avoid not putting these missiles on the bulkhead section, unless they are placed somewhere else on the ship, which may well have to be the consideration.**	to consider missile position somewhere else	position on bulkhead section can be avoided	A4, A5	E1		C8	C8	V2
133	Just out of curiosity, let's move one bank of missiles forward to avoid the generators. It will be alright there. It would be a lot smaller to remove the generators. **But as it stands at the moment, because of the extent of the generator space, we can only accommodate one bank of missiles.**	to move one bank of missiles	generators can be avoided	A5	E1		C8	C8	V2
134	**Another thought is that we can organise the missiles to be arranged at the forward end of the superstructure.** But, this will have the effect of needing to raise the height of the superstructure, which again will compromise the optical signature of the vessel. Take hold of the missiles; let's find out what we can do here.	to consider another thought	unknown	A9	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
135	See whether we have them on file. If we haven't got a problem. CIWS - CIWS Goalkeeper, CIWS Phalanx. That engine has to go somewhere and that's where the bulkhead is. **I don't want that bulkhead any more.** That could be where the superstructure is. Doesn't look as though it can go. Let's try and move this engine and see what comes out of it. Let's grab hold of it down there. It looks as if the hatch is around the bulkhead. We could pass some fixed structure up to that point. OK.	to remove bulkhead	it causes enough space for the engine	A9	E1	C7		C7	V1
136	So, let's put in the rolling airframe missile. Hopefully I have it here. RAM, RAM, RAM. I don't know what it's been called. [Locate rolling airframe frame missile.] Oops, it may not be in my library. I have it in my library. Decoy, Harpoon, Exocet, RAM, Rolling Air Frame. Hmm, cancel, cancel. What else do we have? See whether we can find the other. Looks as though it has been done but not committed to yet. What's that going to be? Oh it's not there. Interesting. Where did it go? 325, 327 F1 or F2 E1 or E2. Let's try E1.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
137	So we're relying on a previous vessel's design, where the same equipment has been used. Just going into that vessel, I am going to extract a drawing. I can see in this particular arrangement as to whether there are other considerations towards other associated electronic equipment that may be installed below the mounting. So, let's see to it.								
138	Let's draw a line from - let's take it from hmm... let's take a line from there to there. Copy that cell, object snap, intersection, intersection there to that intersection there. Hmm. It looks as though there are some space allocations below the mounting for associated electronics. So we just need to make a note of the likely areas. It's normally a 3 m square envelope required below the mounting. Let's just check the schedule to see whether compartment 91 is the CIWS equipment room. It's the same. This is an optional fit. It's either CIWS or Rolling Air Frame.								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
139	That's where our experience comes in. From other clients they either select CIWS or Rolling Air Missile System and not necessarily both. This is where we may have trouble. It is very interesting in this arrangement as we have a few design features that may well benefit us in the new vessel proposal. So what we can do is actually copy a fair proportion of these details into the other drawing so that we'll have them available to us**. No point in re-inventing the wheel.**	re-inventing the wheel	effort can be reduced	A5, A14	E1	C9		C9	V2
140 (02:31)	It's there. It's a different chaff system. That's the layout of the lower deck carousal. Hmm. Drag [Keystrokes.] I just pulled it in from another ship. Just go back to that ship again. Just check.. Hmm. What's that being pulled out? Layer CIWS. It's a LCMK9P, LCMK9P - LCMK9P. Don't know. Don't know where the name comes from. **Let's get into my library and find out.** LCMK9. Well, there it is. After all that. Now there are all the bits and pieces with it. Loading working space. So in order to be able to load missiles into the vessel you need this space as well.	to get into the library	Infor-mative	A16	E1	C17		C17	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
141	**Oops, I better go look at the plan view as well and see what that says.** CIWS, CIWS, CIWS, Phalanx. [Keystrokes.] But we know that the magazine can be arranged under-deck. So we could pull that down at that level where it's slightly there… Hmm, maybe this will go higher to see if we can accommodate it.	to look at plan view	unknown	A5	E1	C3		C3	V2
142	So what else do we have? Minor calibre guns that can be organised on the side. Small guns. Medium calibre guns. Surface to surface we have. Point defence system we have. Decoy launchers. Probably not too bad. Do we have enough accommodations? Chances are we don't. We need a very large operation room. Do we have something in the making? We know the existing vessels in the client's fleet, and the way that the vessels are configured could help us. **The superstructure is extremely far forward, which we don't like from a comfort point of view.**	super-structure extremely far forward	comfort	A10	E3		C22	C22	V1
143	**So let's just mirror the line here and see what we get**. Oh. Why I do that?	to mirror the line	unknown	A5, A14	E1	C3		C3	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion: Prioritised	Criterion: Selected	Criterion: Judged	Value statement
144	Whether we could gain if this was the generator's space from a maintenance point of view, if we could get the generators closer together? How could we get these generators closer together? At the moment, the shaft line is about 1200. **If we could get these generators together, we could limit space between them to 800 mm. That would do it for us.** And where is the centre of the generators? That's the distance to the centreline. That is 1770.	to limit space between generators to 800 mm	unknown	A5, A7, A9	E4		C7	C7	V1
145	Right, we know that for a vessel of this type that the structure distribution at the bottom of the vessel will probably be of the order of 300 to 350 mm pitch. And chances are, we could probably have a much broader space on the main deck. **We'll probably stick to 350 in order to maintain some alignment characteristics.**	to stick in 350 mm	maintaining some alignment characteristic	A5, A18	E4		C8	C8	V2

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion			Value statement
						Prioritised	Selected	Judged	
146	With that in mind we want to organise the shipping operations based on that longitudinal distribution. **So we can start to design some sort of likely areas of the boat where we want either some soft patches or engine casings to be situated.** With those positions in mind it influences the way we organise our equipment.	to design some sort of likely area	there is an influence on the way to organise equipment	A3	E1	C17		C17	V2
147	So we have a distance of 800 mm. Oh. Centre to centre is 1770 mm. 350 mm distribution is 1750. Ah. What is the next one? Let's see what that means. This would enable the centre of the generators to be lifted. What can we do? 2100. That's still leaves us a certain amount of shipside. 2.3 m. Due to the tumble-home effect that may leave us with 2.0 m. What can we do with 2 m?								

Segment. Nr. (Time)	Transcript	Value entity transcript/ key word	Value criterion transcript/ key word	Activity	Entity	Criterion Prioritised	Criterion Selected	Criterion Judged	Value statement
148 (02:44)	What I'm trying to decide is whether I can build on the main deck superstructure. I'm not sure if I can. If I box that in, what am I going to achieve? Subject to what the arrangement is in the deckhouse, you need some sort of superstructure through-fare. **Then you have to come around the casing and then go out by the side of the ship. That's a possibility.** I don't want to do that. Move that for a moment. And 1, 2, 3, 4. Hmm... right, 4. But it could go on the side. Let's work on the premise of At 3 m, 42. I assume this is to be the engine casing.	entrance position	to come round casing and go out by the side of the ship	A5, A10	E4		C7	C7	V1
149	**Move that for a moment**. And 1, 2, 3, 4. Hmm. Right, 4. Let's work on the premise of At 3m, 42. I assume this is to be the engine casing. So we could have the superstructure up to this point. No, don't trim this. Please don't do this. Please don't do this. Oh no. Because this is an auto ship project file there could be countless lines on top of each other. Hundreds of lines and this is still busy working away.	move that for a moment	unknown	A5	E3	C8		C8	V2
150	Well **it's fast approaching the time. I'm going home.**	to go home	time	A5	E1	C27		C27	V2

Appendix F: Interview transcripts

Transcript open-interview on value determination in design, Senior Designer "M", Mechanical Engineering Department, Building Industry, Premium Product Line 8th December 2008, 1h from 09:15-10:15, Germany		
Time	Person	Transcript
00:00:00	R	Mr. M, let us begin with the following images.
		This image [showing an image of a face-vase-illusion] you know. One sees this image again and again.
		If I were to ask: "What is the value of what you are seeing?" what would you say?
	M	**That depends on what the image represents**.
	R	And what do you see?
	M	Two faces and a vase, pedestal or whatever…
	R	Ok, we'll concentrate on the vase.
		What would you say is the value of a vase?
	M	To contain something, no matter what, as a container.
00:01:00	R	And when we think about the faces - what the value of the faces is - what would you see in it?
	M	Well, it is a frontal confrontation of two faces. How that can be interpreted, there are a lot of possibilities.
	R	How do you interpret it?
	M	Well, ultimately there are two more or less silent faces that, let's say, face each other and express tension.
		[thinking] or let's say, they could lead discussions, i.e. there are different views on why they face each other.
	R	Is there value in there?
	M	**Where, in the illustration?**
00:02:00	R	In what you see?
	M	Well, that's always a question. If anyone wants to achieve something with it, then it definitely has a value.
		But, it is so multifaceted that **with only two faces, relatively little can be revealed.**
	R	Ok, we'll come back to it again later.
		So, now we come to the crane image [showing an image of a single crane] what is the value of a crane?
	M	**To lift and move loads**.
	R	Is it different from the cranes you can see here? [showing an image of multiple cranes]
	M	It **illustrates not only the product but also the application**.
		That is the difference. You see not only the hoist but in addition, the construction site.
00:03:00		Furthermore, a lot of cranes, so that is very well different.
		To basically only see the value of the crane is certainly not correct.
	R	Now to these cranes here [showing an image of a mobile crane building a tower crane and another image of a tower crane on a high building] - is this a special case?
	M	This is an application of a mobile crane. It depends on whether this is a brochure for a tower crane.
		It would also be conceivable, that this illustrates the assembly of a tower crane.
		The main illustration would actually be the use of the mobile crane.
		On the right [pointing to the mobile crane image] is an application of a tower

