Incorporating ecological considerations into industrial design practice

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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abbreviations

AT	Adaptive Theory
CEO	Chief Executive Officer
CfD	Centre for Design
DIA	Design Institute of Australia
GT	Grounded Theory
HCD / UCD	Human Centred Design / User Centred Design
ICSID	International Council of Societies of Industrial Design
IDC	Industrial design consultancy
LCA	Life Cycle Assessment
LCT	Life Cycle Thinking
PSS	Product Service System
RMIT	Royal Melbourne Institute of Technology
SHT	Strict Hypothesis Testing
SLCA	Social Life Cycle Assessment
SRD	Society for Responsible Design
UNEP	United Nations Environment Programme
USA	United States of America
VDID	Professional association of German industrial designers (Verband Deutscher Industrie Designer e.V.)

Abstract

Industrial designers play a pivotal role in the development of consumer products. Consumer products contribute significantly to society's ecological impact, which needs to be lowered. This thesis examines the role of industrial design practice in developing consumer products with low(er) ecological impacts by (i) expanding the concept of ecodesign and (ii) collecting evidence on its contemporary application in Australia. Ecodesign refers to both the integration of ecological considerations into commercial product development processes and their conversion into product designs. When practicing ecodesign, industrial designers must consider the entire life cycle of products—an approach termed *Life Cycle Thinking* (LCT).

This research proposes that industrial design practice allows two expansions to the traditional notion of ecodesign. Firstly, it can uncover new opportunities for creating value through eco-designed products by applying solution-focused thinking. *Solution-focused thinking* uses representations of tentative suggestions for product designs to explore responses of the context being designed for. Traditionally, ecodesign only applies *problem-focused thinking*—deductively analysing the status quo to establish requirements for how value can be created. This can result in a lock-in to incremental product-improvement. Secondly, industrial design practice can widen the range of interventions that convert ecological considerations into product designs towards manipulating how products are perceived and understood by consumers, namely, the *meanings* attached to products. Traditionally, ecodesign focuses too narrowly on *technical aspects* of product design and has failed to sufficiently represent influencing *product meanings*.

For this research project multiple-case study research was conducted, investigating the ecodesign practice of Australian industrial design consultancies (IDCs) and their clients. The theoretically developed notion of ecodesign was used to guide and structure the enquiry. Data was collected through content analysis of IDC-websites and sixteen interviews with ecodesign experts, representatives of IDCs and their clients. The empirical insights show that the proposed expansions to ecodesign are appropriate. They can support converting ecological considerations into product designs. In tandem, they can also help with exploring and potentially stimulating opportunities for products that offer new eco-friendly meanings to consumers, which they perceive as valuable. If industrial design practice can identify such opportunities, it can justify ecodesign—guided by LCT—as a value-adding element in the product development process.

In conclusion, industrial designers can contribute to reducing the negative ecological impact of society by embracing the expanded notion of ecodesign. Several factors need to align to enable this; most importantly, they need to practice ecodesign in collaboration with their clients.

CHAPTER 1. INTRODUCTION

Industrial designers are service providers for commercially motivated client-companies (Utterback et al. 2007). Whether working as industrial design consultants or within in-house design departments, industrial designers design products for consumers to purchase. These products need to be designed in a way so consumers see sufficient value in them to buy them for a price that allows the client-company to make a profit. As stakeholders in a commercial product development process, industrial designers can have significant influence on the properties of today's consumer products[1]. They contribute to determining the technological aspects of a product. These include the technology embodied in a product and also the technologies that are used to manufacture and distribute it. Furthermore, they shape the product-consumer interface (Lofthouse & Bhamra 2001). This allows industrial designers to manipulate how consumers perceive and understand a product and how consumers relate the product to themselves. This cognitive phenomenon is also referred to the meanings consumers attach to a product (Krippendorff 2005).

Authors such as Schmidt-Bleek (1994) Lofthouse & Bhamra (2001) and Best (2010) have highlighted that industrial designers can and should play an important role in integrating ecological considerations into product development processes and converting them into product concepts. An ecological responsibility associated with industrial design practice has also been recognised by the International Council of Societies of Industrial Design (ICSID). They state that '[e]nhancing (…) environmental protection' is a challenge that needs to be addressed by industrial designers (International Council of Societies of Industrial Design 2013).

The idea to incorporate ecological considerations into design practice will be termed *ecodesign idea* in this thesis. This is more encompassing than the common use of the term *ecodesign* within the literature. As will be explained in more detail in Chapter 3, authors such as Charter & Tischner (2001) use ecodesign to describe a group of concepts which seek to apply the ecodesign idea in commercially driven product development processes through technological improvements. Charter & Tischner (2001) contrast ecodesign with another group of concepts that also share the ecodesign idea; they term this other group as *sustainable design*. These concepts supplement the ecodesign idea with a social and economic agenda, both aiming at

[1] The term *consumer product* means any article, or component part thereof, produced or distributed (i) for sale to a consumer for use in or around a permanent or temporary household or residence, a school, in recreation, or otherwise, or (ii) for the personal use, consumption or enjoyment of a consumer in or around a permanent or temporary household or residence, a school, in recreation, or otherwise (The U.S. Department of Commerce 1981).

improving equity within society (Bhamra & Lofthouse 2007; Charter & Tischner 2001; Crul, Diehl & Ryan 2009). Sustainable design not only relies on technological improvements but also aims for a higher degree of change that affects the socio-technical context a product is positioned it. A number of authors such as Chick & Micklethwaite (2011) Fuad-Luke (2009) and Walker (2006)—whose concepts classify as sustainable design—see them as either not at all or only to a limited degree applicable in a commercial product development process.

Sherwin (2004) proposes that when industrial designers apply the ecodesign idea, their practice more resembles what is classified as sustainable design than ecodesign. However, industrial design practice is inherently linked to the context of commercial product development. Thus, as there is a potential conflict between concepts that classify as sustainable design and this context, the role of industrial designers for applying the ecodesign idea is ambiguous.

1.1. Ambiguity about the application of the ecodesign idea by industrial designers

Even though the importance of the contribution of industrial designers to the development of lower impact products has been acknowledged, the influence that *industrial design practice* can have is not specifically accounted for in concepts that describe the ecodesign idea. Industrial designers are one of many stakeholders in the product development process, including engineers, marketing professionals and others. Manuals which provide how-to guidelines for applying the ecodesign idea in a commercial product development commonly do not differentiate between individual stakeholders in this process (see for example: Brezet & Van Hemel 1997; Crul, Diehl & Ryan 2009; Lewis et al. 2001; Tischner et al. 2000; Wimmer, Züst & Lee 2004). In particular industrial designers are commonly 'lumped together' with engineers (Lofthouse 2004, p. 222). Treating industrial designers as engineers is problematic. The two professions differ especially in regards to the focus of their practice and how they structure their practice.

1.1.1. The importance of distinguishing engineers from industrial designers

Engineers and industrial designers have an overlapping but different focus. Both influence the technological aspects of a product. However, in this regard engineers can be expected to go into a greater amount of detail than industrial designers. Industrial designers can also manipulate meanings that consumers attach to products, whereas engineers commonly do not address this topic.

Failing to distinguish between industrial designers and engineers also overlooks that the two professions commonly structure their practice differently (Roozenburg & Cross 1991). The underlying form of reasoning of both is described as *Design Thinking;* however, it takes different forms when applied by engineers or industrial designers. Design Thinking comprises problem- and solution-focused elements (Cross 2011; Lawson & Dorst 2009). A product development process which is organised by applying only problem-focused thinking has a linear structure in which individual stages are separated by gates. Gates can only be passed once the preceding stage is completed. The early stages formulate the requirements for the product by conducting research into the status quo. Then representations of solution suggestions such as sketches and physical mock-ups are generated and subsequently assessed against the previously set requirements (Cross 2011). Problem-focused thinking commonly dominates in engineering practice. Industrial design practice is usually more open to draw on the solution-focused element of Design Thinking. Solution-focused thinking does not organise the product development process in a linear stage-gate manner. In particular the formulation of the product requirements does not predate the generation of representations of solution suggestions. In solution-focused thinking representations of tentative solution suggestions are used as a means to engage in a reflective conversation with the context that is designed for. This explorative process facilitates a co-development of understanding the requirements a context poses to a product, and how products can be designed to respond to these requirements (Dorst & Cross 2001). The more that a problem-focused logic dominates in a product development process, the more likely it is that the products represent only incremental changes to the status quo. By contrast, the solution-focused element of Design Thinking facilitates a learning process about new products and their implications, which allows achievement of a higher degree of novelty.

1.1.2. A misalignment of recommendations for applying the ecodesign idea in a commercial context and industrial design practice

Both of these qualities of industrial design practice, namely

- the capacity to draw on the solution-focused element of Design Thinking to explore the reactions of the context that is designed for to more novel products, and
- the capacity to manipulate the meanings consumers attach to products

are acknowledged only to a very limited degree by the literature that discusses the ecodesign idea in the context of commercial product development. These limitations even apply to the how-to manual by Bhamra & Lofthouse (2007) that specifically addresses industrial designers.

Concrete recommendations of available how-to manuals for establishing requirements in a product development process have an underlying problem-focused logic. In other words, these requirements are formulated by research into the status quo, prior to actively engaging with the development of solution suggestions. Techniques such as brainstorming (which can help to generate solution suggestions) and methods to represent these solution suggestions (such as mood-boards and sketches) are only used to develop concepts in compliance with these previously set requirements.

The available guidance for applying the ecodesign idea in a commercial environment predominantly focuses on influencing technical aspects when converting ecological considerations into product designs. That the design of a product can also have influence on the social context in which it is positioned does not receive much attention. The only point that is sometimes highlighted by authors such as Bhamra & Lofthouse (2007) is that the design of a product can influence consumer behaviour in order to achieve ecological benefits. Examples range from designing products that provide information to help consumers behave in a more eco-friendly fashion, to designing products so that such behaviour becomes the default mode of use (Bhamra, Lilley & Tang 2011; Bhamra & Lofthouse 2007; Wever, van Kuijk & Boks 2008).

The available literature does not sufficiently explain how design interventions that seek to influence consumer behaviour in order to achieve ecological benefits can be conducted in the context of a commercial product development process. Lockton, Harrison & Stanton (2009, p. 128) note that 'little work has been done' to present existing knowledge about the interrelation between consumer behaviours and products 'in a form which can be applied during the innovation process.' The findings of Lilley (2009) show that the consequences of design interventions that seek to change consumer behaviour are not necessarily foreseeable before they are conducted. For example, it remains unclear whether consumers actually change their behaviour, based on information provided to them. It also cannot be predicted with certainty if consumers perceive products that stimulate or restrict certain behaviour patterns as positive or as negative. Even though Lilley (2009) does not draw this conclusion, the problem-focused logic that underlies the available guidance for applying the ecodesign idea in a commercial environment does not allow these conflicts to be addressed. The possibility of consumers negatively perceiving products that were designed to change their behaviour points to the necessity to mediate the consequences of such design interventions for the meanings consumers attach to products. This not only applies to design interventions that aim at changing consumer behaviour, but also to any design intervention that has consequences that are recognisable for consumers. However, this topic has generally not received much attention in the literature that provides guidance for the application of the ecodesign idea within the context of commercial product development processes.

1.2. Can industrial designers address shortcomings of contemporary eco-innovation?

The previous section has highlighted that literature that makes recommendations for the application of the ecodesign idea in a commercial context fails to connect with industrial design practice. This disconnect covers the potential influence industrial design practice has on the product designs through manipulating the meanings consumers attach to a product, and on the product development process by drawing on the solution-focused element of Design Thinking. This misalignment is also present in most empirical studies that have been published about the application of the ecodesign idea. Little published research has captured information about the extent to which industrial designers draw on these qualities when applying the ecodesign idea. The deepest insights in this regards are provided by Sherwin (2000) in his PhD dissertation *Innovative ecodesign: an exploratory and descriptive study of industrial design practice*. He investigated a pilot project at Electrolux where industrial designers were motivated to integrate ecological considerations into their practice and to develop innovative solutions.

The work of Sherwin (2000) shows that industrial designers can, under certain conditions, develop their own interpretation of the ecodesign idea. They thereby draw on the qualities of their practice that the literature misses during the discussion of the application of the ecodesign idea in the context of commercial product development processes. Sherwin finds that, when converting ecological considerations into product designs, industrial designers not only focus on technological aspects; they also influence the product-consumer interface in order to manipulate consumer-related aspects such as their behaviour and 'the desirability and acceptability of eco-products' (Sherwin 2000, p. 185). He also finds that the application of the ecodesign idea by industrial designers does not necessarily follow a problem-focused logic. Rather, the application is explorative in nature, drawing on the solution-focused element of Design Thinking. This allows them to achieve higher degrees of novelty than what can be expected from a solely problem-focused approach. These findings show that industrial design practice can address shortcomings of contemporary commercial eco-innovations.

Contemporary commercial eco-innovation most commonly achieves ecological impact reductions through incremental, technical improvements (Banu, Paraschiv & Dorobantu 2012;

Hellström 2007). While technical improvements are a crucial element of designing products with a lower ecological impact, they alone are not sufficient. The negative ecological impact associated with consumer products is not only rooted within the applied technologies but also stems from the interrelationship of the product with individual consumers and the wider societal context. Not only the way how consumers behave in relation to a product can increase or decrease its associated ecological impact. Also, which products consumers perceive as enrichments to their life determines the ecological impact of society as it influences the consumption patterns (Fry 2009; Vezzoli & Manzini 2008). To achieve sufficient impact reduction to address the ecological crisis, it is necessary to influence both the technical aspects of products and the interrelationship between products and their social context (Vezzoli & Manzini 2008). Also, the merely incremental changes of contemporary commercial eco-innovations only have limited potential to contribute to a reduction of the negative ecological impact of society.

While an application of the ecodesign idea by industrial designers may address shortcomings of contemporary eco-innovations, this potential does not appear to unfold in the majority of real-world product development processes. The context in which Sherwin (2000) made his observations differed from the situation in which industrial design practice commonly takes place. The industrial designers were externally motivated, supplied with ecological information and did not experience pressures of a commercial product development process such as time and budget constraints. De Leeuw (2006, p. 9) finds that, in the context of commercial product development processes, the application of the ecodesign idea 'never really managed to escape the purely technical engineering spheres'. Why this is the case and in particular what industrial designers can do about this issue remains poorly understood.

1.2.1. Empirical studies into the application of the ecodesign idea do not focus on industrial design practice

Research that seeks to understand success factors for the real-world application of the ecodesign idea mainly focuses on aspects surrounding and potentially influencing industrial design practice. One area that received much attention is when and how to best provide ecological information in the product development process to enable the stakeholders—including industrial designers—to make appropriate design decisions (see for example: Collado-Ruiz & Ostad-Ahmad-Ghorabi 2010; Lofthouse 2006). In order to provide this information and / or allow industrial designers to acquire this information themselves, a vast number of tools have been developed. There is debate as to whether these available tools are designed well enough and provide appropriate information to support the application of the ecodesign idea in a commercial product development process. Researchers such as Le Pochat, Bertoluci & Froelich (2007) still see them as insufficient. Boks (2006) opposes this view and proposes that the key barriers for the application of the ecodesign idea in commercial product development processes lie elsewhere.

Boks (2006) and other researchers such as Johansson (2002) focus on identifying which aspects need to align within a company to integrate the ecodesign idea into an innovation process. For example, these endeavours showed that, whilst access to ecological information is important, the application of the ecodesign idea in a product development process first and foremost depends on a company's motivation to address ecological issues. In other words, ecological considerations need to be integrated in a product development process in order to allow for them to be converted into product designs. However, it remains poorly understood how individual stakeholders such as industrial designers, engineers or marketing professionals can support these processes. This is problematic because as much as product development is a multi-disciplinary process that requires the collaboration of different stakeholders, it is also dependent on the specific contribution of individual professions.

1.3. Aim and scope of this thesis

The aim of this thesis is to identify pathways for industrial designers to better utilise the influence of their practice to design consumer products with a low(er) ecological impact. Accordingly, the overarching research question is:

> *Where should industrial designers direct their efforts to improve the integration of ecological considerations in the product development process and to strengthen their capacity to convert them into product designs?*

As the integration of the ecodesign idea into industrial design practice is currently insufficiently explored—theoretically as well as empirically—further preliminary research is required before this overarching question can be addressed directly. This resulted in further research questions for the empirical enquiry conducted for this thesis. They are introduced in detail in chapter 4 and are listed below to provide a preview for the reader.

> *Research question 1: Is there empirical evidence for the suggested expanded notion of ecodesign in commercial industrial design practice?*
>
> *Research question 1a: How do industrial designers convert ecological considerations into product designs?*
>
> *Research question 1b: What influence does industrial design practice have to identify goals and drivers for ecodesign processes?*
>
> *Research question 1c: How far do industrial designers apply life cycle thinking (LCT) to identify the most relevant ecological impacts and to inform their decisions for or against ecodesign interventions?*

After answering the research questions 1a–1c the overarching research question of this thesis can is addressed by asking two further research questions.

Research question 2a: What limits the ecodesign practice of industrial designers?

Research question 2b: How can industrial designers progress their ecodesign practice?

The remainder of this section clarifies the scope of this thesis.

1.3.1. The commercial consumer product development process as research context

Industrial designers work for various industries such as machinery, medical equipment and others. However, the most common and also most frequently discussed case in the literature is industrial designers working for the consumer products sector (see for example: De Mozota 2003; Godau 2003; Utterback et al. 2007). This is also the context in which the influence of their practice is best understood. Thus, this context is also the one in which this research is positioned. Consequently, the term *product* in this document always refers to consumer products if not specified otherwise.

Industrial designers work for commercially motivated client companies, hereafter referred to as the *client* (Utterback et al. 2007). The term *client* generally refers to an entity that is seeking the services of industrial designers and is willing to provide them a financial reward for supplying these. In this context they contribute to the development of products that meet the needs of consumers. This context is the reality for the majority of trained industrial designers, a circumstance that this thesis assumes will also apply in the near future. Improving the knowledge about how industrial design practice can contribute to develop low-impact products now—within the current context—is important. Consequently, the enquiry for this thesis was focused on the role for industrial design practice within its current context, rather than speculating about possible future contexts of design practice.

The focus of this thesis on the current context of industrial design practice should not imply that this thesis discards the possibilities that design practice may, in another context, have greater potential to address issues such as incorporating ecological considerations. As highlighted earlier, a number of authors see the current context for industrial design practice as inherently problematic (see for example: Chick & Micklethwaite 2011; Fuad-Luke 2009). Their main concern is that it prioritises the personal needs of individual consumers and the economic goals of the client and the industrial designers over ecological, economic and social goals that are of more global concern. They thus propose that design practice should be taken out of this context and suggest a new context where designers directly account for the needs of society as a whole[2]. Such a new context certainly is a promising pathway to consider issues such as the ecological impact of a product that may otherwise be marginalised. To better understand the tensions and potential overlaps of such a new context as proposed by authors such as Fuad-Luke (2009) and Morelli (2007) with the context for industrial design practice, this thesis positions them relative to each other.

1.3.2. A focus on industrial design practice

This thesis focuses on the influence of industrial design practice in the context of a commercial product development process. This brings along the necessity to take the interrelations of industrial design practice within this context into account. However, this thesis does not seek to develop an exhaustive understanding of all factors that determine this context and their individual dynamics. Thus, boundary factors within the context for industrial design practice, such as trade relationships of the clients, are only accounted for to the extent that they impact on industrial design practice and can be influenced through industrial design practice. This also excludes addressing how factors that impact on industrial design practice but are beyond its influence could be changed to improve the integration of ecological considerations into the product development process.

1.3.3. A pragmatic instead of a normative starting point

The concepts that share the ecodesign idea are developed from a normative starting point. The understanding of the causes of the negative ecological impacts associated with products is taken as a reference point to deduce instructions for design practice. An understanding of the ecological issues associated with products is essential to justify investing in the idea of incorporating ecological considerations into design practice. It furthermore clarifies important points that need to be addressed to successfully design products with a low(er) ecological impact. However, the focus of the concepts that share the ecodesign idea on how design practice *should* be conducted instead of how it *is* conducted has led to a deficit in fully understanding the possible contribution of industrial design practice.

In response, this thesis chooses a pragmatic starting point. It accepts the current situation as given and seeks to develop a pathway to facilitate the application of the ecodesign idea by using the means that are available. To develop a clear understanding of these means, this thesis first describes the influence of industrial design practice on the products that are developed and on the product development process as context for this practice.

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[2] Multiple issues that are possibly associated to such a new context for design practice remain unaddressed. In particular, it remains unclear whether executing design practice can help those who do so to meet their personal economic needs.

1.3.4. The product development process as a boundary for this investigation

Because industrial design practice is situated within the product development process, this is also where the boundary of this thesis is drawn. This thesis focuses on the influence of industrial design practice to integrate ecological considerations into a commercial product development process and to convert them into product designs. This thesis does not account for the outcomes of this process beyond investigating the extent to which they embed the intentions of the industrial designers to achieve a low-impact solution. This implies that this thesis does not conduct detailed assessments that seek to reveal how far the individual results of product development processes contribute to the overarching goal of reducing the ecological impact of society.

1.3.5. An ecological agenda ahead of a sustainable agenda

Even though the aim of designing low-impact solutions is a means to address the overarching goal of sustainable development this research explicitly seeks to understand the role of industrial design practice in addressing an ecological agenda ahead of a sustainable agenda. The context for industrial design practice of a commercial product development process already implies an explicit economic and social agenda, which can conflict with the economic and social agenda of sustainability. Even though they do not necessarily fully oppose each other, incorporating only ecological considerations into commercial activities is less complex. Also, once understood, it can serve further-reaching goals like addressing the economic and social agenda of sustainability (Andersen 2008).

1.4. Structure of the thesis

This thesis is structured in three main parts plus this introduction and a final concluding discussion. Part A (consisting of Chapter 2 and Chapter 3) establishes the necessary background information. Part B (consisting of Chapter 4 and Chapter 5) describes the approach to research. The two chapters cover the research design and the theoretical framework that was used to structure the empirical enquiry. Part C (consisting of chapters 6, 7, 8 and 9) covers the report of the empirical findings and their discussion. This structure is visualised in Figure 1.

Conducting research into industrial design practice, like any research into a real-world situation, requires the use of concepts and models to describe this situation. In the context of product development, many terms are not used coherently throughout the literature. For example, *product innovation, product development* and *product design* are often used interchangeably (Marxt & Hacklin 2005)[3]. Where not discussed in the chapters, this thesis uses break-out boxes to highlight such inconsistencies where they are relevant for this thesis and explains which understanding of a term is used in this document. Break-out boxes are also used to acknowledge discussions in the literature that border the focus of this research.

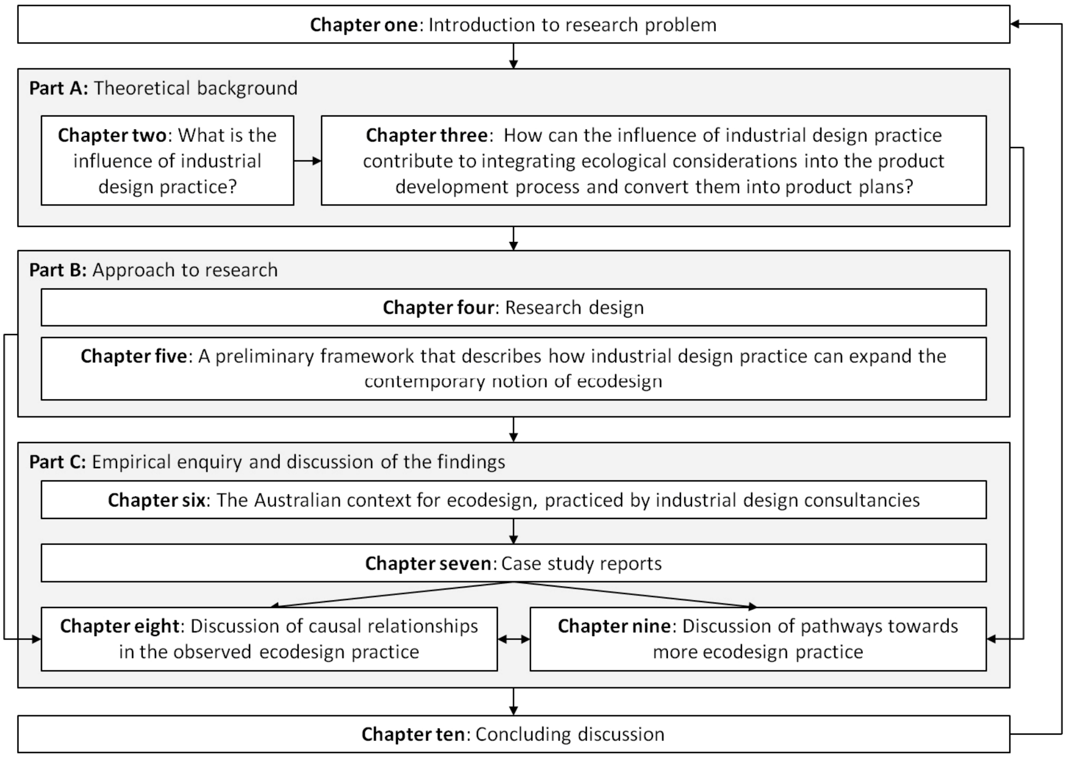

Figure 1: Logical structure of the thesis
(Source: created for this research)

The available literature insufficiently explains the role of industrial designers in integrating ecological considerations into a commercial product development process and how they can convert them into product designs. Thus, to answer the overarching research question:

> *Where should industrial designers direct their efforts to improve the integration of ecological considerations in the product development process and to strengthen their capacity to convert them into product designs?*

it is necessary to first develop a general understanding of the influence industrial design practice can have on the product development process and on product designs. This issue is addressed in Chapter 2 by reviewing literature from the areas of industrial design, design research, affordance, product semantics, design management and innovation management. Chapter 2 specifically draws out the particular activities that enable industrial designers to exert this influence and describes the underlying reasoning that structures these activities.

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[3] How the terms product innovation, product development and product design are understood for this thesis is explained in break-out box 1 in Chapter 2.

Chapter 3 reviews contemporary literature that discusses the incorporation of ecological considerations into design practice. It uses the conclusions from Chapter 2 as a reference point to evaluate the relevance of this theory for industrial design practice. The reason for this chapter is twofold. Firstly, it highlights which of the aspects—which contemporary concepts sharing the ecodesign idea see as important—are also relevant for industrial design practice. This forms the basis of the framework that is developed in Chapter 5 to guide the empirical enquiry into the practice of industrial designers. Secondly, it highlights the gap in contemporary literature in understanding the role of industrial designers for integrating ecological considerations in the product development process. This provides a more detailed justification for the importance of this thesis and informed the research design that is described in Chapter 4.

Chapter 4 develops research questions and the design for an empirical enquiry that this thesis applied to address the research gap outlined in Chapter 3. Industrial design practice is inherently linked to the commercial product development process. Thus, to understand how far industrial designers currently use their influence to integrate ecological considerations into this context and convert them into product designs, it is necessary to investigate their practice within this context. Chapter 4 explains why and how multiple-case study research was applied to investigate the experience of Australian industrial design consultants and their clients in past projects that incorporated ecological considerations.

In order to guide and structure the empirical enquiry, Chapter 5 presents a preliminary theoretical framework that describes the capacity of industrial design practice to integrate ecological considerations into the product development process and convert them into product designs. This framework accounts for the capacities of industrial design practice that contemporary concepts discussing the application of the ecodesign idea in the context of a commercial product development process mostly miss, namely:

- the capacity to draw on the solution-focused element of Design Thinking to explore the reactions of the context that is designed for to more novel products, and
- the capacity to manipulate the meanings consumers attach to products.

Because the empirical part of this thesis investigated Australian industrial design consultancies, Chapter 6 provides background information about the context of industrial design consulting in Australia. Chapter 6 also discusses the dissemination of the ecodesign idea to the Australian industrial design community. Because little information has been published that allows development of a nuanced understanding of the application of the ecodesign idea amongst industrial design consultancies, this chapter also draws on some preliminary empirical investigations. These include a website content analysis and interviews with ecodesign experts.

Chapter 7 reports the findings of the empirical enquiry. It covers the experience of four Australian industrial design consultancies and their clients in specific projects, as well as the general experience of the industrial design consultancies with incorporating ecological issues into their practice. It also provides a preliminary interpretation of the findings by connecting them back to the research questions of Chapter 4 and to the preliminary framework of Chapter 5.

The discussion in Chapter 8 focuses on the aspects where the collected data did not deliver straightforward answers to the research questions posed in Chapter 4. It develops explanations for potential causal relationships within the observed design practice to clarify these ambiguities. These elaborations are then used to improve the preliminary theoretical framework. Chapter 8 concludes by presenting a refined description of the preliminary framework that was developed in Chapter 5. This shows a pathway for how the influence of industrial design practice can be used to integrate ecological considerations into the product development process and to convert them into product designs. This pathway draws on the two qualities of industrial design practice that have been largely missed by concepts that discuss the application of the ecodesign idea in a commercial context in tandem.

Chapter 9 builds on the conclusions of Chapter 8. It contrasts the identified pathway with other suggestions to further the application of the ecodesign idea in the context of a commercial product development process. It furthermore elaborates the factors in the observed industrial design practice that posed difficulties to industrial designers to utilise the pathway that was identified in Chapter 8. These discussions also connect the findings from Chapter 7 and the conclusions from Chapter 8 back to the theoretical foundations of this research in Chapter 2 and Chapter 3.

In a concluding discussion, Chapter 10 develops recommendations for industrial designers in order to answer the overarching research question. It also formulates suggestions for further research.

1.5. Significance of this research

This thesis takes an approach that is different from past approaches that seek to progress the understanding of how to improve the application of the ecodesign idea in the context of commercial product development processes. Traditional approaches to this topic have either taken a strongly normative starting point, illuminated only selected aspects of the practice of industrial designers or investigated factors potentially affecting this practice.