		crane.
	R	That means, on the left the value of a mobile crane would be to build another crane? Can you say it like that?
	M	Yes, as I said, if it's a mobile crane brochure, it shows what you can make with a mobile crane.
00:04:00		The brochure shows a tower crane to illustrate how 'easily' the assembly takes place.
		Clearly, in this example of the turning stage plus the top of the tower, how it is assembled.
	R	So the simplicity (of the assembly)?
	M	Yes. Yes.
	R	And in the case on the right? [pointing to the mobile crane image]
	M	That is the application for tower cranes. Let's say a typical application for tower cranes.
	R	Climbing on buildings?
	M	Yes.
	R	Ok, that was a little leader to the theory.
		I would like to briefly explain the theory to you. We should now discuss it critically. It is not about confirming the theory.
	M	Yes.
	R	The theory says there's a person, and this person has the external world here [sketching an agent with an internal and external world]. The object is in the external world and the person interprets the object. That was the reference to the first image [referring to the face-vase illusion]
		There are two interpretations.
00:05:00		Then he goes and says every person has a personal - here unaware of value system - but rather a criteria system.
		Then the criteria are taken, that at the moment the most important is, and places it opposite what you see, so to which extent this object satisfies the criteria.
		This is a very simple theory, but with a lot of potential - if it is so.
		When you are in your development activities, could you say that you apply such a principle [sketching an agent and the agent's personal criteria system]?
00:06:00		That there is in principle a criteria system in your head that says, yes, that's the most important criteria?
	M	**Yes, that's obvious. Of course one needs that**.
		But, you have only illustrated a personal criterion - or personal criteria.
		Only now there are for us, as developers of tower cranes, various personal criteria. They are our own for the development, so that one sees the effort and a potential path for the development.
		A second criterion is the manufacturing with it; i.e. manufacturing has criteria for a crane.
		The third is, marketing has requests.
		Cost accounting has requests. They see it completely different from us as developers.
		The next is the mechanic - or the carrier comes first.
00:07:00		That means the freight forwarder has a completely different point of view.
		The next is the mechanic - who of course has his reasons to see particular criteria as a priority
		And then there is still the user, the crane operator.
		That means there are so many different (criteria), and to bring it under one hat, that is actually the difficulty.
		If you now say that we'll make an optimal device for the crane operator, then that device certainly looks different than what we're building.
	R	Ok, that means we have different criteria systems.
		To what extent do value systems in the various fields correlate with the

		personal?
	M	(thinking)
	R	I'll say that a personal criterion is that you'll get a certain predefined time … is that a personal criterion?
00:08:00	M	No.
		Let's say, it will be predefined.
		Ah, this is not a fixed criterion. We don't get a development time of, say, six weeks for a particular task, but rather that it should be implemented in the most acceptable time possible.
		We don't get tasks "that must be completed here or there". It is simply expected to be implemented as soon as possible.
		And then with the most sensible results - that's also clear.
		Implement something in the fastest time, which was formerly often the case - and sometimes today with special projects as well - but you don't always get the most sensible solution as a result;
00:09:00		…but simply out of time reasons rushed in the early stages, and then things partly emerge where you say "actually, you could still" improve and/or search for more meaningful partial solutions.
		But ultimately, you must differentiate production units and special units.
		In production units, it goes for this reason that the criteria are combined as optimally as possible. So ultimately to achieve an optimal result, the influencing criteria are much more important.
		…also regarding production and everything.
	R	That means we have different criteria systems for production and special?
00:10:00	M	No. They are sometimes even the same criteria, only the implementation, or let's say the search for an optimal compromise between criteria, which also needs time. It will be more intensively pursued with production units than by single units.
	R	Now as I have also seen, we're discussing very common individual aspects. When the point is to unify the XH and the XB concepts, there is suddenly only one criterion in the room, that of the building height.
	M	Yes, of course.
	R	This was recognised as the point that one requires one more piece of tower to get to the same height. We have "checked off" this concept on the basis of a criterion. Does that make sense in the context of so many criteria, or would one have…
	M	No. The decision was certainly quite useful. Because, what use is it to you, if you meet all of the other criteria, but not that of the customer? The main criteria of the customer. And that is a major criterion.
00:11:00		Then the customer says, that doesn't interest me; we could have met all of the other criteria very well, and nevertheless sell nothing.
		If it were to go internal, for example, regarding costs or a somewhat more optimal shipping possibility, that would certainly favour the decision differently; one would have very probably thought "outside the box", which criteria to be considered decisive.
		But, if the customer value is in question, then we don't need to talk much longer; that is the deciding question.
	R	Ok, let's go to the next image [sketching two agents with their personal criteria system]. This is in principle the same concept. Only here there are several people involved. Does it reflect yet again what you have just said?
	M	Yes.
00:12:00	R	It's the same principle. All that will be said, as we say to the manufacturers, is that other criteria are attractive than the customer. Would you agree to that?
	M	Yes. Logical. This is basically what we are trying to implement. That we fulfil as optimally as possible the criteria for five or six people - or agents as called here.

		And if it come out that everyone has his criteria fulfilled, then we have the "optimal" device. But we can't fulfil the level to 100%. That's impossible.
		Sure, but that is entirely correct.
	R	Ok, a part of the work is directed at getting into "personal" criteria.
		Does a personal criterion come to mind?
00:13:00	M	Sure, design.
	R	Ah…
	M	The appearance of a part, because it is a purely personal thing. You can discuss this at length.
		If a crane doesn't lift the load, the boom isn't long enough, criteria that you can accurately grasp - these are not personal. It's related on the point of view of the individual.
		Of course, if a longer boom is needed and there aren't any, then that is a significant criterion for you. These are things that we don't need to discuss. They are connected to the application and with the "value" of the device.
		Design is really the most personal.
00:14:00		This is exactly the same with a car. Whether you like it or not is purely a personal thing.
		For example - it doesn't belong here - think of how well the old Twingo ran in Germany. That was a "nice" car.
		The new Twingo is a 0-8-15 world face. Renault said we need a device that can be marketed worldwide.
		A product that would meet the "uniform taste" of the world. Since then it also looks like every other car.
		But that is a purely personal thing. In Germany the old Twingo was very well received.
00:15:00	R	A point that is still contained in the picture [referring to the image of two agents with their individual criteria systems], is the situation of the individual. For our customers it changes, for example the economic situation, still current. This changes his value system.
		That means he (the customer) would evaluate our crane with other criteria today than from before the crisis.
	M	I don't think so.
	R	You don't think so?
	M	No. Let's take a crane operation, for example. Why should agent A change the criteria just because the situation is worse?
		I mean, perhaps the importance of the criteria will be somewhat shifted. Ultimately he needs a hoist that carries out his work on the construction site.
00:16:00		That this must be especially inexpensive has always been the case. Of course, this will now be more important than ever, the cost side. But ultimately it is not a reversal of criteria. The weight will perhaps be more important.
		But a complete change in the criteria, I don't see it.
	R	Now there is a second area "exchange value" [sketching the model of value in exchange].
	M	Value exchange?
	R	Yes, there is actually a trade-off, when you consider alternatives.
		Let's say we have Crane A and Crane B. According to the theory, both objects will be interpreted. Just like before.
		Only now, one looks to see which of the objects better fulfils the criteria.
00:17:00		Is that so? Is that actually so?
	M	[thinking]
	R	Let's take two cranes and someone who is considering whether he should buy the cranes.
		He has a weight that the crane must lift, one fulfils this, the other doesn't.
		If it isn't so clear to recognise whether the crane fulfils the criterion, then what happens? Does he take other criteria?

	M	Okay, there are seldom clear comparisons and very clear statements. So that one has it and the other doesn't, is not often the case.
00:18:00		If you take the usual crane manufacturers alone, there are five, six, or seven that are main competitors, you mostly won't find criteria that excludes one or allows the other.
		Because every crane lifts or moves a load. That is normal for a crane. Now it could be, that there's a gap in the crane-portfolio, with us for example, and the competitor has exactly the intermediate device that we don't have.
		But that is mostly a cost or price question, whether one is "in the running", because there one makes concessions, that one offers the next bigger device that can also fulfil it.
00:19:00		But there aren't really criteria that completely exclude a competitor. This is a "hodgepodge" of all the possible arguments that then come, or criteria.
		It's about what comes from the manufacturer, quality, reliability, quality of delivery, supplier reliability, timely delivery, for example. Costs incurred through transportation, assembly, operation, how reliable the supply of spare parts is.
		…as the dealer network, we say the network is a reliable service employee; these are genuine concerns that result in an overall picture for a particular device.
00:20:00		That is certainly for every buyer or potential customer a different judgment.
		Whereas, it is ultimately about quality, reliability and cost. That's also clear.
		That mean, the crane operator wants a device that functions reliably, has little downtime, if it has a breakdown then there must be immediate assistance, and the costs must be manageable.
		That goes into the calculations of the construction site. Those are points where you can never say the cheapest crane is the best for the customer, and the customer indeed recognises that as well.
		Otherwise we would have no chance whatsoever of selling something, because we are always the most expensive anyways.
		But ultimately only a certain part of the crane goes into the calculation of the construction site, and the problem is if the crane stands and the entire construction site stands, then the costs are far higher than if he buys a somewhat more expensive crane.
00:21:00		…but it functions reliably.
		You know, say you have "umpteen million projects", one customer told us, if a crane stands still and it takes a week until a replacement part gets there, the costs rise so high that he could buy five cranes for it.
		These are then criteria from the construction site that are not only primarily concerned with the original price.
	R	I understand - is that virtual risk?
	M	Yes, the reliability of the device and the supply of spare parts is the bottom line.
00:22:00	R	Ok, let's respond to the situation as a developer. If you are developing something and two alternative solutions work, then is the decision based on similar principles?
		It is often not clear either, which is necessarily the best.
	M	No, that basically lies in the approval of the developer, what he considers better.
		One never gets everything under one hat, meaning one must always consider which solution is the most sensible. There are very often conflicts between the single criteria, where one must decide which to consider critical.
	R	Quickly something different, Mr. M, how long have you been a developer?
	M	20 years.
	R	If you were to compare your decision-making criteria with those of "youngsters", are they different criteria, or are they simply more criteria?
00:23:00	M	Yes well, that is a matter of experience, meaning, to first of all teach a

		"youngster" what criteria are, is not really so simple.
		To get an overview of what matters is not really so simple.
		There you surely need several years with us until you are really "inside" the material and can decide for yourself.
		So a "youngster" decides for himself - that will certainly make the design look different, but certainly not to his advantage.
		I mean it is clear, everyone views his field. With us that starts with the developers already.
		We have crane technicians, we have electrical and electronics suppliers, and we have a structural analysis section, and then also drive equipment suppliers.
00:24:00		This means everyone has his criteria within this development for starters. Then there are often also other different views between structural analysis and design.
		Meanwhile there is already a discussion on what predominant criteria are. And structural analysis has predominantly statics criteria in mind - which is actually correct.
		Only, far from what I previously listed, which is actually the best solution to cover all the criteria, is a point that structural analysis doesn't quite see and doesn't accept.
		To look within structural analysis for solutions, this doesn't always mean that this is also altogether the best solution.
		But they are everywhere.
	R	Normal - I think so too.
		[pointing to the model of value in exchange]
	M	Exchange value.
00:25:00	R	I'll tell you briefly what the theory says.
		It gives the term "Exchange Value". That indicates that there is an exchange of values.
		The theory here says otherwise. Developers don't exchange values with one another, but rather exchange criteria.
		The value is then generated in individual decisions personally for the developer.
		According to this theory, there is no "Exchange of Values".
	M	Hm…
		Do you understand what I mean?
	M	What does "Exchange of Values" mean?
		So, there are criteria…
00:26:00	R	Exactly, there are criteria. You say to me "watch out, decision criterion is the limit" and that's it.
		Then it's proven, Reber, yes that is decision criterion.
		Now you also said before "it is not always so clear". You cannot always clearly decide.
		Rather there is - as you previously formulated - "it's up to the developer's decision-making freedom" to say we'll go in the left or the right direction.
		This decision-making freedom seems to have something to do with evaluation. Somehow you evaluate the "direction".
	M	Yes.
		Yes, I must really, let's say, cross-evaluate the criteria and then determine which one to regard as authoritative and then implement it.
		[thinking] or fulfil.
00:27:00	R	That means - if we look at the training - what would you provide to the developers, decision criteria, right? We've already answered this question.
		Is such a definition of criteria provided? It really also has something to do with "Intuition".
	M	Yes, it does.
	R	Yes, the business of development has something to do with "gut decisions",

		where you say you'll go in one direction or another.
		Here the theory says I can't transfer such "kinds of values" - I only have them personally.
		The youngster next door would assess the value differently for himself.
	M	**Yes, that's right**.
		That's why every design looks different, according to what he does. Logically that's it.
	R	So would you confirm that the value is not exchanged, but rather if we exchange something, it's the criteria?
	M	Yes, that's it. That's really it.
00:28:00	R	Good, these are really the important things. It will be a little more theoretical here.
		Let's briefly switch over [sketching the VDM]
		This is a systematic treatment of what we have just discussed.
		The theory is, someone develops a condition and then "judges" the condition.
		The resource for the "value" is "knowledge". This includes expertise but also gut feelings, emotions.
		That fits together?
	M	Yes.
00:29:00	R	A question in connection with this image is, to what extent do we correlate the applied criteria with the development goals?
	M	Already [thinking]. Let's say one should not lose sight of the development goal.
	R	I'll ask now quite specifically: We should build an XH for the Bauma trade show. Is that the goal or is it already better defined?
		What is the goal and what are the criteria - it is not so clear for me.
00:30:00	M	Now, primarily we don't make cranes for the trade show. The Bauma is a fixed point where you say something new must be developed and built, so that you can show something useful everywhere at the trade show.
		It's like that with auto manufactures also, the new design must be at the trade show, otherwise it'll be too late and it will go under.
		And of course that's exactly like our trade show.
		Certainly there are times when you overwork somewhat for the decision - it's already started - these are often internal matters where you finally say, we have to revise the device.
		That means it's not that a kick absolutely comes from the outside. We know exactly where there are opportunities for improvement. We know that ourselves the best.
		We know where there are complaints, where there are problems.
00:31:00		If we make a revised version, then we already know ourselves where it must be tackled.
		That later you have to provide it to the customer, that is also clear.
		Where you take the revision into the exactly same consideration as with **customer benefits, the benefits for cost calculation, the benefits for the production, for the shipper, for everyone.**
		That means we fulfil the criteria not only when we make a new device, but it's always in sight, even when you only make a revision.
	R	That brings up an interesting question that means in principle, you develop the development goal.
	M	Of course.
	R	You would call on the criteria, now according to this theory, to develop the development goal.
00:32:00	M	Yes. We have a requirements specification where if we make a new device it's defined what the device should be able to do.
		Now it is of course relatively briefly prepared, i.e. mostly only technical data is stated inside, such as building height, boom length, what kind of controls...

		Let's say the entire criteria aren't listed. That is knowledge that exists in individual design departments.
		Where in the context of a revision, the goal will very probably be defined, what should be intended.
		That means, the goal will actually be defined by us in the department.
		You know that exactly, we often have disruption in the cubicles. It is clear, that you have to eliminate them. To remove broken pieces, that is entirely clear.
00:33:00		Then at the same time you create another fit-up solution for climate control, one better than today, that you change the storage compartment, and eventually change the covers for the pass-thru, these are genuine things that are actually defined by me.
		And that is for us the development goal; it has emerged from various directions.
	R	That is an interesting point, because many theories begin with a given development goal.
	M	When you start with something new, then that's how you would do it. With the new XB series, when we made that new, that was somewhat different.
00:34:00		There you had nothing that had to be used other than the tower. The tower systems were clear, but how the device looked, how it came out, that was actually open, i.e. there was no experience.
		There from the requirement specifications you defined the technical data and then from the criteria - that didn't come from us but rather what I already explained - defined a new goal.
		And then you sketched up the system. Then you made preliminary calculations to see whether it was at all feasible, in a "meaningful" way.
		And then you had already, with a defined goal, something to work towards.
		It is somewhat different with revisions, because there it's primarily about improving weaknesses.
00:35:00	R	Ok, Mr. M, now I have two films that I'd like to discuss with you. If it is so, that values are defined using such criteria systems, then that results in an interesting question:
		Namely the question, what must I do to increase the value of a product?
		What can I do?
		The theory says the following here. "Added value" is often in conversation.
		The theory says you now have three options.
		One possibility is - if you have a face-to-face with someone who is supposed to evaluate your product - that you can give him criteria with which he can evaluate. That would be a possibility to make your product more valuable.
		That means for us, **if my customers don't know certain things about my crane, then he can't even consider it valuable.**
00:36:00	M	Right.
	R	That means, I have to give him information about the criteria that I as the developer applied in order to develop the product.
	M	That you must only develop the criteria that someone perceives to be valuable is also correct.
		That means, you must not develop the criteria, i.e. indications that you fulfil the criteria he has anyways - that is a crucial matter where Sales and Marketing are a part of.
		To convey it to the customer.
		And that is…again and again you very probably notice…I have had customers in the house and struck up a conversation. I normally know the customers only by telephone.
00:37:00		Then I got into conversation with them and naturally brought up the subject of XB.
		That was then…now perhaps half a year ago…still relatively recent that you came to the market with this device.