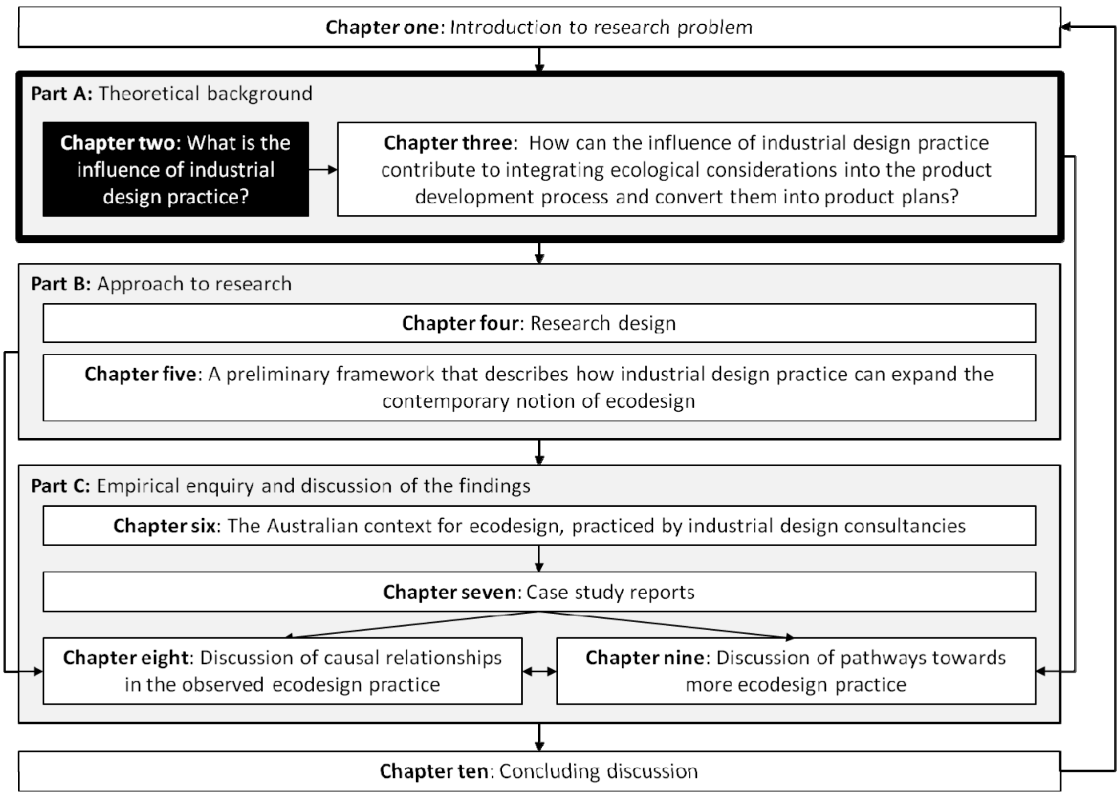
In contrast, this research takes a pragmatic starting point by first establishing the influence that industrial designers have within their current context and exploring how they acquire this influence. By first outlining the opportunities industrial designers have to exert influence, this research restructures the available theory about using design to address an ecological agenda to reflect the possible contribution of industrial design more appropriately. This restructuring of the literature already represents a contribution to knowledge. It shows a new perspective on the distinction between concepts that are classified as *sustainable design* and *ecodesign*. It demonstrates that industrial design practice can take ecodesign beyond how it is commonly understood by addressing aspects that are traditionally understood as sustainable design. Thereby, this thesis develops a framework that clearly articulates the theoretical influence industrial designers can have to integrate ecological considerations into the product development process and to convert them into product designs.

The empirical enquiry also tested the developed framework. This supported the robustness of the initial assumptions that underlie the framework. The empirical data furthermore identified a pathway to enhance the application of the ecodesign idea that is specific to industrial design practice. This pathway draws on both of the qualities of industrial design practice that have been largely missed by concepts that discuss the application of the ecodesign idea in a commercial context. Explicitly articulating this pathway and discussing it in relation to other suggestions to progress the application of the ecodesign idea in the context of commercial product development processes, helps to position industrial design practice within the context of eco-innovation.

This thesis informs in particular:

- **Industrial designers** about where they should direct their efforts to contribute to the integration of ecological considerations into product development processes and to converting them into product designs.
- **Researchers, studying eco-innovation with a focus on industrial design.** The theoretical framework developed by this thesis reflects the potential contribution of industrial design to applying the ecodesign idea more accurately than currently available theory. It thus can provide a valuable foundation for further research into that area.

CHAPTER 2. WHAT IS THE INFLUENCE OF INDUSTRIAL DESIGN PRACTICE?



The goal of this chapter is to articulate the influence of industrial design practice. This is necessary to understand how industrial design practice can support the integration of ecological considerations in the product development process and convert them into product designs. The insights from this activity are used in this thesis as a reference point to critically review the body of literature about the ecodesign idea in Chapter 3.

The relationship between the context of industrial design practice, its underlying structure and the influence it can exert on the goals of a product development process and the product designs are shown in Figure 2.

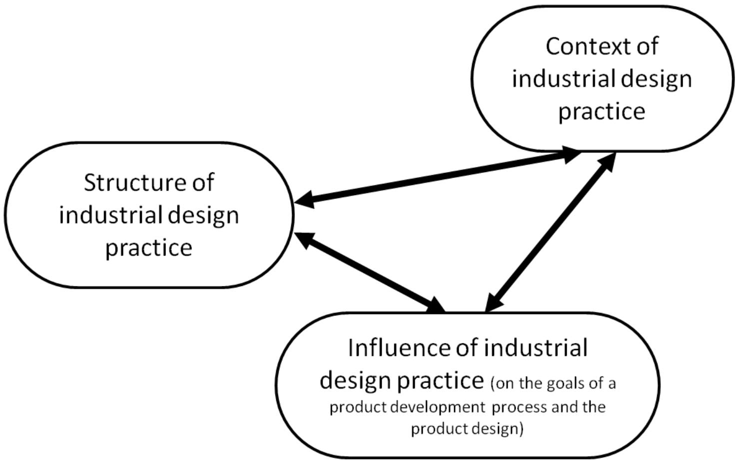


Figure 2: The interrelationship between the influence of industrial design practice, its underlying structure and its context
(Source: created for this research)

The extent to which industrial design practice can influence the goals of a product development process and the product designs depends on how it is structured. This structure again depends on the context industrial design practice is situated in. This context again can be influenced through industrial design practice. Because of the dynamics of this situation, each of the individual factors can be described only in relation to the others.

This chapter is structured in six sections:

- **Section 2.1** describes the general nature of the context of industrial design activity as confronting industrial designers with partially open and underdetermined problems. These kinds of problems are also referred to as *design problems* (Dorst 2003).
- **Section 2.2** introduces the concept of *Design Thinking* as the underlying logic that structures design practice in order to understand and address design problems. Design Thinking is not unique to industrial design practice. Other design professions such as architecture, industrial design, urban planning and engineering design are also

confronted with design problems and draw on Design Thinking to structure their practice. The characteristics of Design Thinking can vary. It comprises problem- and solution-focused elements that gain or lose prominence depending on the degree to which a design problem is open and underdetermined. Understanding variations in the characteristics of Design Thinking is particularly important for this thesis. As highlighted in the introduction, concepts that discuss the application of the ecodesign idea in a commercial product development process prioritise a problem-focused logic. This limits their useful application by industrial design practice, which also draws on the solution-focused element of Design Thinking.

- **Section 2.3** develops a model that illustrates the relationship between the application of the levers of industrial design practice to shape the properties of a product and the value consumers can derive from these properties.
- **Section 2.4** describes how industrial design practice can purposeful exert influence on the product properties
- **Section 2.5** discusses the influence of industrial design practice with respect to the product development process.
- **Section 2.6** summarises the insights this chapter provides regarding the general influence of industrial design practice on the goals of a product development process and the product designs. This serves as a reference point when reviewing contemporary theory about incorporating ecological considerations into design practice in Chapter 3.

2.1. The context of industrial design practice

The traditional commercial context for industrial design practice is that industrial designers offer it as a service to clients who usually seek to manufacture and commercialise the product designs this practice generates (Utterback et al. 2007). There are two dominant forms that the relationship between industrial designers and their clients can take. Industrial designers are either (i) employed in-house or (ii) work as consultants that are commissioned by the client (Best 2010). Relationship-specific differences for the industrial designers exist. For example, in-house industrial designers usually focus exclusively on designing the products of one client. This may allow them to develop a greater depth in understanding the specific products of that client than industrial design consultants who work for a variety of clients. Also the industrial designers may have different political influence on the client if they are employees or hired consultants.

Despite variances in the influence industrial designers have as individuals depending on their relationship with their clients, the background chapters of this thesis (Chapter 2 and Chapter 3) do not distinguish between the two settings. This is because the background chapters seek to build up an understanding of the influence of *industrial design practice* and not of the relationship-specific influence of the individual industrial designers in regards to the application of the ecodesign idea. Industrial designers in both relationships draw on industrial design practice. Consequently, for the background chapters the term *client* refers to both: (i) a client who directly employs industrial designers and pays them a monthly salary for their services, and (ii) a client who purchases these services from an industrial design consultancy. Also, the term *industrial designers* in the background chapters refers to professionals executing industrial design practice in general, and does not distinguish as to whether they work in in-house design departments or in industrial design consultancies.

A distinction is made between in-house industrial designers and industrial design consultancies (IDCs) in the later research design and the empirical part of this thesis. The empirical part of this thesis collected data from Australian IDCs and their clients. The implications of this research environment are discussed in Chapter 5 and Chapter 6.

BOX 1
On terminology: Product innovation process, product development process and design process

The terms ***product innovation process, product development process*** and ***design process*** are often used interchangeably, mostly without making the understanding of what is explicitly described by the individual terminologies (Marxt & Hacklin 2005). For this research, these terminologies are understood and used as follows:

The product innovation process comprises the full product development process that delivers a plan, describing the properties of a product, the realisation of this plan and the commercialisation of the outcome of this activity (Hauser, Tellis & Griffin 2006; Verloop & Wissema 2004; Von Stamm 2008).

The product development process is understood for this thesis as a sub-set of the product innovation process, comprising the set of activities that supply the plan, describing the properties of a product. This plan can take various forms such as technical drawings, a prototype, renderings and written instructions. Also, the product development process has two further outcomes: the strategy and the design brief. (continued on next page)

The strategy comprises the specific drivers for a company to engage in the process of designing a product, what goals the company seeks to achieve and a high level direction of how this should be done. The design brief describes concrete ideas and goals for the product itself, including the surrounding conditions of its realisation.

These three outcomes: (i) the strategy (ii) the design brief, (iii) the design or plan of the product properties and their interrelationship are discussed in Section 2.4. While this understanding of the product development process is shared by some authors like Melgin (1991), others such as Roozenburg & Eekels (1995) see it as furthermore comprising the development of manufacturing facilities and the development of a marketing plan. As explained in the remainder of this section, industrial designers need to consider these processes in their work but are not actively involved in these sets of activities. Thus, it is more appropriate to see them in the context of this thesis as belonging to the innovation process rather than to the product development process.

The design process not only refers to designing products but to describe the process of design practice in general (see for example: Cross 2011). This is also how this term is used in this thesis in Section 2.2, where it describes industrial design as one design profession which shares Design Thinking as a form of reasoning with the other design professions.

2.1.1. The goals of industrial design practice

The goal of industrial design practice is to create value (Shove, Watson & Ingram 2005). To achieve this goal, industrial design practice develops a description or plan of the properties of a product. This plan or description is also referred to as the *design* of the product (Ralph & Wand 2009) and always has some degree of novelty. As Krippendorff & Butter (2008, p. 17) express it: ‘By definition, designers propose something new that would not come about naturally.’ These product designs need to balance feasibility, viability and desirability (Brown 2009).

Exploring the goal of creating value in the specific context of a commercial product development process reveals that industrial design practice seeks to generate value for only a bounded group of stakeholders. This group comprises the industrial designers who supply the industrial design practice, their clients who use this service in a product innovation process and the consumers of the product that is generated in this innovation process. The goal of generating value for these three stakeholders sets an economic and a social agenda for industrial design practice. It also imposes feasibility constraints for the product designs that can be generated by this practice.

The economic agenda of industrial design practice

The economic agenda of industrial design practice requires the creation of monetary revenue for the industrial designers themselves and their client[4] (Granet 2011). The industrial designers seek to gain a financial return for their activity from the client. For the client to be willing to provide this financial return, they again need to expect to derive financial profit from using the service of industrial design practice (De Mozota 2006). This latter requirement drives the social agenda of industrial design practice which is to satisfy the needs of individual consumers. It also imposes feasibility constraints industrial designers need to consider.

The social agenda of industrial design practice

Clients can only expect to derive financial profit from using the service of industrial design practice if this practice prioritises satisfying the perceived needs of the individual consumers (the use of the term 'consumer' in this thesis is discussed in Box 2). This is because clients derive their revenue from selling the implemented product designs to consumers. This is only possible when consumers see value for themselves in the products (Drucker 2001). This value consumers seek is not financial in nature, but a fulfilment of their perceived personal needs (Boztepe 2007). So, the social agenda of industrial design practice is designing products to meet the perceived needs of individual consumers.

Perceived consumer needs or demands that are addressed by products can be allocated to two categories: those that can be satisfied by a utilitarian function and those that can be satisfied by an emotional function (Godau 2003). An example for a utilitarian function of a product is the capacity of a cup to hold a certain volume of hot liquid. While utilitarian functions are easy to identify and can be quantified, emotional functions are qualitative and subjective. An example for an emotional function is when a product allows consumers to have a joyful experience while using it (Green & Jordan 2002). Another example is when a product becomes a means for self-representation for consumers. Even though seeded within the product itself its emotional functionality is also shaped by subjective and context-specific factors such as the personal background of the consumers, how they experience the product and the wider social

[4] As explained in the beginning of this chapter, 'client' refers to a company that is seeking the services of industrial designers and is willing to provide them a financial reward for supplying these. The two common relationships between clients and industrial designers are that the latter either work in an industrial design consultancy commissioned by the client, or they are employed in in-house design departments.

environment within which this experience is embedded (Godau 2003). In other words, the emotional functions that consumers derive from a product are facilitated by their perception of a product within their specific context.

How industrial design practice seeks to contribute to the development of products that have utilitarian and emotional functionality consumers perceive as valuable is discussed in Section 2.3.

BOX 2
On terminology: Consumer or User?

Two different terms are applied to describe the individuals that purchase the product in order to derive emotional and utilitarian functions from it: *consumer* and *user*.

These two terms are often used interchangeably and most authors do not argue their decision for one or the other. Only some authors such as Krippendorff (2005) make their understanding of the applied terms explicit. He claims that all stakeholders along the life cycle of a product, spanning from its development to its final disposal *use* the product for their purposes and are thus appropriately classified as users.

To avoid confusion with those more inclusive understandings of the term *user*, this thesis uses the term *consumer*.

The feasibility constraints that industrial design practice needs to consider

The feasibility constraints arise from the requirement that the client needs to be able to manufacture, distribute and commercialise a product design in order to derive financial profit from it. The entire process of developing a product design and then realising and commercialising it is also referred to as the *product innovation process* (Hauser, Tellis & Griffin 2006; Verloop & Wissema 2004; Von Stamm 2008). The product innovation process depends on the support of a broad network of stakeholders (Krippendorff 2005). Examples are engineers who develop the tooling and a manufacturing plan, manufacturers who implement this plan, marketers who communicate the product to consumers, distributors who transport the products from the manufacturing facility to the retailers and finally retailers who sell the product. The cost to the client to employ the services of all the stakeholders whose contribution is required during the product innovation process (including industrial designers) must not exceed the monetary return the client can achieve by selling the product to consumers.

This context poses two sets of feasibility constraints on industrial design practice. Firstly, there is a limit to which it is financially possible for clients to invest in the services of industrial designers. Secondly, the way industrial designers plan the properties of a product has implications for the effort that is required from the other stakeholders of the innovation process. This again determines the cost for the client to use the services of these stakeholders. Thus, to make sure their product designs are feasible, industrial designers need to understand and mediate the implications of their design decisions for all the stakeholders that need to contribute to the innovation process.

Industrial design practice plays an important role in mediating the requirements the various stakeholders set for a product design. In addition, it can play an important role in developing an understanding of these factors. The innovation process and the role industrial designers can play in it are described in more detail under Section 2.3 and Section 2.4.

2.1.2. The problem situation of industrial design

Section 2.1.1 outlined that industrial design practice has to incorporate the perspectives of a range of different stakeholders to create value for the industrial designers, their clients and the consumers of the products that are developed. Industrial design practice develops a product design with some degree of novelty. By doing so it determines the effort for realising and commercialising the product and the personal value the product can offer to consumers. These two factors are interrelated via the client of the industrial designers. They also influence the resources that the client is willing to invest into the service of the industrial designers. The client needs to expect that consumers will see sufficient personal value in the product that is developed, in order for it to be purchased at a price that allows the client to reclaim both the investments for realising and commercialising the product and for using the services of the industrial designers. This problem situation for industrial design practice is visualised in Figure 3.

The requirements arising from the perspective of each stakeholder in Figure 3 differ and indeed can contradict each other. For example, consumers may see higher value in products that involve more effort in their realisation, whereas the client and the stakeholders involved in realising the product may oppose investing this effort. Similarly, the effort that the industrial designers invest in developing a plan of the properties can be expected to be positively related to finding a solution that keeps the effort for realising and commercialising the product low, while providing a solution that consumers see as valuable. At the same time, the client is interested to minimise the effort invested by the industrial designers, in order to keep the cost down for their service.

While the stakeholders shown in Figure 3 exert direct influence in the product development process, the network of stakeholders is positioned within the wider socio-technical context that again influences the perspectives of the individual stakeholders. Examples of such influences are potential government pressure on the client to avoid certain practices in realising a product that are identified as too harmful for the environment, new technologies becoming available and changing perceptions amongst consumers about what they see as valuable.

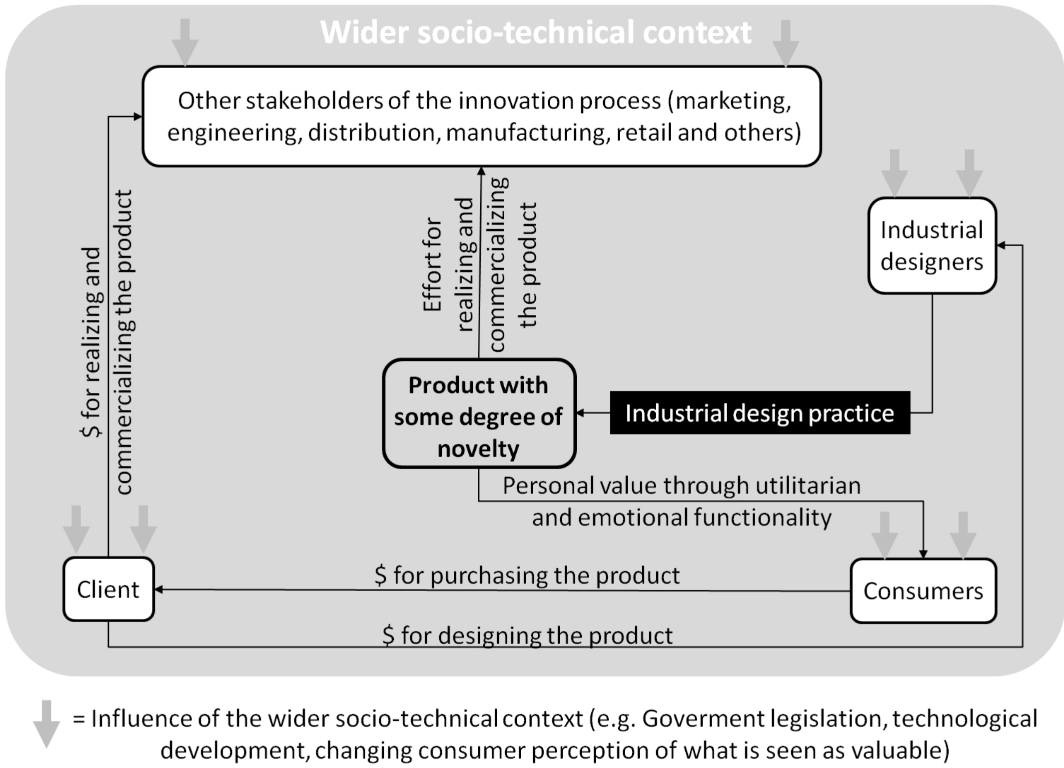


Figure 3: The problem situation of industrial design practice
(Source: created for this research)

Industrial design practice can never arrive at one single ideal solution (Simon 1969; Visser 2006). Because the product design always has some degree of novelty, there is always some uncertainty about how well it meets the economic and social agenda of industrial design practice while it is being designed. How far a product design complies with this agenda can only be fully evaluated once it is realised and commercialised (Coyne 2005). However, as soon as the design is realised and commercialised, there is no capacity to change it. It thus remains uncertain if a product design that would have required less investment to realise and commercialise would have been perceived by consumers as equally valuable and generated the same financial revenue for the client. Also, there is always the possibility that a higher investment in design practuce could have revealed a solution that better balances feasibility, viability and desirability.

Such complex situations are also referred to as *open problem situations* or *wicked problems* (Buchanan 1992; Coyne 2005; Rittel & Webber 1973). Thereby, the term *problem* should not be confused with 'deficiency' or 'difficulty' (Visser 2006, p. 15). A problem merely refers to a situation to which a solution is unknown but identifying the unknown is of value for the affected stakeholders (Jonassen 2000). The term *wicked* describes the multi-faceted nature of the problem, resulting from the different perspectives of the involved stakeholders and the openness of the problem situation. The openness and uncertainty of wicked problems entails that there is not one single right solution to them (Coyne 2005). Possible solutions can only suffice—meeting the requirements of all stakeholders to a satisfying degree (Visser 2006).

Dorst (2003) explains that the problem situations industrial designers work on are not completely open. Instead of calling them 'wicked', he prefers the term *design problems*, a term that is also adopted for this thesis. He points out that they have some degree of '*a priori* structure' (Dorst 2003, p. 140) that determines them. An example for such a determining factor is the laws of physics. As discussed in the next section, the notion of an *a priori* structure in the design problem also plays an important role in the way design practice is structured.

2.2. Design Thinking to understand and address design problems

Every design profession, be it engineering, architecture, urban planning or industrial design seeks to resolve design problems. Design problems are inherent to any real-world situation that deals with 'preliminary study and planning' to change that situation in some way (Perks, Cooper & Jones 2005, p. 112). Even though the various design professions are different, 'there is a level at which design is fundamentally one and the same activity across fields and domains' (Goldschmidt & Porter 2004, p. xii). This mutual base is a shared way of reasoning, which design professionals apply to structure their practice in addressing design problems. This way of reasoning is also referred to as *Design Thinking* (Buchanan 1992; Cross 2011). In this regard, industrial design practice is no different to the practice of other design professions.

The key factor that distinguishes the individual design professions is the focus that they have when applying Design Thinking and their Design Craft that allows them to take this focus (Chick & Micklethwaite 2011). This focus for industrial design practice, for example, has been explained in Section 2.1. It is to develop plans for products that offer consumers emotional and utilitarian functionality they perceive as valuable enough to purchase them for a price that allows the clients of the industrial design practice to reclaim their investments in developing and realising the products. *Design Craft* refers to a particular knowledge and skill-set that design professionals hold which is specific to the things they design.

An example for the Design Craft of industrial designers is their proficiency in model-making they can apply to the products they design. For a detailed explanation of Design Craft, it is useful to first discuss the characteristics of Design Thinking. Thus, after describing the concept of Design Thinking in Sub-sections 2.2.1 and 2.2.2, Sub-section 2.2.3 gives a more comprehensive introduction of the Design Craft of industrial design practice. The combination of Design Thinking and Design Craft to describe a design profession is illustrated in Figure 4. As the skills in which individual designers are proficient vary slightly, the boundaries around the design professions are blurry (Lawson & Dorst 2009).

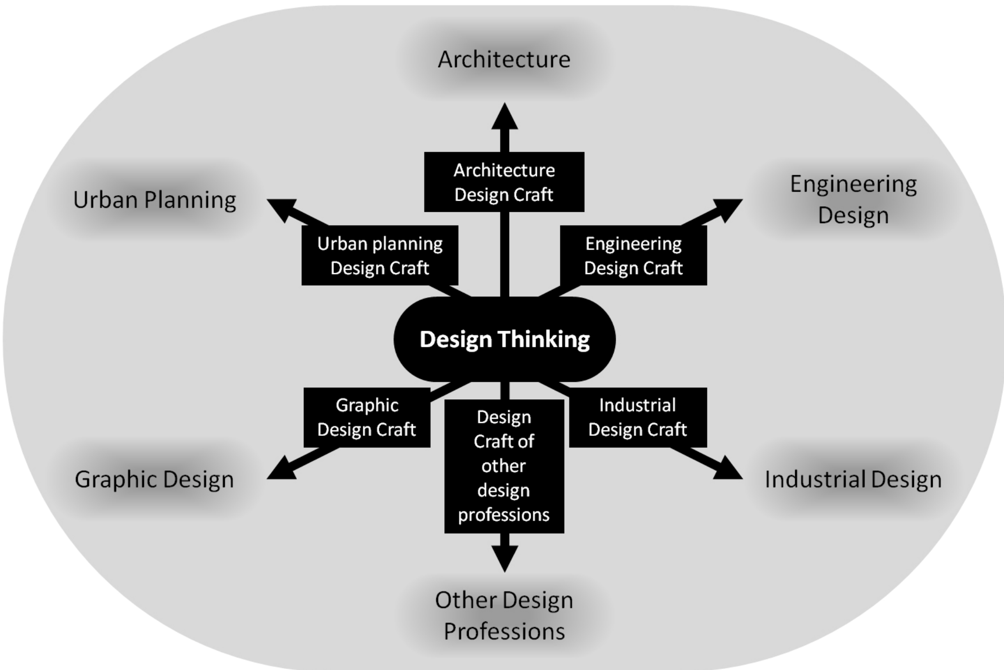


Figure 4: The combination of Design Thinking and Design Craft to conceptualise different design professions (the location of individual design professions adjunct to each other in Figure 4 does not imply a closer relation in their Design Craft) (Source: created for this research)

2.2.1. The two paradigms that govern Design Thinking

Design Thinking has become a popular and widely-used term, yet it remains inconsistently defined. Many authors who use the term Design Thinking do not invest the effort to discuss the concept in detail, but rather describe its application to a specific design problem or a specific group of design problems (see for example: Ambrose & Harris 2009; Brown 2009; Young 2010). Linking the explanation of Design Thinking to a specific design problem or even group of design problems causes complications for developing a comprehensive appraisal of it.

This is because the form Design Thinking takes varies significantly, depending on the degree of *a priori* structure that is present in the design problem. In other words, authors who deal with Design Thinking only in relation to a specific design problem or a specific group of design problems merely cover a specific form of it.

The ambiguity around the concept is further reinforced when authors adopt descriptions of Design Thinking in forms that are not necessarily appropriate to the context in which they use it. This can for example be observed in the work of Ambrose & Harris (2009). They conceptualise Design Thinking in a rigorously linear form. As discussed in Sub-section 2.2.2, this form of Design Thinking can be expected to be specifically prominent in cases where the design problem is determined to a high degree—when a high degree of *a priori* structure is present. An example for this may be an engineering design task to optimise the performance of a mechanical part. However, in their book Ambrose & Harris (2009) discuss graphic design, a field where design problems can be expected to have a high degree of openness.

Only those authors who specifically research into Design Thinking fully articulate their view of the concept and discuss its implications. The understanding of Design Thinking for this thesis as described below is in particular influenced by the writings of Cross, Dorst, Lawson, Schön and Visser.

Two dominant paradigms that informed the concept of Design Thinking are contrasted by Visser (2006) and Dorst (2003): the rational problem-solving paradigm which these authors attribute initially to Simon (1969) and the reflective practice paradigm, coined by Schön (1983). The three key differences between these two paradigms that are important for this research comprise:

- How the two paradigms view the problems that designers work on
- How they suggest that an understanding and appraisal of the design problem and possible solutions is developed
- How the design process is organised

The rational problem-solving paradigm

The rational problem-solving paradigm assumes that it is possible to identify all the relevant aspects of a design problem upfront. It furthermore assumes that it is possible to break the problem down into hierarchically structured sub-problems that can be solved individually. Dorst (2003, p. 138) explains that this paradigm sees design as ‘a rational search process’. Even though a design problem may first be lacking a visible structure, it can be structured by defining clear goals in the beginning of the design process and progressively narrowing down the solution space.

The rational problem-solving paradigm organises the design process in a linear, directional manner as visualised in Figure 5. The logic that the rational problem-solving paradigm applies to design problems is also referred to as *problem-focused* (Cross 2011; Lawson & Dorst 2009). This term expresses that an understanding of the problem stands at the beginning of the design process and governs all consecutive steps. Through the problem structuring and analysis, the requirements for the design are identified. The synthesis seeks to meet these requirements by developing a range of possible solutions. These are then evaluated against the initial requirements to select a preferred design solution.

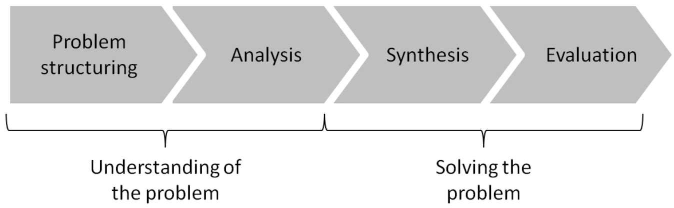


Figure 5: The proposed structure of the design process according to the rational problem-solving paradigm (Source: created for this research)

In its initial development, the rational problem-solving paradigm was not grounded in research into real-world activity of professional designers (Visser 2006). The intention was to improve the management, effectiveness and efficiency of design processes and to facilitate transferring knowledge from designers to other stakeholders within a design process (Buijs 2003; Roozenburg & Cross 1991). The suggestion to structure the design process in two sequential steps of first understanding and then solving a problem was informed by the experience scholars had with the established way of addressing scientific problems (Roozenburg & Cross 1991). In other words, the rational problem-solving paradigm sees design as a scientific process.

The models of the design process that are based on the rational problem-solving paradigm are also referred to as *prescriptive* models, due to their lack of grounding in empirical observations and the intention to develop ideal or better ways of designing (Roozenburg & Cross 1991; Visser 2006). A number of models of the design process and of product innovation processes have a strong prescriptive character (for an extensive collection of models of the design process see for example: Dubberly 2004). In particular, conceptualisations that propose breaking it down into individual, clearly distinguished sets of activities—so-called stages that are separated by gates—are strongly informed by the rational problem-solving paradigm (see for example: Kagioglou et al. 1998).

The reflective practice paradigm

The reflective practice paradigm does not see design problems as having an *a priori* structure that can be identified in an analytical search process. It understands the problem situation as dynamic and socially constructed. The activity of how the designers try to solve the problem also potentially changes the problem itself. This makes the designers and their work an integral part of not only understanding and resolving, but also shaping the problem situation.

The reflective practice paradigm was informed by real-world investigations of the activities of design professionals that were conducted to challenge the rational problem-solving paradigm (Visser 2006). The research showed that designers develop an understanding and appraisal of the design problem through a 'reflective conversation' with the situation they design for (Schön 1983). Their work starts out from an initial, provisional problem frame—Darke (1979) refers to 'primary generators'—that they use to develop their interpretations of suggestions for solutions. These suggestions are not solutions in the classical sense. Besides being possible pathways forward, they are also a means to explore the actual problem. Designers make these suggestions strategically to test their anticipation of the reaction of the problem situation. This is why they are also referred to as 'moves' (Cross 2011; Schön 1983). They can be seen as the designers posing the question, 'what if the solution looked like this?' (Lawson & Dorst 2009, p. 36).

The solution proposals are represented by the designers in a way so that the response of the problem situation can be observed. Schön (1983) terms this response as 'back-talk'. Consequently, Design Thinking is inherently dependent on the capacity of designers to develop representations of solution suggestions. This capability is an important element of Design Craft. The specific Design Craft of industrial design is discussed in more detail under Section 2.2.3.

Critically reflecting upon this response allows designers to revise the way they initially framed the problem and to plan the next moves. These iterative explorations are partially guided by the intention of the designers. However, in addition to purposefully exploring different ways of 'framing' the problem (Schön 1983), design practice is also to some degree open to chance, as the response of the problem situation can bring unforseen insights, which Schön (1983) termed 'surprises'. These 'surprises', as well as the learning from the purposefully conducted explorations, are essential in reframing the problem to facilitate a better matching of the understanding of problem and solution.

Within the process described above, the understanding of the problem and of possible solutions co-evolve (Dorst & Cross 2001). As Best (2010, p. 40) puts it: 'design a problem-solving (…) as well as a problem-seeking process.' A conceptualisation for this iterative search for a 'problem-solution pair' (Lawson & Dorst 2009) is proposed in Figure 6.