		Then I noticed that they knew nothing at all about it. Zero-point-zero, what advantages this type of machine has.
		They were surprised when they saw it. And as I say, there is no simple path to placement.
		Where there is a lot happening. In comparison to earlier times, our Marketing presented the values very well at the trade shows.
		And not, that a brochure is distributed somewhere, but rather it was very well presented and it should actually be very well received.
		Only the people who weren't at the trade show could not also get familiar with it.
00:38:00		And often it is so that there are some people "from above", allowed to the trade show and have something to do with the device. But to recognise the advantages, isn't at all there.
		That means to come on the run and present the advantages, is of course a difficult thing.
		I mean you can't present a crane over television. That is nonsense. Out of 8 million Germans, perhaps a hundred thousand are interested. That is throwing away money.
		It is certainly a difficult task, and it really only works with direct contact.
		Even if our sales people go to the customers, usually only the "superiors" are around, i.e. they don't deal with the device daily…
00:39:00		With XB it is so, we have very positive feedback, but you still have to ask. Customers don't know their way around.
		As always you have to ask again. But customers who buy XB, for the most part French, are already very satisfied.
		The thing is, that they would like to have one bigger than the nXB, the next size up, which would create difficulties for the tower.
		Purely from principle, both the assemblers as well as the users of the crane are very satisfied here.
		Providing satisfaction to the buyer only works when they have the information or already have the device.
00:40:00	R	This confirms the need that the same criteria must be used, or at a minimum to know that that, that, and that are advantages?
	M	Yes. This is… Let's say the criteria with the crane are still the same. It is not that it's a brand-new product where you have to define it as new.
		You can do that relatively easily - if you know what it takes.
		Let's say, to fulfil the criteria as well as possible from different directions, that is the war-ending question.
	R	In principle, this also indicates that there is not "best" product.
	M	Yes, correct. You know, say you take competitor X, they are cheaper than us. Let's say the list prices are indeed the same, but in principle they undercut every price.
00:41:00		Only there the cost side is more prominent that with us. Of course we try to keep our costs low - but not at any price. This is what X sometimes does.
		They buy component A complete, component B complete, make steel structures where it's cheapest, there are of course quality problems.
		Of course we have that too, i.e. we are of the opinion that we have far too many problems, with false deliveries, with defective parts produced, but that it's far worse at the competitor.
		You hear that very seldom, but it comes through anyway in principle.
00:42:00		That shows, that the criteria we apply aren't so bad.
	R	As a final question, since you have just mentioned the concept: What would you see as the difference between quality and the value of a crane?
	M	[thinking] I don't know, whether they absolutely must be a difference, because quality is to me not only that parts are cleanly crafted, fit well and function reliably, but also, for example, that there is good service.
		That the care of the customer belongs with it, you could just as well define

		that as value.
		That is a question of definition.
		So, I would apply quality to not only the product, but rather the "total package", so to say.
00:43:00	R	The proposal to be made there is that quality is related to a specific set of criteria between two parties - can you say that?
	M	[thinking]
	R	So if we were to talk with our customers about quality, we say that something was welded correctly. We could perhaps agree on ten criteria and say that is what we define as quality, while value isn't so definable.
		Value seems to be much more dynamic.
	M	Let's say, that's true. The personal assessment, as you have also previously defined value, is alone by the evaluation of criteria…yet…
00:44:00		Look at the auto now - you can't represent design as quality, rather something that represents a personal point of view.
		And let's say, that the crane operator is proud to have one of our cranes, that shows we are simply better, we can build a good crane, that's a value, but has nothing to do with quality.
		It's more of a value where the assessment of the customer plays a role.
	R	Ok, Mr. M, thank you.
00:45:00	M/R	(personal issues are addressed)
	M	Yes, it's always difficult to represent something and to put it in words.
		And to make it so clear that it is simple to recognise.
		Where it is actually already simple.
		But, when I think of myself, about what runs through the head of a developer, what types of criteria and points of view you must consider, that is nowhere to be written. It is indeed nowhere with us.
		They are simply things where the individual must find out for himself what he considers important and that everything must be taken into consideration.
		It is very interesting to see it presented that way.
00:46:00	R	If you are interested I'll gladly show you a graphic.
		Especially for - sorry that it's so small, I'll make it bigger.
		This is a model of the development process.
		That will detect a problem that defines a goal, establishes requirements, a first draft, then to be evaluated, calculated perhaps also, then to be interpreted and then you come to a decision.
00:47:00		What the value now regards, I'll rate on each of these levels. A problem for one on this level is perhaps not a problem for the other.
	M	Yes, logical.
	R	What would be a development goal for you, e.g. to have the development complete by Christmas. You would set that as a personal goal.
		At the level we virtually rate what is important.
		The requirements to fulfil this goal are also of course individually assessable.
00:48:00	M	Yes, that's all right.
	R	What is not yet clear
		If you are assessing in the end phase of the product, then you come back and assess the problems that you have.
		Is that so?
	M	What that means, is not made explicit. Of course it is already so that you, if you sometimes are well into the design, that you see, that what the requirement there is, is actually not cleanly fulfilled.
		That the wrong priorities have been set, there are of course things like this.
00:49:00	R	It is also clear that this is an iterative process. That would also mean I see it and assess, whether the problem is actually my problem. There are indeed new findings there.
	M	Yes, there are also such things.

		Good, and when that part is finished, I'll say the crane is complete. Then the others can judge whether it has met the criteria.
		To say, production, assembly, customers, i.e. that what we try to keep in mind, these criteria as a guideline for the development, which we then evaluate, which are afterwards evaluated by the "criteria bodies".
00:50:00	R	And the assessment is perhaps different from your own?
	M	Yes.
		Logically, it's always like that, because we can never implement everything. We can never fulfil every mechanic's wishes.
		Otherwise "the crane builds itself". Sure this can be done, but it's priceless.
		Consequently, you must always find a compromise.
		And it's the same with the customer. The operator wants certain other things that you can't fulfil. From this perspective we're already evaluating a compromise. Hopefully a most optimal compromise.
		The evaluation, however, we get afterwards from all possible corners.
	R	Interesting.
00:51:00	M	That's clear. Production says "you can't produce that", "you can't weld that" or "it can't be built accurately enough". That makes me destroy my assessment.
		Then it perhaps turns out, that the evaluation that I have taken is false, from his perspective.
		The customer says super, that's a great device.
		It is always a difficult path, to find the optimal way.
	R	In principle, you check in advance whether "such" can be produced.
		Now you say you must make compromises.
		In a compromise, we fulfil the set criteria to a certain degree.
	M	And then comes the first one who bitches that his criteria aren't 100% fulfilled.
00:52:00		Well logical. And afterwards it comes back immediately - whether the device is good for something or not.
	R	I understand - the various point of views come back.
	M	Yes, again to the auto industry. They decide on an average design that should be popular worldwide.
		If, however, the design is not popular - then is the evaluation of the design was wrong.
		By that, I mean to fulfil this criteria was totally wrong.
	R	Yes.
	M	But they see that in hindsight.
	R	Yes, you see that in hindsight. Interesting.
		Yes, so Mr. M, thank you for your time.
00:53:00	M	It was very interesting to see something like that.

Transcript open-interview on value determination in design, Senior Designer “T”, Electronic Engineering Department, Building Industry, Low-Price Product Line 11th December 2008, 1h from 13:15-14:15, Germany		
Time	Person	Transcript
00:00:00	R	Mr. Trieloff, first of all many thanks for taking the time.
		But I think we'll be through in an hour.
		I would like to start by showing you some pictures and later I'll explain to you how they are related.
		This is an image that you've surely seen before [showing an image of a face-vase-illusion]?

		If I were to ask you what the benefit is in what you're seeing, what would you spontaneously say?
	T	[thinking] difficult.
	R	Why?
00:01:00	T	**It depends…**Due to the fact that I know the picture; I would say there are two faces.
	R	Two faces or?
	T	A vase.
	R	Exactly, it is a relatively known image.
		Now let's "pick" on the vase.
		Where would you say lies the value of a vase?
	T	[thinking] I see **no value there within**.
	R	Ok.
		And with the two faces?
	T	[thinking]
	R	Also nothing…how do you define "value" yourself?
		What would be a "value" for you?
00:02:00	T	**I think rather materially**. Faces or a vase, I think you could spend hours discussing.
		When it comes to value to me, I would rather use something three-dimensional, a laptop, for example.
	R	Ok, let's go to the next image [showing an image of a single-crane]
	T	Exactly, something like that.
	R	We see a typical crane. Where would you say lie the benefits of a crane?
	T	The value itself…first in the material itself, and in the technology and development behind it.
		That's how I define value for me. When I see things which I think don't occur so often.
		Then my appreciation is quite different, from my side.
	R	Occurring often, pertaining to availability?
	T	Yes, exactly.
00:03:00	R	Let's look at the next image now [showing an image of multiple cranes]. If I would now ask about the value of a crane…
	T	When I look at that now, I would say the value of a single crane moves more likely backwards, as opposed to the value it has on a construction site.
	R	So even here, the material value?
	T	Yes.
	R	Here we have two more images [showing an image of a mobile crane building a tower crane and another image of a tower crane on a high building].Where would you say lays the value of this crane?
	T	That is an assembly.
	R	That is an assembly.
	T	[thinking] Well, purely by feel I would say that the value of the device that is currently being built isn't so high.