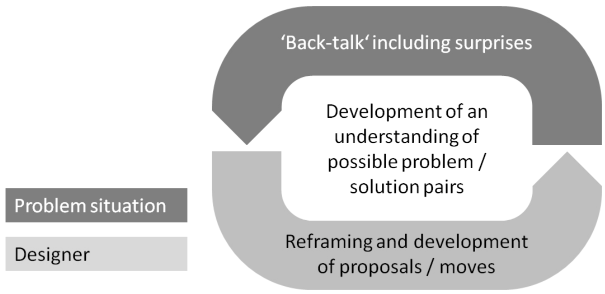


Figure 6: Co-evolution of appraisal and understanding of problem and solution
(note that for the case of industrial design practice the *problem situation* is shown in Figure 3)
(Source: created for this research)

Because this way of organising the design process jumps to formulating suggestions for solutions before having achieved an exhaustive formulation of the problem, the underlying logic is also referred to as 'solution-focused' (Lawson & Dorst 2009, p. 28).

Most models of the design process that have an iterative structure can be assumed to be informed by the reflective practice paradigm. Because they are based on describing empirical evidence of how designers work, they are also referred to as *descriptive* models of the design process (Roozenburg & Cross 1991; Visser 2006). These descriptive models of the design process are much more difficult to conceptualise than the linear ones, which are based on the rational problem-solving paradigm (Visser 2006). They usually only represent elements of the design process instead of conceptualising it from start to finish. This is also true for Figure 6, which focuses only on the development of an understanding of possible problem-solution pairs.

Design Thinking alternates between problem- and solution-focused thinking

In Design Thinking, both problem-focused and solution-focused thinking play a role (Brown 2009; Cross 2011). Designers use both types of thinking throughout the design process to develop an understanding about the problem situation. Problem-focused thinking helps designers to identify and understand *a priori* structure within the problems they work on. Solution-focused thinking allows them to progress in developing an appraisal of the undetermined nature of design problems. This is visualised in Figure 7. The extent to which a design problem is underdetermined is usually positively related to the degree of novelty of the solutions that are suggested. This makes the solution-focused element of Design Thinking particularly important for resolving problem-situations with a high degree of novelty (De Mozota 2003).

Besides allowing designers to develop an understanding and appraisal of the problem situation for which they design, both types of reasoning also play a role in progressing the understanding of satisficing[5] solutions. Alternating between problem-focused and solution-focused thinking is crucial for the capacity of industrial designers to simultaneously develop solutions with novelty and be capable of bringing the design process to an end and produce an outcome. Even though solution-focused thinking helps designers to develop an appraisal and understanding of the problem situation, this way of reasoning alone does not allow them to make the step to resolving the problem situation. At some point of the exploration, the designers need to start moving from reframing the problem and asking ‘what if’ to narrowing down their explorations (Cross 2011). Otherwise, their work will be an endless exploration without a concrete outcome. In order to narrow their work down to a final design, designers need to rely on problem-focused thinking (Cross 2011). This is also described as the *divergent/convergent nature* of a design process (Brown 2009). The alternation between problem and solution-focused thinking to develop an understanding of the problem situation and possible solutions is conceptualised by the bidirectional arrow in Figure 7 that combines the two elements of Design Thinking.

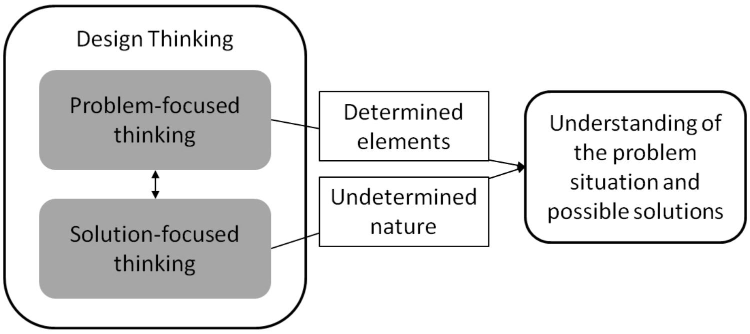


Figure 7: The application of Design Thinking to develop an understanding of a problem situation and possible solutions
(Source: created for this research)

[5] Satificing is a compound word of ‘to satisfy’ and ‘to suffice’. In the context of working on design problems or wicked problems it is used to express the following phenomenon: A solution to a design problem or wicked problem needs to satisfy the needs of the stakeholders that are relevant to the problem situation. However, because of potentially opposing needs and the possibility of other, better but unknown solutions it cannot be expected to arrive at a solution that satisfy the needs of all stakeholders ideally but only sufficiently to their contentedness.

2.2.2. The reaction of the design professions to the prescriptive and descriptive models

The various design professions differ in the way they see the structure of their work, represented by the two paradigms for the design process. Roozenburg & Cross (1991) observe that engineering designers favour the linear, prescriptive models that are informed by the rational problem-solving paradigm, while industrial designers and architects see the way they work better conceptualised in the descriptive models.

An explanation for this observation can be the differences in the degree to which an *a priori* structure exists in the design problems engineering designers are most commonly confronted with, compared to architects or industrial designers. Goldschmidt & Porter (2004) see engineering designers and architects as situated at opposite ends of the continuum that describes the design professions. They explain that:

> *'Architecture, for example, has been primarily concerned with space and its enclosure, with questions regarded as pertaining to "aesthetics", with cultural integrity and continuity over time, and hosts of other material, as well as non-material, mostly qualitative issues. Engineering design is much more, if not exclusively so, about material qualities of objects. Function and performance precede consideration of any independent aesthetic nature, and design entities are not single, individually designed "one-off" products but often "revised models" of prior existing products, the properties of which are usually quantitatively evaluated.' (Goldschmidt & Porter 2004, p. xvi)*

This illustrates nicely that engineering design problems can be expected to have a high degree of *a priori* structure that better fit within the rational problem-solving paradigm. An underlying reason for this phenomenon appears to be that they focus on the quantifiable, material properties of the product, as opposed to architects that try to understand the building within its socio-cultural context.

A proposition by this thesis for a visualisation of the continuum of the design professions, referred to by Goldschmidt & Porter (2004), is shown in Figure 8. Figure 8 also shows how this thesis proposes to position industrial design on this continuum. Industrial design is positioned on the left-hand side of the diagram for two reasons. Firstly, Roozenburg & Cross (1991) observed that industrial designers see the way they structure their activity more appropriately represented in the descriptive models of the design process. Secondly, as Section 2.3 explains in detail, industrial design practice focuses on influencing the product within its socio-cultural context. However, because it also accounts for the product's quantifiable, material properties, it is not positioned completely on the left-hand side of the diagram.

In regards to positioning the engineering design profession on the right-hand side of Figure 8 it needs to be noted that there have been efforts by the engineering profession to develop models of the design process that account for its explorative and determining nature. These efforts are described in Box 3. Box 3 also provides an explanation as to why these models do not allow for a comprehensive representation of industrial design practice and thus are not discussed further in this thesis.

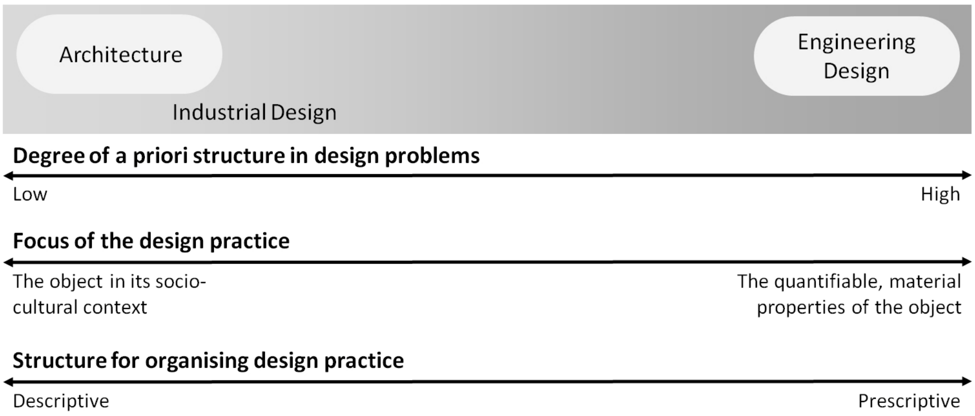


Figure 8: Proposed visualisation of the continuum of design professions
(Source: created for this research)

BOX 3
The move of the engineering profession towards more iterative models

More recently, a number of authors with an engineering background acknowledge—at least partially—the explorative and problem-determining nature of product design processes. These authors accept that a more explorative approach is necessary, in particular, when a product design process aims for a high degree of novelty (see for example: Gassmann, Sandmeier & Wecht 2006; Herstatt, Verworn & Nagahira 2004). The structure of the early stages of the so-called *new product development* (NPD) process is therefore sometimes conceptualised as a cyclic search process (see for example: Koen et al. 2001). This is also referred to as the *fuzzy front end* (FFE) of new product development. The FFE concept still strongly prioritises problem-focussed thinking as it strictly separates the activity of structuring of the design problem, formulating requirements for solution suggestions and synthesising these requirements. In other words the FFE concept represents an attempt to accommodate for the explorative and determining nature of design practice in a contained element that stands in the beginning of a linear stage/gate process. As main tool to identify promising design directions the FFE concept suggests a multi-criteria selection approach (Herstatt, Verworn & Nagahira 2004). In a multi-criteria selection approach key performance indicators are formulated against which the progress of a product development process is then assessed. (continued on next page)

The FFE concept is limited in explaining the influence of industrial design practice due to prioritising problem-focussed logic and its preference of applying a multi-criteria selection approach to identify promising design directions. Prioritising problem-focused thinking conflicts with how the Design Thinking as the underlying logic of industrial design practice is understood in this thesis. In Design Thinking problem-focused and solution-focused thinking are important. Their individual prominence depends on the nature of the design problem at hand, the activities of the designer and again the reaction of the context to these activities. An upfront prioritisation of problem-focussed logic and organising design practice in a linear stage/gate process makes utilising solution-focused thinking for formulating the strategy of a product development process difficult. In a stage/gate process representations of tentative solution suggestions such as sketches or physical prototypes are merely means to evaluate how well previously formulated requirements are met. This limits the influence that industrial designers can have on the strategy of a product development process through the reflective dialogue they lead with the problem context via representations of tentative solution suggestions.

Multi-criteria selection approaches are limited in developing insight into how products can be designed that consumers perceive as valuable. This is particularly true in regards to products with a high degree of novelty that is perceptible for consumers. A multi-criteria selection approach proposes that a design problem can be broken down into individual, hierarchically structured, mostly quantifiable, factors. As will be explained in Section 2.3 such an approach allows to only partially understand how products are designed that consumers perceive as valuable. Even though individual quantifiable product properties—later referred to as their *technological dimension*—are essential in providing functionality, it is how consumers perceive and interpret a product that allows them to access this functionality and allocate value to it. This perception and interpretation is based on the impression they get when being confronted with a product. Krippendorff (1989) describes this as 'sense making'. This is a cognitive and subjective process that cannot be understood by breaking a product down into a list of individual parameters. As discussed in more detail in Section 2.3, engaging in a reflective dialogue with the problem context via holistic representations of tentative solution suggestions is a more appropriate approach to develop insight into the sense making activities consumers are likely to conduct.

Due to its shortcomings in explaining the influence of industrial design practice the FFE concept is not used in this thesis.

2.2.3. Industrial Design Craft

The Design Craft of industrial design practice can be allocated to two categories. One category describes the knowledge and skill-set industrial designers require for solution-focused thinking. The other category describes the knowledge and skill-set they require for problem-focused thinking. As introduced in the beginning of this chapter, this Design Craft allows them to apply Design Thinking to the specific focus of their profession: to develop plans for products that offer consumers emotional and utilitarian functionality they perceive as valuable enough to purchase them for a price that allows the clients of the industrial design practice to reclaim their investments in developing and realising the products.

The category of their Design Craft that allows industrial designers to apply solution-focused thinking comprises the skills and knowledge that are necessary to develop representations of the solution suggestions. This includes 'activities such as sketching, making physical models and so on as well as utilizing graphical software, hardware, and electronics' (Vyas et al. 2009, p. 106). They can usually be applied broadly across various different tasks industrial designers work on (Vyas et al. 2009).

The second category of industrial Design Craft comprises knowledge about general principles[6] such as physical laws, domain-specific knowledge about the context of the product and the skill to apply this knowledge in an analytical process. The sources of this knowledge can vary. It can be based on conventional research methods conducted by the industrial designers themselves, or by others that pass this knowledge on to them (Bürdek 2005). It can also be based on the experience of the industrial designers with previous projects or generated within the project through solution-focused thinking. The products that industrial designers work on are diverse (Erlhoff, Marshall & Bruce 2008). The kind of knowledge that industrial designers require for problem-focused thinking can vary and consequently so do the sources of this knowledge.

The two groups of skills that make up Design Craft are shown again in Table 1 with some examples below. As they may vary between individual industrial designers, depending on the products they work on such a list of skills will never be exhaustive nor will it entirely apply to all industrial design professionals.

[6] It needs to be highlighted that because Design Thinking alternates between problem- and solution-focused thinking the knowledge about the general principles also informs the solution-focused element of design thinking. It helps the industrial designers to come up with solution suggestions (Cross 2011).

Table 1: Industrial Design Craft that supports problem- and solution-focused thinking
(Source: created for this research)

Design Craft for solution-focused thinking	Design Craft for problem focused thinking
Skills to develop representations: Mood boards[7], hand drawing, different model making skills, CAD rendering, animation	Analytical skills: Competitor analysis, market analysis, Technical calculations, Knowledge of physical principles, Ergonomics
Most skills can be applied broadly, model making skills can vary between products	Likely to change with each problem

An expanded understanding of the term product

Products as physical, tangible objects are only a means for consumers to derive utilitarian and emotional functions they perceive as valuable (Erlhoff, Marshall & Bruce 2008). This recognition has two implications for industrial design. Firstly, it frees industrial designers from the imperative of merely redesigning existing solutions. They can also develop new concepts to provide certain utilitarian and emotional functionality to consumers. Secondly, it allows questioning whether these can also be fulfilled differently, through intangible things like services (Saco & Goncalves 2008). The Design Craft that is used to develop representations of solution suggestions of services differs from that for physical, tangible objects (for a description of service design see for example: Moritz 2005). This difference in Design Craft justifies seeing service design as an individual design profession in its own right. The contribution of service design in its pure form to reduce the ecological impact of society is a promising area of further research but beyond the focus of this thesis. However, service design and industrial design may overlap as the difference between products and services is a continuum (Brezet et al. 2001). The relatively recent idea of combining physical objects and services to offer utilitarian and emotional functionality to consumer requires a collaboration of both design professions. This concept is also referred to as *product service system* (PSS) and requires industrial designers to consider the role of the physical object they design within the context of the complementing service. While industrial designers cannot be expected to design an entire PSS (Tukker & Tischner 2006a), they can potentially initiate its development by proposing appropriate physical objects. PSSs are covered in more detail under Sub-section 5.2.3.

[7] Mood boards are collections of inspirational examples that illustrate goals for a design process. These goals can be a certain meaning that is for example captured by a mood board through a collage. Mood boards can also show certain a functionality that is anticipated for the product. They serve as very early high-level solution-representations that support the explorative activities in a design process (for more details on moodboards and their use in a design process see: McDonagh & Storer 2004).

2.3. A model of the product properties to explain how industrial design practice creates value for consumers

Industrial designers have three 'levers' to influence the properties of a product[8] (Rampino 2011). Firstly, they have a voice in selecting the 'technology' of a product. 'Technology' does not only describe the technology embodied in a product and how it is brought together, but also the technology that is necessary to manufacture and distribute it. Secondly, they determine what authors such as Bloch (1995) refer to as the 'form' of a product. The term 'form' comprises the product's sculptural qualities as well as its surface treatment like colour and degree of surface smoothness. Thirdly, industrial designers influence a product's 'mode of use'. The 'mode of use' lever describes the influence industrial design practice has on the procedure and types of interactions between consumer and product. These three levers are visualised in Figure 9.