00:04:00		There the value is created first.
		In the second image [showing the image of a single crane on a high building] it is quite clear; they are already at a relatively great height. A relatively great value is presented there.
	R	Ok…so…
	T	First of all, in the preparation you have to meet on the entire layout, the structural analysis that is behind it, and the entire time that is already in the assembly. Furthermore, the correct know-how is in there.
		Not only from our side, the design, but also from the side of the construction site.
	R	Ok.
		This image shows the theory [showing an image of an agent and the agent's personal criteria system]
		It's about a suggestion on how people develop value.
		The model looks simple. I would like to critically discuss this model with you now.
		You may be quite critical. It's not about confirming this, but rather to critically examine it.
00:05:00		Is the model as it really proceeds…
		Value generation has a lot to do with thought processes.
		Basically the theory assumes that value originates in the head.
		Here you see an object, for example, the crane. We interpret the crane and then we compare what we see with certain criteria that are in our heads.
		The statement is therefore, that we have a criteria system with which we evaluate.
		Material value was your criterion and you have evaluated the crane, to what extent it has fulfilled this criterion.
00:06:00	T	Yes.
	R	That is the simple theory behind it.
		Is that so?
		Does that correspond with what has occurred?
		Does anything stand out?
	T	**In principle that corresponds.**
		Something missing?
	T	[thinking]
	R	Let's go a little further. This is an image that aims to show that several people are participating [showing two agent's with their individual criteria systems] in determining value.
00:07:00		Let's take the example of customer value. This, for example, would be one of our developers (Agent A) and there is the customer (Agent B). This functions on the same principle.
		Both interpret what they see, both have a personal criteria system in their heads, and both, in some style or manner, judge what they see on the basis of this criteria.
		A critical point here is that what customer evaluates could be something different from what we evaluate within the development.
		Is that so?
	T	I think in any event, yes.

00:08:00		A customer who puts our device on the construction site, there is for him no criteria that technology stands behind.
		That is a minimal proportion.
		Whereas we have a very different perception. We're interested in what technology and which refinements stand behind it
		The customer or contractor will say, I bring my load from A to B, and it must work for him.
		Whether a "frequency converter" is behind it or another technology, this isn't so important for him in the first step.
		Only in the second step, if he has a problem with connection loads, for example, then he says "ok, I'll get on board with more modern technology".
	R	I see, ok.
	T	Whereas from the outset we plan something quite different. We say from the beginning that we want to give the customer a device that will give him no problems from the start.
00:09:00	R	Ok, can you grasp what the main criteria are for you (the team)?
		Or what typical criteria are? You have named latest technology, for example.
	T	Exactly.
		And they will be characterised more and more externally, for example, a frequency converter, because they say we no longer make the connection ratings innately available.
		When I go to larger cities, they say they don't want to see any more "commutator rings" that fully "beat up" the network.
00:10:00		And that's why we in the development say that we won't build anything else. For example, in the top-slewing area there is nothing other than frequency converters.
	R	There you bring me to an interesting point.
	T	Where, when a customer first sees our product, it certainly isn't in his head that he's thinking about the technology. He says, I need the power, the height, and I need the handling.
		A certain handling with speed must simply be achieved.
	R	Let's come briefly to the topic "power surges".
		Now this is probably also an area of discretion.
		Here we're talking about a personal assessment.
00:11:00		I imagine, for example, that a parameter is defined with a certain tolerance zone.
		That means it's up to the developer to personally assess "where he wants to go".
		Is that so?
	T	Partially, yes.
	R	What is the driving decision in this case?
		What drives you now to say we'll go in "the upper third" or in "the lower third"?
	T	Yes, good…with electrical equipment it is actually like that, to the extent I can't choose it myself.
		We again **depend on the calculations with the mechanics** and all.
00:12:00		With us that means we do it on a specific schedule, we don't have much more elbowroom.
		I need this and the power so that I can operate this or that motor.

	R	Ok. Where do you have elbowroom?
		Application of technology? Control room was recently a topic.
	T	Yes, by such things (the talk is about supplier selection), there we have some elbowroom. But not by connection loads.
		At the most with the calculated values - there we can say at our discretion how we will calculate it.
00:13:00		X-factors for example, in the top-slewing area we have a factor of 0.8, in the bottom-slewing area 0.7.
		Then we get "a bit more friendly numbers" on our data sheets.
		Where this is yet realistic.
	R	So is experience ultimately decisive?
	T	Yes, exactly.
	R	Also, what about, how it will be assessed?
	T	Yes, right.
	R	Does that make the difference between an experienced engineering and a "youngster"?
	T	Quite clear. Or that you see things as solvable.
		Or if I carry out calculations today and "smash together" dimensions, I see that it simply goes no more.
00:14:00		Regardless of whether there are safeguards. Where you say that you can't achieve more, where you say "there you could go down one" and then there is no problem with it.
		Although, regarding the calculation and the dimensioning, if I would only trust my PC, I am not allowed to do so.
	R	That is an interesting point: The question that presents itself is "what is evaluation, i.e. analysis?" and what is "valuation", i.e. estimation.
		That seems to me to be an example where it separates. I cannot rely 100% on it…no, I trust the calculations, but then decide otherwise.
	T	Mhm.
	R	To move forward.
00:15:00		You see here under the small line, there is a situation there [showing the image of two agent's with their individual criteria systems] That is supposed to mean…now, for example, we have the economic crisis. It changes the situation for our customers. Then the theory says the customers shift their criteria.
		Do you see it the same way?
	T	Hard to say…I think there are customers who say, I'd rather spend more and get excellent quality for it.
		(disruption by telephone)
00:16:28	R	So stable criteria - or how would you interpret this?
	T	Yes, you could say that. A trust is hidden behind it.
		That is how it is in the auto industry as well. There are also reasons that move people to say, I'll buy a Mercedes, BMW or Audi.
00:17:00		It's also not about the money. He says, I'd like a certain configuration. He knows there's a certain technology behind it; people who think about these things; and will certainly help if there's a problem.
	R	Do you follow a similar pattern in evaluating the selection of technology that we implement?
	T	Correct. Yes.

	R	And also the basis of trust on the supplier.
	T	Of course we have brought our suppliers as required upstairs, so that they can deliver all that we need.
		There are things today, for example, control rooms, that you simply cannot change.
00:18:00		It's exactly the same in my area of components, for example, current collectors that have worked trouble free for years. But the supplier there has also grown with us.
	R	Mhm…I understand.
		Ok, let's elaborate on a second topic here within [sketching a model of value in exchange]
		Perhaps you've already heard of the phrase "exchange value".
		There are also very different opinions on what that is.
		I'd like to briefly describe the model and then discuss with you whether this is so.
		Here [referring to the model of value in exchange] a comparative situation is presented.
		Let's take as an example the two cranes, interpret the two, and then place the cranes against the criteria.
00:19:00		For example - it doesn't have to be a direct criterion of the product - on-time delivery.
		So, he doesn't compare two cranes, but rather two suppliers.
		Or you in your role, you'll compare two suppliers for a control room.
		Somehow you'll choose which of the two you prefer.
		That is what is meant here with "value in exchange", virtually the appraisal of a situation where you can choose between alternatives.
		The first question would be basically "yes"?
	T	Yes.
	R	Now if you plunge into your development process and consider two alternatives, do you also proceed according to such a principle?
00:20:00	T	**Typically. Yes.**
	R	Would you then say "the one alternative is of higher value than the other alternative"?
	T	[thinking] rather less…well then again with regards to the perceived value they're pretty equal.
	R	Now, perceived value in what sense?
	T	The perceived value regarding the quality and of the execution of course.
	R	Why do you indeed decide then for one or another solution?
	T	In this area, I sometimes have no other choice.
		If we say they would both be at the same level, then I would probably choose the cheaper version.
	R	Ok, I understand.
00:21:00		If we shortly stay with the image…there is also the same thing now in an environment where several people are.
		I'd like to now speak with you about a specific item. It's specific to the question…that is really the basic concept of the theory…in so far as this theory actually applies to the development process.
		Now there is of course a model of the development process.

		First you define the function, then the goal, then the requirements…
		Then a first draft, then we consider whether we'll do some calculations, then we go back again.
00:22:00		The question that arises…where do you actually estimate "value"?
		Where do you use the value principle to make a decision?
		If we "shimmy down" to a development goal, do you have an example of a development goal?
		What are we currently making?
	T	Crane type XM. Additions to the controller.
	R	Someone defined it…and it is now to be done?
	T	Exactly. [affirmative nod of the head]
	R	That means, there was nothing to evaluate at this point, rather it is to be done and that's it.
00:23:00	T	Correct. [affirmative nod of the head]
	R	Here is the next step, the requirements in order to reach the goal.
		Is that the specification - or what would that be?
	T	Exactly.
	R	You define there what has to be done in order to reach the goal.
	T	Exactly.
	R	Is an appraisal involved here?
	T	In principle, yes. Where we often go along the path where we say "what could we adopt from the current production series?"
		We can't say we'll design everything new now.
		Rather, we'll say, good, we already have a production series now, there's something new. Now you could take a step and say we could re-evaluate everything that was previously good or bad, and eventually make a variety of things differently.
00:24:00		But mostly we take the step that has already proven itself. We take it in again and I'll revise where we had problems, but throughout the entire production series.
		So we try to avoid making intermediate steps, where we say we're getting into a new control room.
	R	Ok, let's continue with the first draft.
		Now we're really at the situation to decide: it will be or it won't be.
		Is that such an assessment - that's not really a "hard" estimate.
		With regards to feelings, you say "this is the right direction".
00:25:00	T	Yes, exactly, that's again experience telling me "that'll definitely work".
	R	With the next point we have a calculation again.
		You decide that you'll perform a calculation for something specific…or perhaps you don't need any?
		Would that also be an assessment?
		What would be the criteria to say, I'll actually go through the calculations now?
	T	With certain things it will be in any case estimated at the beginning.
		Only when we have the components together, will we then cleanly go through

		the calculations.
00:26:00	R	Ok.
	T	The problem currently for us in finishing is, we live on parts that others make available to us.
		First the frame is roughly defined…for example, the drive components will be determined.
		And we only start with this "figure".
		How the definition then looks, I only get that with specifications from various departments.
		The information only comes to us when it's complete.
		But to first of all make something, you have to make estimates to some extent.
		Or values from existing things, where you simply say - good, plus/minus a few percent works.
00:27:00	R	Exactly, plus/minus a few percent is also an estimate of value.
		So, experience there again?
	T	Correct.
	R	In product development, at least in theory, the topic of evaluation will be featured very highly.
		That's supposed to mean, we have at some point defined a goal and have assessed whether we have reached that goal
		I don't want to anticipate you, but my experience is different.
		Namely, that the original goal appears in the background during the development process.
		Is that so that…
		[disruption by a visitor]
00:28:25	R	Excuse me.
	T	So with us it comes out as we predicted, as we planned.
		At least from the time when we got involved.
00:29:00		How that looks in the preliminary stages, i.e. in the basic design, if marketing determines something, others also have to say something there, for example Mr. H. A. or Mr. M. J.
	R	You mean how to arrive to a result?
	T	Exactly. Correct.
		The concept is there the moment we become involved.
	R	Good, now let's make a little jump.
		We started from the model here [referring to the image of an agent and the agent's value criteria system], which was the basic principle.
		If you consider it and ask yourself the question: "How can we build or develop a valuable product?", then the theory draws to an interesting conclusion.
00:30:00		First it says, I can't build absolute value, as it depends upon the criteria that the individual people have in their heads with which they evaluate the product.
	T	[nods head]
	R	I'll quote from the agreement, ok?
		If you think ahead a step you'll come to these three images [sketching three images outlining opportunities to add value]. They actually show how they

		believe the value of a product can be generated.
00:31:00		One way to tell the customer how valuable a product that I've built is, I'll give him a specification that hopefully fits his requirements, and therefore the product is valuable.
		The second possibility is, I'll give him additional specifications. I'll tell him, you can raise and lower, but you also have an electronic control that allows this and that. An additional quality.
	T	Yes.
	R	The third aspect would be, I'll raise the appreciation of a criterion, i.e. I'll explain why the electronics are so incredibly valuable to him.
		You nod…
		I don't see a contradiction…
		Have we forgotten anything? Is there another possibility?
00:32:00		The interesting thing is, that our developments are very strongly function-oriented. My theory - or the theory that lies within here - is that somehow the function has to correspond with its value criteria.
		So if I offer functions that don't fit into this pattern, it has relatively little merit.
		We once had a conversation; it was about the question of explaining the product to the customer.
		This image suggests that I have to push a lot of information onto the customer.
		Because otherwise he won't value the product, because he can't recognise it.
00:33:00		Is that so?
	T	Is that with every product then?
		I only recognise after the second or third look what's really behind it.
		Today when I buy something, a stereo, for example, I first go "in" with the idea that I'd like to "merely hear music".
		Or another example is a cell phone or some other electronic device.
		If I'm then standing with the salesman, who explains many things to me and at some point I'm so far as to say, that sounds good and perhaps I even need that.
		And then all of a sudden my buying decision is somewhere entirely different.
00:34:00	R	Yes.
	T	That's right.
	R	There's yet another context…a brand, for example.
		Does a brand suggest a certain value criteria?
	T	That is also such a question. That is very interesting to us in the department.
		There are some people, and I'm one of them, who only buy certain brands.
		I buy a certain brand because I simply say, what's in there is already more than what I need.
	R	I see.
00:35:00	T	And I know, I won't have any big problems with it.
		The best example is when someone buys an MP3 player today, there are thousands on the market, but I simply say it has to be an AX, that's it.
	R	Yes, I recognise that pattern with me as well.
		Where at the time when we make the decision, we don't really know it.

		We only see it afterwards, when we have it in use.
	T	Good, but there are such products that simply don't disappoint you.
	R	Yes, exactly.
		Ok, finally back again, without me wanting to push the theory to the extreme.
		Here is now a small model [sketching a simplified model of the VDM], that basically summarises what we have just seen.
00:36:00		It says here, the definition of a value…the definition at the beginning.
		The theory also says, the value criteria that we use depend solely on the knowledge of the individual.
		That is coincident; we've already touched on that with the topic of experience.
		Experience of course belongs to knowledge, but there is more within.
		There is expertise within, experience, and also includes something like personal experience.
00:37:00		Someone would like to distinguish himself, for example. The theory says he may apply other criteria during product development than someone who has been recognised for several years.
		Would such likelihood exist?
	T	Whether someone wants to distinguish himself, maybe.
		But there are certain things where some say, I'll support that one hundred percent. Some things I'll accept, although I don't do it out of conviction. Or perhaps there's nothing else.
	R	Ok.
00:38:00	T	You have to thus make concessions. Not only that you say, I'll take the best in, but also there are perhaps things that you'd like to make better. But either it isn't how I imagine it…
		…or it is linked to a price, so that I have to say, I have to compromise, although I would have gladly made it different.
	R	That means, if I interpret it correctly, you're talking about a conflict situation.
	T	Yes. Correct.
	R	That means, you have personal criteria where you'd say you'd like to do it, but boundary conditions virtually dictate you don't do it.
	T	That is rather still, what runs through a complete design…crosses a complete development.
		That you have to make concessions for many things.
00:39:00		I've also heard that from the other side. My brother, for example, who did his internship at Mercedes. At the beginning he was at the C-Class, and then went to the S-Class.
		He told me his work is quite different there. If I don't have to deal with money or can deal with totally different materials, then anyone can realise their potential.
	R	Ah.
	T	With him it has gone so far, that's he has left Mercedes and is in Switzerland with XPP.
		They make aircraft modifications for individuals. There he can fully enjoy life.
		He can do things there, what he couldn't do before, because no one looks at the money.
		If you develop there, that is quite interesting.
00:40:00	R	Ah, are there differences there to us?

	T	[smiles]
		With them the developers fly to Rolls Royce or Bentley in England and take a look how they make the interiors, because the customers say they'd like an interior that's exactly the same.
		He's there for three or four days, looks around, writes notes about the material, etc.
	R	That means my personal criteria, what I'd like to do, they clash there.
	T	Correct.
	R	The fewer the conflicts, the better it probably is to work.
00:41:00		Ok. Good, to finish up here…
		What is happening here, he generates a value condition.
		If I take your brother, he made up his mind, and it was probably a criterion for him "if I can realise my potential".
	T	Yes.
	R	The second process is then, your brother has to make a decision, whether this company will enable his realization. That is virtually this "judging" step.
		Then he says ok, that is good enough. Here I can realise 80% of my potential as I imagine it. And so the image is settled. That actually fits quite well.
00:42:00		So from principle it seems that the model integrates quite well into reality, correct?
	T	I think so. Yes.
	R	Yes, Mr. T, that was what I wanted to talk with you about.

Transcript open-interview on value determination in design, Senior Designer “K”, Mechanical Engineering Department, Building Industry, Low-Price Product Line 12th December 2008, 1h from 09:15-10:15, Germany		
Time	Person	Transcript
00:00:00	R	Mr. K, I would like to show you some images in advance;
	K	Ok;
	R	I'll explain to you why later. The first image you surely know. Now we'll talk about value today. Firstly, what do you see?
	K	That depends on what I want to see. I can perhaps see two faces or one vase - or a pillar.
	R	If I were to ask you about the value of what you see, how would you describe them? What use is what you see or what value would you see in it?
	K	I can say nothing about it. Values develop only in context. I still don't see any context.
	R	Ok, let's take the vase. What would be the **value of a vase?**
	K	**A place to keep flowers**;
	R	And if we now see the two faces? Can you also associate a value to the faces?
00:02:00	K	[thinking] I can perhaps associate a meaning. But no values.
	R	What would the meaning be then?
	K	The meaning, for example, would be a conversation - or an approach
	R	Ok, you interpret the faces then as communication?
	K	Yes.
	R	I don't want to put any words in your mouth.
	K	Yes.