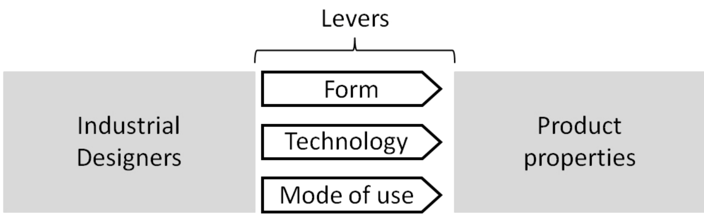


Figure 9: The levers of industrial designers on a design
(Adapted from: Rampino 2011)

As explained in Section 2.1, industrial designers apply their levers seeking to develop products with emotional and utilitarian functionality that individual consumers perceive as valuable enough to purchase them for a cost that allows the industrial designer's client to achieve a financial benefit. To better understand this process this section develops a model that illustrates the relationship between:

1. the product properties,
2. the application of the levers of industrial design practice to shape the product properties and
3. the utilitarian and emotional functionality these properties can offer to consumers.

For this purpose three widely-used approaches that seek to characterise product designs are reviewed:

- a distinction between form and function,
- that of affordance and
- that of product semantics.

[8] Because the product design describes the plan for the properties of that product, the terms 'product design' and 'properties of a product' are used synonymously in this thesis.

None of these approaches provides a comprehensive description of the correlation between the three factors, mentioned above. In response, this thesis adapts a fourth approach that was initially developed by (Verganti 2009) to conceptualise the capacity of industrial design to drive an innovation process. This conceptualisation builds on the strengths of the other approaches that are reviewed, and addresses their weaknesses.

2.3.1. Form and Function

Traditionally the properties of a product are often described by distinguishing between a product's form and its function (Luchs & Swan 2011). The origins of this concept are unclear but a distinction between form and function is often attributed to Louis Henry Sullivan who stated that 'form ever follows function' (Sullivan 1896, p. 408). The way Sullivan initially understood the term 'form' refers very broadly to the physical embodiment of a product (Sullivan 1896). Sullivan sought to highlight a causal relation between this physical embodiment and a product's functionality. Opposed to Sullivan's understanding the way the term form is usually applied is more limited. As described under Section 2.3 it is most commonly used when talking about the sculptural and aesthetic qualities of a product (see for example: Bloch 1995; Luchs & Swan 2011). The way the term function is usually understood when distinguishing it from a product's form commonly prioritises what is described in Section 2.1 as a product's utilitarian functionality. This is explicitly expressed for example by Townsend, Montoya & Calantone (2011, p. 375): 'function refers to product specifications and standard architectures—essentially the utilitarian aspect of product design.'

Sullivan's claim that form follows function has been critiqued because it suggests a hierarchical relation in which a product's intended function somewhat dictates which form designers give it (Crabbe 2012). Crabbe (2012) illustrates that within a design process designers can also discover that forms can fulfil a previously unintended functions. In this case function follows form. That the relation between form and function is bidirectional is particularly important in regards to the explorative quality of the solution-focused element of Design Thinking. The reflective dialogue industrial designers engage in by developing representations of tentative solution suggestions can very well uncover that a certain form can be used in ways that had not been anticipated upfront.

Limitations of the concept of distinguishing form and function

For illustrating the relationship between the product properties, the application of the levers of industrial design practice to shape them and the utilitarian and emotional functionality they can offer to consumers, the approach of describing a design by distinguishing between its form and function is limited. It lumps together the levers ‘technology’ and ‘mode of use’ in that they both influence the function of a product. Furthermore the way *function* is commonly understood only describes what has been introduced as utilitarian functionality in Sub-section 2.1.1. This makes it difficult to account for the emotional functions consumers derive from a product.

The distinction between form and function also has limitations in regards to explaining how the influence of industrial design creates consumer value. Townsend, Montoya & Calantone (2011, p. 376) find that ‘the form and function of a product jointly affect consumer beliefs about a product, and these beliefs likely in turn affect consumer preferences and responses’. For example, the joy somebody feels in using a product depends to some extent on its utilitarian functionality and its formal aspects (Green & Jordan 2002). Also, a product’s form is an important factor in making a product understandable to consumers so they can access the utilitarian functionality a product provides (Gaver 1991).

2.3.2. Product affordance and perceived affordance

The concept of ‘affordance’ directs its attention specifically towards explaining how products allow consumers to derive functions from them. It was initially proposed by Gibson (1977) and highlights that objects have inherent physical features that offer to fulfil certain functions independently from their individual context. For example an object that has similar proportions to a chair, is robust enough and has a sufficiently clean and smooth surface affords sitting. In his work, Gibson (1977) focused more on the role of the objects that exist and have been made than on the act of designing them. Norman (1988) gave this connection more prominence and introduced the concept of affordance to the wider design community.

In its original definition, the affordance of a product can be accessed directly by consumers without requiring mediation by their subjective perception (You & Chen 2007). This idea of a ‘direct perception’ (Gibson 1966, in You & Chen 2007, p. 23) underlying the original definition of affordance is not supported by the way Norman (1988) introduced the concept to design. In particular in his later work, Norman (2004) explicitly distinguishes between real and perceived affordances. *Real affordance* describes what functionality the physical properties of a product can provide to consumers. The concept of affordance implicitly focuses only on what has been described in Section 2.1 as utilitarian functionality. *Perceived affordance* is what utilitarian functions consumers expect from a product based on their personal perception and interpretation. Perceived and real affordance do not necessarily align, as consumers may be misled by the information that is available and how they interpret it (Norman 2004). This information is also referred to as 'perceptual information' (Gaver 1991).

The matrix in Figure 10, adapted from Gaver (1991), illustrates the relationship between the perceptual information and the real affordance of a product. Four different scenarios are possible. Two in which perceptual information and real affordance align, highlighted in grey, and two in which this is not the case, highlighted in white. The top left box of the matrix describes the case when a function that a product affords remains unrecognised by the consumer due to shortage of or misleading perceptual information. An example is an electronic device where buttons are not noticeable as such, hidden or arranged in a way that obscures the effect of pressing them. The top right box of the matrix illustrates the scenario when a product has a real affordance that is also supported by the provided perceptual information. An example for such a scenario is a clearly pronounced handle for a product that can be moved around manually by for instance carrying it. The box on the bottom right corner represents the scenario in which the information, supplied through the design of the product suggests functions that are not provided by its real affordance. An example for this is the visible application of the pattern of carbon fibres on conventional injection moulded plastic parts. Products made of carbon fibre are exceptionally light, durable and flexible—attributes that conventional injection moulded plastic parts do not have. However visibly applying the pattern of carbon fibres on them may evoke just that impression by consumers and lead to a false affordance. The bottom left box of the matrix, labelled correct rejection stands for a situation in which the perceptual information does not suggest any functions that are not provided by the real affordance of the product.

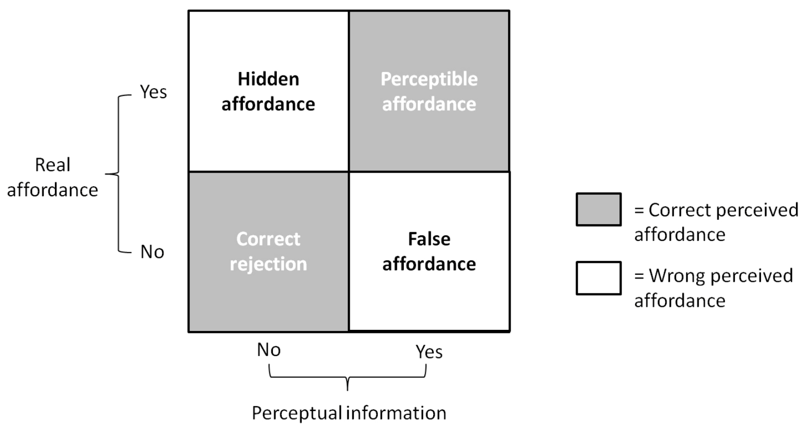


Figure 10: Interrelationship between perceptual information and real affordance
(Adapted from: Gaver 1991—shading added to highlight correct and wrong perceived affordances)

Only alignment of real and perceived affordance allows consumers to access the utilitarian functionality a product provides. The concept of affordance explains the role of the designer as establishing this alignment. The properties of a product should be planned in a way so the available perceptual information allows consumers to understand and access the utilitarian functionality provided by a product's real affordance (You & Chen 2007).

The concept of affordance has progressed the understanding of how design can improve the usability of products in facilitating easier access to their utilitarian functionality. It also highlights that the capacity of consumers to derive utilitarian functions from a product depends on the interrelation between the physical properties of the product and their perception and interpretation by the consumer.

The diagram in Figure 10 allows an allocation of the three levers industrial design practice has to influence the properties of a product. By selecting and incorporating the appropriate technology industrial designers can equip a product with real affordance. The other two levers—form and mode of use—allow industrial designers to provide perceptual information to consumers through the product. These levers allow industrial designers to shape what Krippendorff (2005) refers to as the *interface* of a product. Thereby *interface* comprises all aspects of a product that are perceptible for consumers. This understanding which goes beyond the commonly used one, referring mostly to how buttons are arranged on an electronic device or how computer software is visualised (Krippendorff 2005) is also used for this thesis. An example of using the lever form for supplying appropriate perceptual information is concentrating the buttons of an electronic device in a well accessible area possibly emphasised by the use colour or other means. To supply appropriate perceptual information via the lever mode of use industrial designers can for example to plan the interaction sequence with a product in a logical order.

Limitations of the concept of affordance

The concept of affordance has limitations in illustrating more subjective and unquantifiable aspects in design such as the emotional functionality products provide to consumers. As promoted by Norman (1988) the concept has an inherent but somewhat oblique denial of these aspects in design. This also constrains the application of the concept of affordance for explaining how the levers of industrial design practice can be used to shape product properties accounting for its non-quantifiable qualities. The concept of affordance also has shortcomings in providing an exhaustive explanation of the role of design in providing appropriate perceptual information to consumers in regards to new functionality. Norman (2004) acknowledges that context-specific factors influence how perceptual information is perceived by consumers. However he still seeks solutions that can be universally generalised to provide this information and suggests identifying them via problem-focused thinking. He for example proposes that designers should look for already-established conventions, formulate explicit instructions and establish a coherent logic of use within a product (Norman 2004). These provide valid pathways towards generating perceptual information that allows consumers to access the utilitarian functionality of a product. However they strongly build on existing user patterns and already established understandings of objects held by consumers. Industrial designers can seek to innovate how consumers understand and use products via the use of metaphors as it allows them to transfer meanings from other contexts (Krippendorff 2005). However Norman (2004) states that: 'I personally believe that metaphors are more harmful than useful'. He sees them as possibly ambiguous and open to misinterpretation.

2.3.3. Product semantics and product meaning

The concept of product semantics, strongly influenced by the work of Krippendorff (see for example: Krippendorff 1986; Krippendorff 2005; Krippendorff & Butter 1984; Krippendorff & Butter 2008), overlaps to some extent with that of perceived affordance. Both concepts are concerned with the interaction between products and consumers (You & Chen 2007). Thereby product semantics delivers explanations for filling the gaps in the concept of affordance in regards to the subjective and unquantifiable aspects of design.

The concepts of product semantics and perceived affordance differ in regard to their starting point for explaining the origins of the value that consumers derive from a product. The concept of perceived affordance takes the physical, tangible properties of a product and the afforded utilitarian functionality as a starting point to develop appropriate perceptual information. The concept of product semantics starts from the perception of the individual consumer and seeks to understand which signs can help them to 'make sense of things' (Krippendorff 1989, p. 9). In seeking these signs, the concept of product semantics accepts the subjective nature of consumer perception. Besides aiming at understanding that already established patterns, logic and instructions may support the sense-making process, it also explicitly explores metaphors that can be used to communicate messages that help consumers to make sense of things. As highlighted already by the concept of perceived affordance, it is essential that consumers make sense of a product—that they understand it and can relate it to their individual situation. Otherwise, they will not be able to derive any functions from it. Other than the concept of affordance, product semantics acknowledges that this functionality is not exclusively of a utilitarian nature, but also covers aspects that are partially or exclusively emotional (Steffen & Bürdek 2000).

The outcomes of the sense-making activity by consumers are the meanings they attach to products. Analogous to perceived affordances, meaning allows consumers to access the functionality of a product. However, it goes beyond the concept of affordance in that it considers a product's emotional and utilitarian functionality. Verganti (2009, p. 4) proposes that 'people do not buy products but meanings.' Krippendorff (2005, p. 43) even goes a step further and claims that 'Humans do not see and act on the physical qualities of things, but on what they mean to them'. You & Chen (2007) explain that some authors use the term *product meaning* when describing the perceived affordance of a product. However, in product semantics, the concept of product meaning is more inclusive than that of perceived affordance. Krippendorff (1989) describes affordance as merely one factor in triggering a meaning that is attached to a product.

Most authors mainly refer to the formal aspects of products when discussing how they can stimulate consumers to attach certain meanings to them (see for example: Rindova & Petkova 2007; Rompay, Pruyn & Tieke 2009; Steffen & Bürdek 2000). This view has limitations. Krippendorff (2005) explains that every aspect of a product that can be experienced by consumers potentially plays a role for the meanings that they attach to it. This includes not only its form but also the way it is used and the experience consumers have in using it. These factors have already been introduced under the concept of affordance as the product's interface.

Even though a product can trigger meanings, these meanings are not inherent to it. A product itself does not have a meaning (Krippendorff & Butter 2008). Meanings are constructed by the consumer within the individual socio-cultural context in which the product is situated (Bürdek 2005; Helfenstein 2005; Krippendorff 2005). In other words, the meaning that is attached to a product is the result of three factors: (i) the interface of the product itself, (ii) the socio-cultural context in which the product is positioned and (iii) the perception of the consumer of this entire situation. A product can have different meanings according to the individual background of the consumer and the socio-cultural context it is situated in. The construction of product meaning is shown in Figure 11.

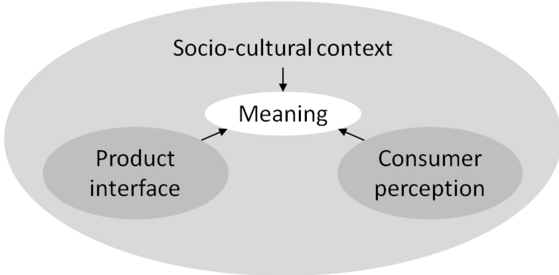


Figure 11: The construction of product meaning
(Source: created for this research)

Product semantics and the associated concept of *product meaning* describe the subjective nature of the way products are perceived and understood by consumers better than that of perceived affordance. Furthermore, it accounts for the emotional functions consumers derive from a product in addition to the utilitarian functions.

BOX 4
On terminology: Every product is *meaningful*

The common use of the word *meaning* or *meaningful,* when associated with a product, is likely to seek to express that a product is highly valued by someone and that they have strong personal memories, emotions and experiences which they attach to the product. In the context of converting ecological considerations into product designs, design interventions that achieve such *meaningful* products are often discussed as possible pathways to avoid perceived obsolescence of a product (Chapman 2005; Van Hinte 1997; Van Hinte 2004).
However, this is not the way meaning should be understood for this thesis. The *meaning* of a product describes how consumers understand and perceive this product and how they relate it to themselves and their wider context. The creation of this meaning is a cognitive process that is inevitable when a consumer comes in contact with a product. 'Every product has a meaning' (Verganti 2009, p. 19) and is thus meaningful (Krippendorff & Butter 2008).

Limitations of the concept of product semantics

The concept of product semantics better accounts for the subjective, qualitative aspects of design, than that of affordance. This helps in particular to illustrate how consumers can derive emotional and utilitarian functions from products. However it is limited in conceptualising how industrial designers use their levers to shape the product properties to provide that value. The concept of product semantics acknowledges that the affordance plays a role for the meanings consumers can attach to a product. However, product semantics omits the role of technology somewhat. The technology that is applied in a product and for manufacturing and distributing the product is essential for allowing consumers to perceive a product in certain ways and in making it possible that products take a certain form. These factors do not receive much attention by the concept of product semantics. In other words, the role of technology in facilitating the product in a way that allows certain meanings is not well represented.