	R	I'll show you a different image now [showing an image of a single crane]. A crane, unmistakable. Where would you say lie the values of a crane?
	K	Values of a crane [thinking] in **moving loads from A to B**.
	R	Ok. Now what would you say are the values of a crane [showing in image of multiple cranes]?
	K	**Organised movement of loads from A to B**, C, D, E.
00:03:00	R	Organised meaning?
	K	Organised meaning that several devices are working in connection.
	R	Ok. Now the left image here [showing an image of a mobile crane building a tower crane and another image of a tower crane on a high building]. Where are the values?
	K	The left image shows the assembly of a crane and - values of this function or values of this image? That must also be clarified.
	R	What would be the difference?
00:04:00	K	The image is a representation - the value is perhaps an instruction for someone who wants to make it (the assembly) or hasn't made it yet, or clearly the value is the preparation of the crane for its use.
	R	Ok, and the right side [pointing the tower crane on a high building]
	K	Actually the same as before, to move a load as required from A to B.
	R	Ok, let's go into the theory now. The theory says people interpret objects, transfer it in their mental interpretation [sketching an agent and an agent's personal criteria system].
00:05:00		And now if the value of the object is supposed to be evaluated, then each person compares that what he sees against a certain criteria system. A criteria system that you carry yourself. A personal criteria system.
	K	That is absolutely correct. This also an approach that I have, i.e. I compare what I see immediately with previous experience.
	R	Here we raise it up - literature speaks about a value system that you carry within yourself. However, these values are based on ethical and moral principles.
00:06:00		This is in contrast to current theory that says we have certain criteria that we use to evaluate things. So, a very simple system.
		This of course also allows things to be evaluated under ethical and moral principles, but it also allows things to be evaluated under purely minor principles. So, an object corresponds to what you expect.
	K	Ethics and morals are things that we hardly touch with what we do. In our development process or support process in manufacturing, ethics and morals, you don't talk about them.
00:07:00		I also don't see a direct connection [thinking] ok, perhaps if our vendors bring in too little profit then you wonder whether that's ethical. But otherwise that is an entirely different level.
	R	An interesting point, let's address that when we come to it. I didn't think that we would get to it so quickly.
		But, part of this theory says that some of these personal criteria absolutely plays an important role - even within development processes.
		I'd like to make an example: a young engineer comes fresh into our company and want to present himself.
00:08:00		The assumption is, this young engineer will use criteria in the development process other than perhaps what an experienced engineer had in his place found, in order to distinguish himself.
		The hypothesis is, there are very probably personal criteria that have an influence on the product development process. Would you so agree?
	K	**By all means I can confirm that. That is also something that should be desired. It is not always desired.**
		But, that is a very, very strong enrichment in the entire process, i.e. it all begins with "want"; meaning if we have people who want something, want something more, then we also have many more opportunities to develop faster

		and better.
00:09:00		Ok, it must always be controlled and the methods of the young engineer applied, and the results of the application of these methods must be controlled. In the end the results count.
		If these new methods lead to a result faster, leading to equal or better results, then you have to accept them.
	R	Would you say there is a certain set of criteria used in the testing of the results?
	K	**There are only objective criteria: that is the marketability of the product (in the market) together with the profit.**
		There are only one or two criteria for product acceptance and the profit that you can achieve with the product.
00:10:00		In my opinion there are actually no other criteria.
		With acceptance, many small elements are combined, like, for example, product stability, reliability, ease of assembly, nice design, etc. It all depends on this acceptance concept.
	R	Ok, let's look at the next image [Image of two agents with individual value systems]. The same principle. The main point here is if two people evaluate an object, then the people refer to their individual criteria to come to a verdict.
00:11:00		We were just talking about it; we have an experienced engineer for example and a young engineer who has his own value system. They both look at a development problem for example, and then will evaluate this problem differently.
		The difference could be that you're using different criteria, but it could also be that you're using very well the same criteria, but the evaluation of these criteria is different.
		Do you have a suitable example that comes to mind? We could for example take a development engineer and someone from structural analysis.
00:12:00		The one from structural analysis would use other criteria than from the development engineer.
	K	**Ok, this approach is also part of the task that he has. If we speak about two different tasks, a development engineer and a structural analyst, then there are quite different views on how a part appears.**
		The development engineer would say we'll make it (the product) so that the force curve has as few corners as possible, that there are no jumps, that parts are not built not too, and that **there are different wall thicknesses in order to develop the force curve.**
00:13:00		**The development engineer would say "there's no way you can make that" because we need far too many raw materials,** we need many more welds, that part will be easy, but the cost here won't be acceptable.
		So there are different views here, dependent on the task that each has. And, to look at the two faces [referring to image of two agents with individual value systems] you have to be in conversation and you have to find the solution that is satisfactory to both sides.
		And so we reach the correct results.
00:14:00	R	Now you could even assume that the basis for these criteria is actually in the specification.
	K	Specification? You mean in our sense in the requirement specifications?
	R	Yes, if we look closely - is that so? Are there criteria with which you can decide on the development process?
	K	In my opinion that is not so. The requirement specification is actually the rendition of what the salesman learns outside from the customer.
		The requirement specification describes the properties that the customer uses: radius, payload, load torque, speed, ease of installation, package weight.
00:15:00		However, in the requirement specification there are no guidelines concerning how you can reach these goals. That is always free for the designer, the developer.

		"Freedom" shifts within the possibilities that you have in order to achieve the best possible economic results.
	R	Ok, that would confirm the theory; there is a requirement specification, but this specification does not reflect the criteria against which the development process is driven.
	K	Yes.
	R	Ok, next point. This image is about "Value exchange" [Image of a model of exchange value] You've surely heard about "exchange value" from literature.
	K	[unsure] Help me a little to understand.
00:16:00	R	In fact, it has been distilled that the image of "exchange value" isn't clear. There are very diffuse and diverse opinions.
		The theory presented here says the following: if we talk about value, i.e. if we exchange truths, for example we'll exchange pens, then there is first the interpretation that something of value lies in the exchange.
		But this assumes that we are in pairs.
00:17:00		There is however - per theory - an "exchange value" for a single person, i.e. when I assess for myself, which of the two objects (pens) is worth more to me.
		Then I judge this - that's why we're talking about "value in exchange" here, it isn't there [Image of model of exchange value], but it's about determining value in an exchange situation.
		The theory says here, that a person interprets two objects as before, and now assesses to what extent both objects fulfil certain criteria, and to what degree.
		Whether the objects will be assessed on the basis of the same criteria, remains to be seen. The theory says "no, not necessarily".
00:18:00		So, for example, I lay two pens across from one another - or better yet, let's take a pen and a coffee cup - then it could be, if I determine the value, it depends on if I have a craving for coffee.
		or if I absolutely must mark up a document.
	K	Yes, and now we must transfer this to the crane.
	R	Exactly, now we come to the crane.
	K	Ok.
	R	The question here in the room is, whether this concept is transferable for the weighing of alternative solutions in the development process. I have two concepts or considerations, and decide which I prefer.
00:19:00	K	Yes, in all cases. What I have learned from my professional experience, is we must present to the customer or the owner something that he also understands. To interpret something you have to understand it too.
		To get to the point - we're not staying with the crane - the simpler the function of the crane, the easier it is to interpret; the clearer the picture of the device, the faster it will be accepted and considered superior.
		Devices that you don't understand and are chaotic in the design - these won't be understood. Even if it functions superbly.
00:20:00		That means the observer (A) here sees a crane A and a crane B, and crane A has a clear structure, he (the observer) knows how to operate it.
		This device is classified as "more superior" than a device that is chaotic and where the lines i.e. force curves won't be understood.
	R	Interesting point, that means we'll go back again to the image from before [Image of two agents with individual value systems], that could be the supplier (A) and there the customer (B) assesses on the basis of "simplicity" criteria. Ok, I understood that.
		Please contradict me if I say something false.
	K	[nods head]
	R	[Simplified model of exchange value], so, and here let's now say the customer compares two products.
00:21:00	K	Yes, that means the customer has a "cube" and a "cylinder' [entities in the simplified model of exchange value], and that what he better understands

		right away will be also considered "superior".
	R	The criterion "better understood" will be for you expressed in the form of "clear lines", "clear structures", "simple functions" - is that correct?
00:22:00	K	Yes, ok. That also depends on the experience of those observing the two objects.
		There are also very complicated, very intricate designs to understand.
		But nevertheless, the "acceptance" will occur faster for devices that are "simpler".
		So, now I'll talk about my experiences.
	R	That's what it's all about.
00:23:00		Ok, I'd like to pick up a point here; here we see several people in this image. The background of this picture is an exchange situation [one pen at K, one pen at R].
		So, we both want to make a deal.
		The theory says we must arrive at a contrary assessment so that we trade.
		So, you have to make my pen more important that yours and I have to make your pen more important than mine - then we would trade. Is that so?
00:24:00	K	I have difficulty interpreting that. A commodity exchange in itself?
	R	Ok, let's say a customer is buying.
	K	Ok, that means how I can convince the customer that the product I have has an adequate value.
	R	Yes.
	K	Well, the argument. Technical argument.
	R	We don't need to "overdo" it - simply say what you think about this.
		Do you believe we could argue technically?
		Do you believe we could technically convince or only with technical criteria convince?
	K	Certainly not, but in our business, technical conviction is one of the most important.
00:25:00		I estimate with certainty that we technically argue 80% - that is the actual conviction - and the remaining 20% is the price negotiation.
	R	Meaning what would you do? You would give the customer technical details and explain that it behaves in such and such?
		To educate the customer, to give more information?
	K	So be it.
		I would painstakingly explain the technical properties of our product. "Painstaking", as I say it, meaning it must be very precisely explained.
		You must assume that the customer is at the same level as us. That he also understands the technology and can understand.
00:26:00		That is for 99% of the cases. The buyers of our devices are technically well prepared. For this reason it is also very necessary to argument technically.
	R	Ok, now we have arrived at a point where we arrive at a specific question - a background theme of this theory:
		Is there a possibility to specifically develop the "value" of a product? Is there a possibility to specifically develop the "added value" my product provides?
00:27:00	K	The question isn't so. That's what you have to do. There are no other possibilities to position yourself well in the market if the value of the product is not specifically developed.
		That means, customer value must be assigned to the value of the product or better, the cost of the product.
		I cannot pass by customer values and drive up the cost of the product, i.e. product benefits must with… i.e. easier said with the market value of a product…must be consistent.
		That is always a very clear target, in every development.
	R	That means in order to remain a model, the customer assess the cost and a