2.3.4. A holistic conceptualisation of the product properties—accounting for the interrelation between meanings and technology

None of the approaches reviewed thus far provides a comprehensive description of the correlation between:

1. the product properties,
2. the application of the levers of industrial design practice to shape the product properties and
3. the utilitarian and emotional functionality these properties can offer to consumers.

Distinguishing between form and function has limitations in regards to explaining how the levers of industrial design can be used to create consumer value as both, form and function, are jointly responsible for a product's functionality. The concept of product semantics somewhat omits the role of technology in facilitating the construction of product meanings that provide consumers access to the functionality of a product. The concept of affordance does not explicitly account for emotional functions that consumers derive from a product, nor does it fully acknowledge the subjective nature of how consumers develop an understanding of a product.

To address these issues, whilst still incorporating the points highlighted in the review of the three approaches this thesis proposes to adapt a model that Verganti (2009) developed to conceptualise the capacity of industrial design to drive an innovation process. He describes the properties of a product as being situated in a two-dimensional space. One dimension is termed the *technological dimension* and the other is the *meaning dimension*. The *technological dimension* describes the quantifiable, physical aspects of the properties of a product. The *meaning dimension* describes how consumers perceive and interpret a product and relate it to themselves. This includes the consumer's understanding of the utilitarian functionality of a product and how to access it as well as the consumer's emotional associations. As Figure 11 illustrates this depends on the product interface but also on the individual perception of the consumers and the specific socio-cultural context their interaction with a product takes place in.

The conceptualisation, shown in Figure 12 allows explaining how the emotional and utilitarian functionality a product offers are connected to its properties. The technological dimension provides functionality while the meaning dimension gives consumers access to it. The process of consumers attaching meaning to a product in order to understand it and relate it to their individual context can be seen as a particular form of communication that industrial designers can facilitate through the product interface. To express this communicative nature of the product interface, its design is sometimes also described as *product language* (Bürdek 2005).

This thesis uses this model of the product properties to allocate the three levers of industrial design practice to shape these properties that were introduced in the beginning of this section. The levers form and mode of use allow industrial designers to shape the product's interface, thus allowing them to manipulate a product's meaning dimension. The technology lever allows them to influence a product's technological dimension. Thereby, this lever not only comprises the technology that is embedded in the product but also the technology that is used to manufacture and distribute it. The conceptual model of the product properties, based on Verganti (2009), is shown in Figure 12. This model is a sufficient conceptualisation of the product properties to be used in this thesis but it is important to note that it still is a simplification. A more comprehensive model is described in Box 5. Box 5 also explains the reasoning why the model in Figure 12, despite the simplifications, still is appropriate to use for this research.

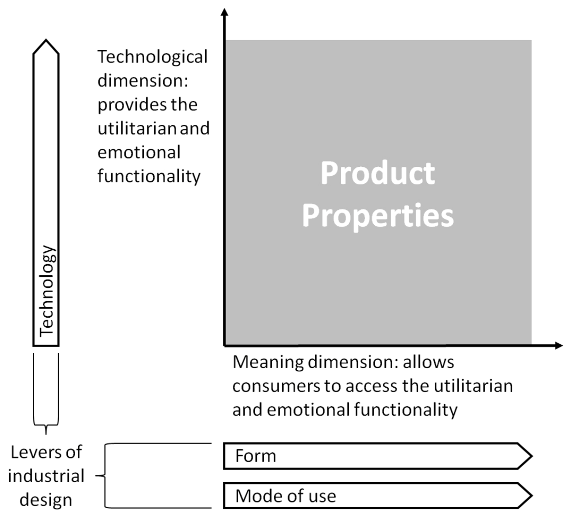


Figure 12: Levers of industrial design to exert influence on the two dimensions, describing product properties that facilitate a product's emotional and utilitarian functionality
(Adapted from: Verganti 2009)

BOX 5
The visualisation of the product properties in a two-dimensional space is a simplification

The visualisation of the product properties in a two-dimensional space is a simplification that should not be misinterpreted. The technological dimension of a product can be quantified and described in an unambiguous manner. This is different for the meaning dimension. Multiple different meanings can be attached to a product and their prominence is subjective. For example meanings such as safety, efficiency, freedom and attractiveness can be associated to a car by one consumer. Another consumer might also attach meanings of safety and freedom to the same car but perceive it at the same time as an outdated ecologically harmful mode of transport. The multi-layered and subjective nature of the meaning dimension is not illustrated in Figure 12. An attempt to visualise this multi-layered nature of meanings is shown in Figure 13.

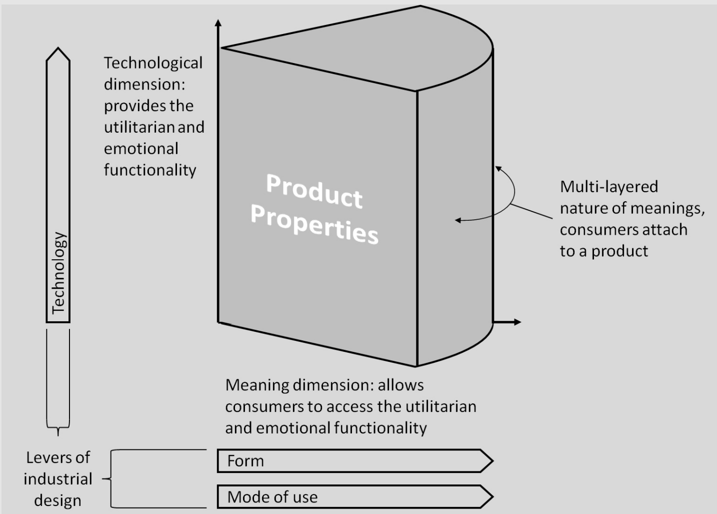


Figure 13: Representation of the product properties accounting for the multi-layered nature of the meanings consumers attach to products
(Source: created for this research)

Even though the conceptualisation of the product properties as shown in Figure 13 captures the complexity of the meaning dimension more accurately than the two-dimensional model shown in Figure 12, the latter is still sufficient for the purpose of this thesis. As explained in more detail in Chapter 5, this thesis discusses the capacity of industrial design practice to manipulate the meanings consumers attach to product in two regards:

1. with regard to the ability to mediate design interventions to reduce the quantitative ecological impact of a product on the meaning dimension, and
2. with regard to facilitate product meanings that consumers perceive as eco-friendly.

For discussing these two aspects, the two-dimensional model is sufficient.

2.4. Influencing product properties through industrial design practice

Industrial designers approach a product development process by developing visions for possible product meanings with some degree of novelty to make sure that consumers see value in a product (Utterback et al. 2007). To realise opportunities for consumers to construct these product meanings, designers need to develop appropriate product languages. This activity also has implications for the technology that needs to be applied to offer these meanings to consumers.

2.4.1. Influencing the meaning dimension—design as sense-creating activity

Industrial designers 'cannot possibly "build" meanings into artifacts or "force" others to see the meanings their way' (Krippendorff 2005, p. 230). They can merely create possibilities for intended meanings to arise and also direct effort towards preventing undesired meanings by planning the product interface appropriately. This is because the meaning that is attached to a product is a result of the interplay of three factors: the product interface, the socio-cultural context and the consumer perception. The meaning attached to a product can change when any of those three factors changes. Industrial designers have direct influence only on the product interface. The other two factors are beyond the control of industrial designers are subjective and can vary for each individual case. Thus, industrial designers need to develop what Krippendorff (2005) terms a 'second order understanding'. They need to seek to understand how consumers will understand a design within their individual context. Only then can they intentionally propose product languages that allow consumers to attach meanings to a product they perceive as valuable.

Developing a second order understanding-integrating the consumer perspective into the product development process

Some authors refer to the integration of the consumer perspective as being a *human-centred design* (HCD) approach (see for example: Brown 2009; Krippendorff 2005; Norman & Verganti 2012) or *user-centred design* (UCD) approach (see for example: Krippendorff 2005; Sanders & Stappers 2008). How these terms are interpreted by different authors varies. This sub-section uses a map, developed by Sanders & Stappers (2008), to illustrate the spectrum of HCD (see Figure 14). Within this spectrum the interpretations of HCD by Krippendorff (2005) and Verganti (2009) are positioned to exemplify different understandings of the concept. It also is explained how this thesis proposes to position the approach of industrial design within this map. Whilst this sub-section uses the term HCD, neither HCD nor UCD are applied in the remainder of this thesis. This is because the context of developing consumer products always demands to integrate the consumer perspective. This makes the attribute human centred or user centred redundant.

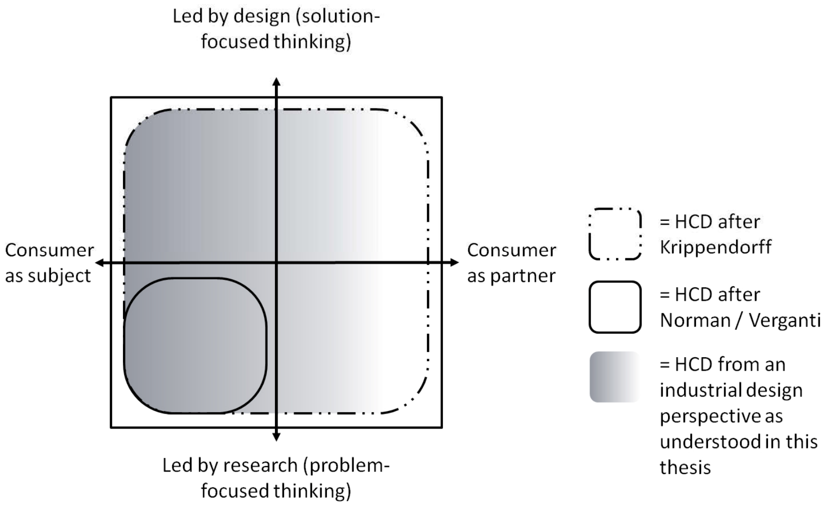


Figure 14: Map to describe human-centred design (HCD)
after Sanders & Stappers (2008), positioning the understanding of HCD expressed by Norman & Verganti (2012) and Krippendorff (2005) and for the understanding of industrial design for this thesis

The vertical axis in Figure 14 describes whether the design activity is guided by problem-focused or solution-focused thinking. Understanding how to design interfaces that stimulate consumers to attach meanings akin to the ones that are already constructed around similar products can, for the most part, be informed by problem-focused thinking (Verganti 2009). This thesis proposes that with an increasing degree of novelty in the interface of a product, solution-focused thinking becomes more important to develop insight into the consumer perspective.[9] Making sense of products comprises a cognitive experience of consumers when being confronted with the product as a hole. Thus gaining insight how consumers make sense new product interfaces can only be achieved by engaging in a reflective dialogue with this situation via holistic representations of tentative suggestions for product interfaces. This facilitates learning in two regards. Firstly, it allows understanding of how far a new design triggers meanings that allow consumers to access utilitarian and emotional functions, which they currently seek in products. Secondly, it potentially uncovers new meanings that allow consumers to access utilitarian and emotional functions they did not explicitly demand, but once provided, perceive as valuable (Best 2010). In particular, these new or hidden demands cannot be uncovered by relying only on problem-focused thinking. They can only arise or

[9] There are also approaches that try to innovate product meaning by solely following problem-focused logic such as Kansei engineering. These approaches have thus far not gained significant influence on industrial design practice and therefore are not discussed further in this thesis. Box 6 provides more detail on Kansei engineering and explains why this concept is not considered further in this thesis.

surface through speculating about solutions that allow consumers to attach new meanings. Industrial designers need to take their interpretation of the question: 'what could the consumer perceive as valuable?' as a starting point to generate representations of solution suggestions to the problem context. Only these explicit representations will enable an understanding of whether the solution suggestions may be successful in creating value. The necessity of making these speculations and explicitly proposing them is illustrated by a quote attributed to Henry Ford: If I'd asked my customers what they wanted, they'd have said 'a faster horse.'[10] (Brown & Wyatt 2010, p. 33; Meyer & Schwager 2007, p. 5).

The horizontal axis in Figure 14 describes the involvement of the consumer in the design process. At left end, the consumers are seen as a passive subject. In this context, they are either subjects of traditional market research (if Design Thinking is dominated by problem-focused logic), or they merely respond to the solution suggestions represented by the designer (if Design Thinking is dominated by solution-focused logic). At the right end, they are seen as actively delivering creative input to the design process and potentially developing their own representations of solution suggestions.

In Figure 14 the understanding of HCD by Norman & Verganti (2012) is positioned in the lower left. They link HCD to problem-focused thinking. Verganti (2009) describes HCD as an approach where industrial designers base their activity exclusively on detailed research into current preferences and problems that are explicitly articulated by consumers. Norman & Verganti (2012) correctly point out that such an approach can only help to understand current product meanings and inevitably leads to mere reinforcement of these meanings. Consequently, Verganti (2009) proposes that efforts to develop product meanings that are novel should not apply HCD. Verganti (2009) bases this assumption on numerous cases where products with a high degree of novelty were rejected initially by focus groups, but turned out to be successful in the market after their implementation. He believes that consumers can only understand products that offer possibilities for new meanings once they are fully implemented and explained in their real-world context. The complete rejection by Verganti (2009) of the possibility to integrate consumers into the development of new meanings somewhat opposes the notion of Design Thinking as an explorative learning process. Heiskanen et al. (2007) find that when consumers are brought into a design process, they usually do understand radically new products. They propose that a nuanced investigation into the reasons why these new

[10] Even though it is not confirmed that Henry Ford actually used these words they underline the importance of solution-focused thinking in a design process to achieve novel solutions.

products are potentially rejected can deliver valuable information for adjusting the innovations to allow for more market acceptance.

HCD as interpreted by Krippendorff (2005) covers the entire spectrum visualised in Figure 14. He does not see a compulsory link between the concept and a problem-focused approach to design. The 'second order understanding' Krippendorff (2005) calls for refers to contemporary products as well as to new products, and can be achieved through problem as well as solution-focused thinking. When developing representations of tentative solution suggestions which offer new meanings he also sees consumer involvement as beneficial for helping designers to better understand their perspective. However he also highlights that design practice has an epistemological problem—the full knowledge about the implications of a design can only be evaluated once it is realised. Thus, while carefully testing representations of products that propose new meanings during their development with consumers can provide insights into the implications of these products, it cannot fully eliminate the risk of a market failure.

The positioning of HCD in Figure 14 from the perspective of industrial design is visualised by the gradient fading from left to right. The extent to which consumers are allowed to actively deliver creative input through proposing their own solution suggestions requires a change in Design Craft. The Design Craft that is necessary to empower consumers to deliver creative input demands industrial designers to provide them with generative tools that allow them to develop their own representations of solution suggestions (Raijmakers, Thompson & van de Garde-Perik 2012). In this context the industrial designer's role would be more of a facilitator by, for example, providing consumers with modules they can arrange in a way they consider as appropriate. Because it remains unclear how far the industrial designer takes this role of a facilitator, the grey area that shows the positioning of industrial design in Figure 14 fades out to the right.

BOX 6
Kansei engineering—a problem-focused approach to influence the meaning dimension

When discussing the influence of design practice on the meaning dimension of product properties, a concept that needs to be mentioned is that of Kansei engineering. There is awareness within the engineering profession about its current limitations to exert influence on the meaning dimension of a product. This has resulted in efforts to try to address this shortcoming.

(continued on next page)

In particular, Kansei engineering directs effort towards shaping the emotional relation between the consumer and the product. The Japanese word *Kansei* describes the 'impression somebody gets from a certain artefact, environment or situation using all the senses of sight, hearing, feeling, smell, taste, as well as cognition' (Schütte et al. 2004, p. 216). Very generally speaking, Kansei engineering starts out by defining certain impressions that a product should evoke in consumers. To realise a product design that evokes accordant impressions, Kansei engineering uses a database, which—building on codified elements such as forms and colours that are analysed statistically—provides directions for the design of the product interface. (for more details on Kansei engineering see for example: Nagamachi 1995, 2002; Schütte et al. 2004).