		number of other criteria?
00:28:00	K	Yes.
		There is a difference but it is only slight, i.e. the customer is more than willing to pay a little more, for more quality for example, or for some features of the crane.
		But only "a little" more, i.e. if I offer something more or have more quality, doesn't that mean that the customer is ready to pay much more?
00:29:00	R	Ok. Let's take one look at what options are available; it is about the question of how I can present a higher value to the customer.
		The theory presented here says I can either (1) give the customer extra criteria that he previously didn't know, on which to evaluate the crane; let's take for example, Litronic control.
		Litronic allows more load to be lifted in an area.
		The second point is (2), the customer knows his criterion, but I give him information to better assess the fulfilment of criterion. He can be informed about the existence of Litronics, but doesn't know about all the associated values.
		Understand the product, that's what you previously formulated.
	K	Yes.
00:30:00	R	…and I can give him an additional criterion (3).
		These are the three things suggested here to increase the value of a product.
00:31:00		It is therefore interesting because we are strongly focused on providing performance. The theory says yes, performance too, but I have to give the customer the appropriate information. Would you confirm that?
	K	**Yes, I can absolutely confirm that. The most important for the customer is that the main functions always work without disruption.**
	R	May I shortly chime in? It's often claimed that the main features are taken for granted by the customer. If they aren't implied, could it be that these features are not valued?
00:32:00	K	The [thinking]…The customer is always very clever. He gives money for our products and he never addresses these features in purchasing talks. He regards them as implied, as you said, but outwards.
	R	Ah…
	K	Inwards, of course he looks for a main feature that is indestructible, that always works, where he gets no problems in operation.
		That is also the explanation for the acceptance of a little higher price for our products.
		But, in the direct negotiations he will simply not want to mention it, because it would be to his disadvantage in the negotiation.
00:33:00	R	Ok, good point. Now unfortunately it will again be a small dose of the theoretical [Simplified model of VDM] but it is in principle a summary of what we have discussed so far.
	K	What is "VDM"?
	R	That's called "Value Determination Model", i.e. a model that shows how you believe people define value.
		In principle we see the same as in the previous graphic, only divided into two steps.
		First, the model says that knowledge is the basic resource, for how something will be evaluated.
00:34:00		Expert knowledge belongs to knowledge here, but also includes knowledge about a personal need, or knowledge about a personal goal, these are also very personal things.
		So, what is he doing now, he interprets an object and develops a so-called value condition. That is a condition that must be fulfilled so that an object is of "value".
	K	And he assigns the criterion (to the object)?
	R	Exactly. This crane is of value to him, if it is reliable. For example what you

		previously mentioned.
00:35:00		This is an if/then condition. So if "that", then it is of value to me.
		The second step says, that he takes the condition and evaluates. The reliability must be evaluated to come to a conclusion on whether the product is indeed of value.
		Then afterwards, to be judged.
	K	He judges.
	R	Exactly, he judges.
		So, he says that is my condition, reliability, and in a second step he goes in and says ok, to what extent is this condition fulfilled. The condition is up to 80% fulfilled because…good material was used.
	K	Good, yes.
00:36:00	R	These two steps are basically a simple model of how people come to a value statement, to a value agreement.
		Getting back to the customer, a lot can be suggested.
		The value of customer benefits depends on the knowledge of the customer. It depends not only on technical knowledge but also on his personal needs.
		That means in a first conclusion - and please contradict me if you see it otherwise - that products can never be specifically developed for Customer Value. We do not know, what knowledge the customer carries with him.
		We also don't exactly know his personal situation.
00:37:00	K	But now we're not talking about a development that we're developing for a group of partners. And we can in any case estimate the level of knowledge for this group of partners.
	R	Are we doing that today specifically?
	K	We're not doing that specifically today. That's always… Previously that was so, every one of us that already had a few years on the job had of course experience of what those "across the corridor" bring, what experience they collected.
		Where they worked, which other products they were confronted with - that those are the criteria.
		Otherwise we would be totally in the dark "about developing"…
	R	We don’t do that.
00:38:00	K	We don't do that. We had to assume some things - otherwise we may or may not meet.
	R	Ok, is this model of principles suitable?
	K	Yes.
	R	The model also explains difference in the regions…
	K	Yes.
	R	Including country-specific differences and cultural differences…
	K	Yes. That is the task that I've taken over now in India, i.e. our products will be regionally adapted.
		That's why the visits, the many conversations, construction site visits, conversations with the construction supervisors, to understand what they "think of the crane", how it looks in the perception of the construction supervisor, what he has to contribute.
00:39:00		We try in this way to determine the "knowledge of the agent".
	R	That's all what the model says. I'd like to finally come back once again to a point.
		Again to the development process.
		Now there is for the product development process [looks for a suitable graphic]
00:40:00		Ah, I'll draw a model of the development process.
		Problem analysis, first draft, and evaluation.

		A cycle that repeats itself during development.
		Does the "value model" allow the assignment of these cycles in the development process?
00:41:00		Sounds detached - are we "evaluating" during the development?
	K	[thinking] I am in any case. I do. It can't go otherwise.
		That is how you have drawn a continuous circle.
		We're drawing ever closer, if you represent the three-dimensional, as a spiral where up is Analysis, then there are different criteria at various points.
		With each rotation we get closer to the goal.
	R	It would it be "like that" [draws vertical cross sectional value determination" or "like that".
00:42:00	K	It's better if I draw it three-dimensionally.
		Here we are far away (left) and there somewhere is my goal.
		I have Analysis here, then here is the first draft, then I have to analyze again.
	R	Where would we have in this process the topic "Value"?
	K	That definitely belongs to Analysis.
	R	To Problem Analysis?
00:43:00	K	Yes, because that is something that compels us later, then an analysis comes - now in my language - preliminary draft, then comes the final draft, then comes the final design, which is then or sometimes prior connected to structural analysis.
		Then comes the result, and then we analyse the result again, and compare what happened with the "Values", let's say Customer Values.
		Of course we always have two points here: manufacturing cost and customer values.
		If we are already here practically pleased with the analysis [points to the left, then we end up here next.
	R	With that I have another question: If you made a first draft, on the basis of which criteria do you evaluate?
		How do you decide - yes, I'll take this first draft or another?
	K	Those are criteria "within" design elements - stability, feasibility…
	R	An example: you decide on one or another first draft, the theory says you do so on the basis of the evaluation of criteria.
	K	That is so.
	R	So, the decisions within the development processes are driven by such a "value cycle", not just the evaluations against the targets, as asserted.
	K	That's right.
	R	Can you see that?
	K	You can certainly see that.
		That is illustrated very simply. But these are processes that extend over several people and groups of people. Yes, it has to be coordinated. In discussions the goals must be repeated.
00:44:00		That means, in the development process the goal has to practically be repeated over and over again.
		The members of the teams, in fighting over details, forget very quickly where the goals are.
		It is the task of the team leader to constantly show - this is the direction.
	R	That brings me finally to the interesting question: Is "Value" the "Goal"?
	K	[thinking] Yes.
00:45:00		Clearly, I'm not ready to create something that is "worthless".
	R	Ah..ok, interesting perspective.
		Yes,
		Let's hold on shortly, for you again, and return to the picture from the beginning.
		The theory claims that the value is dependent on the interpretation on what you're seeing

00:48:00		That's why I asked you previously what the value is of what you're seeing. You said "it depends on how I interpret it". That is what this arrow in this model reflects from left to right.
		That is exciting, as it means for example, if two developers look at a drawing, then they interpret what they see differently.
		Consequently it takes some time until you come to a state of interpretation of what you're seeing.
		That was the value model.
	K	What I have experienced in the many years in the profession, the more often you show the goal, the quicker the developers come to a common opinion.
00:49:00		If you concentrate on a detail here and develop an opinion on a part, then you lose sight of the real thing - the value of the product!
	R	Interesting point.
		[Image of single crane] Here it was clear; you named the "values", your criteria.
		[Image of multiple cranes] Represents the crane in context. This leads to another interpretation. Your interpretation was primarily the interaction of the cranes.
		Another interpretation would be to develop a building: not just the lifting and lowering of loads.
		[Image of mobile crane building a tower crane and image of a tower crane on a high building] Here again the interpretation of the cranes in various situations.
00:50:00		What the model also shows is that we can only generate a "piece" of value.
		But not "the value". There are some on the go - it hopes to be able to develop "the value".
	K	"The Value" isn't there - that would be nice.