Kansei engineering is not discussed further in this thesis for two reasons. Firstly, it structures the design process in an exclusively problem-focused manner, also to influence the meaning dimension of product properties (see for example: Schütte et al. 2004). It therefore is not helpful in accounting for the strength of industrial design practice to also draw on the solution-focused element of Design Thinking to develop and explore opportunities for new product meanings. Secondly, at least in a western context, it does not seem to be applied widely enough to compete with the approach of industrial designers. It was developed in Japan and thus far, most published case studies of the application of Kansei engineering were either conducted in Asia—or to a lesser extent, in Sweden.

The decisions to leave Kansei engineering aside for this thesis should not be seen as a general dismissal of the concept. A small number of researchers have even set out to explore the potential of Kansei engineering to support incorporating ecological considerations into design practice (see in particular: Bouchard, Brissaud & Aoussat 2011; Chen, Yeh & Lin 2009; Rasamoelina, Bouchard & Aoussat 2012).

Co-design: integrating the perspectives of multiple stakeholders into the product development process

Some authors such as (Sanders & Stappers 2008) also use the term *co-design* instead of HCD. Co-design more broadly refers to design methods and approaches to generally integrate the perspectives of different stakeholders into the design process. Thus HCD can be seen as a form of co-design that specifically seeks to integrate the perspective of the consumer. More radical forms of co-design seek to do so with the perspectives of all stakeholders affected by a design process (see for example: Fuad-Luke 2009). As shown in Figure 14 for the perspective of consumers, this integration can happen via an active or passive contribution of the individual stakeholders and a ‘second order understanding’ for their views and values can be helped by problem-focussed as well as solution-focused thinking.

Section 2.1.1 explained that industrial designers seek to integrate the perspectives of those stakeholders that are of financial interest to their clients. Thus, they practice co-design to some extent. As this thesis expects this to be inherent to industrial design practice, it does not specifically highlight this practice as co-design. The concept of co-design will only be taken up again in Chapter 3 in the context of the discussion about distinguishing the concepts of sustainable design and ecodesign.

2.4.2. The interrelationship between the meaning and the technological dimension

Norman & Verganti (2012) propose that the meaning dimension and the technological dimension can be influenced independently. This may be possible in some cases. The interface of a product is only one of the three factors that influence the meanings that are attached to it. Thus, new product meanings can also be constructed when the other two factors change. Any effort from industrial designers to influence the interface of a product is inevitably linked to some changes on its technological dimension. For example, Ford could not have proposed his vision of mass manufacturing individual mobility without the appropriate technology. The necessary changes in the technology that are applied in a product that offers possibilities for consumers to attach novel meanings to them may, in most cases, be smaller than in the example of Henry Ford. However, industrial designers always need to consider both dimensions when attempting to propose new meanings.

This thesis also proposes that most changes on the technological dimension require taking the meaning dimension into account. Technological changes (such as using a different material for a product-housing, or a different manufacturing technology) are likely to have implications for the product interface. Therefore, they are perceptible by the consumer and may have an impact on the meanings that are constructed around a product. Understanding if these meanings are positive or negative and mediating these implications by manipulating the product interface can be essential for the commercial success of a product. However, in some cases when technological changes can be hidden from a consumer, it is possible to influence the technological dimension independently of the meaning dimension.

2.5. The influence of industrial designers on the product development process

The extent to which industrial design practice can exert influence on the properties of a product to achieve novelty on its meaning dimension and its technological dimension is interrelated with its influence on the product development process as context for this activity. As explained in Section 2.1, industrial designers contribute to the product development process, which is again situated within the product innovation process. This wider context poses constraints in terms of the feasibility of a design and the effort that can be invested into developing it (Ralph & Wand 2009). Even though the influence of industrial designers is usually limited to the product development process, they need to consider these constraints for the products they design. To conceptualise how constraints are identified, defined and integrated in the product development process, it is most commonly split into three elements (Buijs 2003; Roozenburg & Eekels 1995):

- **The strategy**—This element comprises the specific drivers for a company to engage in the process of designing a product, what goals the company seeks to achieve and a high level direction of how this should be done
- **The design brief**—This element describes concrete ideas and goals for the product itself, including the surrounding conditions of its realisation
- **The design or plan of the product properties**—This element describes the product properties. This can take various forms such as technical drawings, a prototype, renderings and written instructions.

These elements are usually conceptualised as defining sets of activities (Buijs 2003). This is problematic from the perspective of industrial design. In particular, the allocation of industrial design practice as synthesising and representing solution suggestions only to the design or plan of the product properties—as proposed, for example, by Roozenburg & Eekels (1995)—is contested. Various authors highlight that this practice can also deliver valuable input to the other two elements of an innovation process (Blaich & Blaich 1993; Brown 2009; Kotler & Rath 1984). To resolve this ambiguity, it is helpful to see the three elements not as sets of activities, but as outcomes that need to be generated in a product design process.

2.5.1. The operational role of industrial design

Some authors allocate industrial design practice as synthesising and representing solution suggestions to a design problem exclusively to the development of the plan that describes the product properties (see for example: Marxt & Hacklin 2005; Roozenburg & Eekels 1995). They see the activities that contribute to this element as separated by a *gate* from activities that deliver input to the strategy and the design brief. Authors supporting this position usually come from an engineering or management background and lean towards the rational problem-solving paradigm. Thus, design practice is structured according to prescriptive models. The strategy and brief formulation precedes the development of the plan, describing the product properties. It is informed by traditional research approaches into the current context. For example, how products need to be designed so their properties allow consumers to derive emotional and utilitarian functions from them they perceive as valuable is usually identified through market surveys and observations. In this context, the activity of synthesising and representing solution suggestions is a mere execution of predefined requirements. Building on the terminology of Bakker (1995), this role for industrial designers is termed 'operational'. The contribution of industrial design practice in an operational role to the three outcomes that need to be achieved in a product development process is shown in Figure 15.

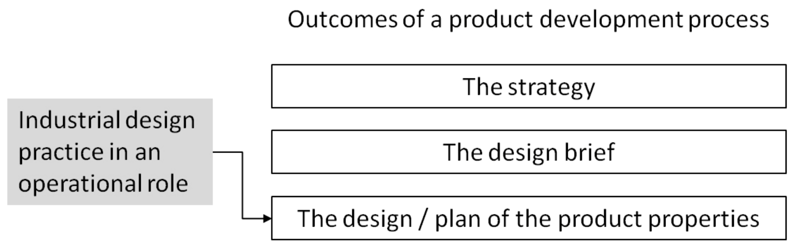


Figure 15: The contribution of industrial design practice in an operational role to the outcomes of a product development process
(Source: created for this research)

2.5.2. The strategic role of industrial design

A number of authors argue that a strictly operational role for industrial design practice constrains opportunities to innovate (see for example: Blaich & Blaich 1993; Brown 2009; De Mozota 2003; Melgin 1991; Utterback et al. 2007). They highlight that the activity of industrial designers to synthesise and represent solution suggestions is an important means to practice solution-focused thinking and facilitates learning about the design problem. This learning can become a valuable input for identifying and defining the goals and constraints for a product development process that are formulated in the strategy and documented in the briefing. Because in this case the activity of synthesising and representing solution suggestions plays an active role for formulating the goals for the design process this will be referred to as designers taking a 'strategic' role (after Bakker 1995). The contribution of industrial design practice in a strategic role to the three outcomes that need to be achieved in a product development process is shown in Figure 16.

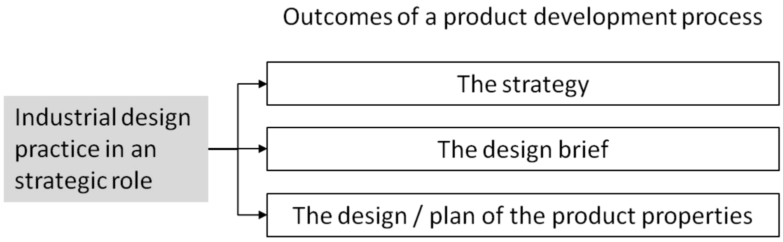


Figure 16: The contribution of industrial design practice in a strategic role to the outcomes of a product development process
(Source: created for this research)

The availability of representations of tentative solution suggestions facilitates exploring the appropriateness of these suggestions from the perspective of various stakeholders (Krippendorff 2005). Industrial designers are particularly capable of generating holistic representations of tentative solution suggestions—for example in the form of sketches and prototypes. This activity and critically reflecting on the suggested solutions are important for understanding a consumer's perspective on them. This makes the explorative capacity of industrial design practice particularly relevant for the strategy and the formulation of the design brief in cases where high degrees of novelty from a consumer perspective are achieved (De Mozota 2003). It can not only help to evaluate how well new designs meet current consumer needs, but also to 'discover hidden needs' (Best 2010, p. 40) which have been unexpressed or not yet fully articulated previously. This probably represents the most frequently discussed strategic use of solution-focused thinking in a product design process. Understanding what type of novelty consumers potentially perceive as valuable allows companies to gain a competitive advantage if they are amongst the first to offer these to the market.

Krippendorff (2005) highlights that industrial designers not only need to incorporate the perspective of the consumer into the way they plan the product properties. Even though they take the consumer perspective as a starting point, they also need to accommodate the requirements that are relevant from the perspective of the stakeholders who are involved in realising and commercialising the product. The explorative capacity of practicing solution-focused thinking through the generation of representations of suggestions also plays an important role to consider the positions of these stakeholders, including their clients. For example, the engineers who are responsible for developing the tooling can only estimate the cost once they have access to a representation of the product (Goldschmidt & Porter 2004). Figure 17 restates the problem situation of industrial design practice as introduced in Sub-section 2.1.2. It highlights the capacity of industrial design to explore the perspective of the consumers and the requirements from the various stakeholders, involved in realising and commercialising the product with the dotted, bidirectional arrows. The arrows are bidirectional because the learning from the explorations in turn influences the industrial design practice.

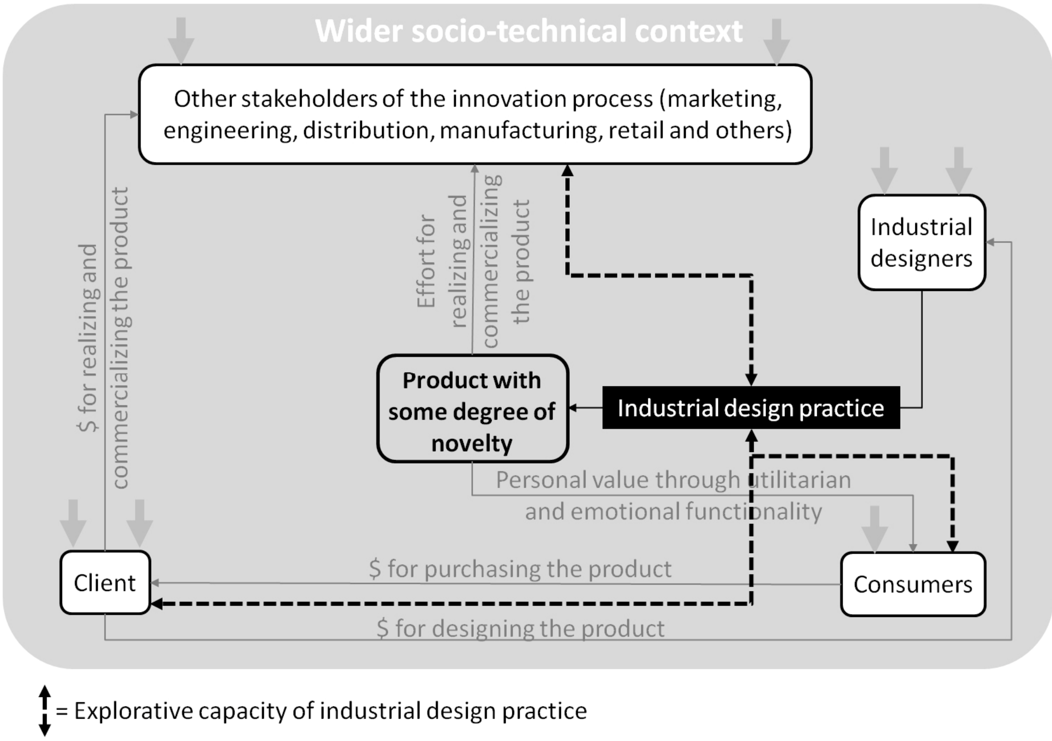


Figure 17: The explorative capacity of industrial design practice
(Source: created for this research)

2.5.3. Classifying product development processes—a more refined typology of the design problems of industrial design practice

There is a strong preference in the literature concerned with product development to classify seemingly clear-cut categories of product development processes, according to the degree of novelty that is achieved in a product. The most common one is to distinguish between new product development processes and redesign processes (see for example: Gassmann, Sandmeier & Wecht 2006; Herstatt, Verworn & Nagahira 2004; Koen et al. 2001).

The notion of clear-cut categories of product development processes can be problematic because it depends on the perspective from which this process is evaluated. The degree of novelty of a product always needs a reference point. Garcia & Calantone (2002) propose that products can be either new to the industry, new to the company; or new to the customers. While the differentiation of the degree of novelty that is perceived by individual consumers is subjective and can vary (Hekkert, Snelders & Wieringen 2003), distinguishing between improving an existing solution or designing a new one is fairly straight forward from the perspective of a company, conducting a product development process. From their perspective this distinction is also highly relevant as redesigning a product they currently have in their portfolio or developing one they have not been offering previously has different implications. This potentially applies to their supply chain, their skills and in some cases even to their business model.

On the other hand, from the perspective of the industrial designers distinguishing between product redesign and new product development is less clear (HCL 2007). As explained in Section 2.2, industrial designers apply in both cases the same way of reasoning, comprising an alternation between problem and solution-focused thinking and critical reflection. Drawing on the solution-focused element of Design Thinking 'primary generators' (Darke 1979) and learning from an active involvement in trying to resolve a problem situation both stimulate industrial designers in the development of solution suggestions. As industrial design practice always seeks to achieve some degree of novelty, these 'primary generators' can never be situated only in the current product of their client. Thus, they always go beyond merely building on these products. How far they diverge from this reference point not only depends on where they draw their inspiration, but also on the 'back-talk' from the problem situation and the 'surprises' they encounter (see Figure 6). Case studies such as the one conducted by Feldman & Boult (2005) also show that the explorative capacity of solution-focused thinking can potentially expand the scope of product development processes that initially start out as redesign processes to new product development processes. The important factors that need to align to allow for such expansion of scope include facilitating an environment that does not prevent solution-focused thinking, and the capacity of the industrial designers to propose solutions that allow the exploration of new directions (Feldman & Boult 2005). In other words, the degree of novelty that can be achieved in a product development process partially depends on the solutions that are proposed by the industrial designers.

In conclusion the two roles, industrial designers can play in a product development process are not clear-cut distinguishable categories. They are more appropriately seen as two ends of a spectrum. The more the role of industrial designers can be described as strategic, the more it is structured according to the descriptive models that are based on the reflective practice paradigm. The more the role of industrial designers can be described as operational the more it is structured according to the prescriptive models that are based on the rational problem-solving paradigm. While the positioning of the role of industrial design on this spectrum depends partially on the preconditions for the product development process, it also is influenced by the extent of solution-focused thinking and the directions that are explored.

2.6. Concluding summary

This chapter has described the general influence of industrial design practice on the goals of a product development process and the product designs. It has highlighted three important points.

Firstly, industrial design practice has an inherent economic and social agenda. Its economic agenda seeks to generate monetary value for the clients of industrial design practice and for the industrial designers. The social agenda of industrial design practice demands the prioritisation of the needs of the individual consumers by developing products with utilitarian and emotional functionality consumers perceive as valuable. The economic agenda of industrial design practice can only be met by addressing this social agenda because the monetary value that can be generated through industrial design practice depends on consumers perceiving a product as valuable enough to purchase it.

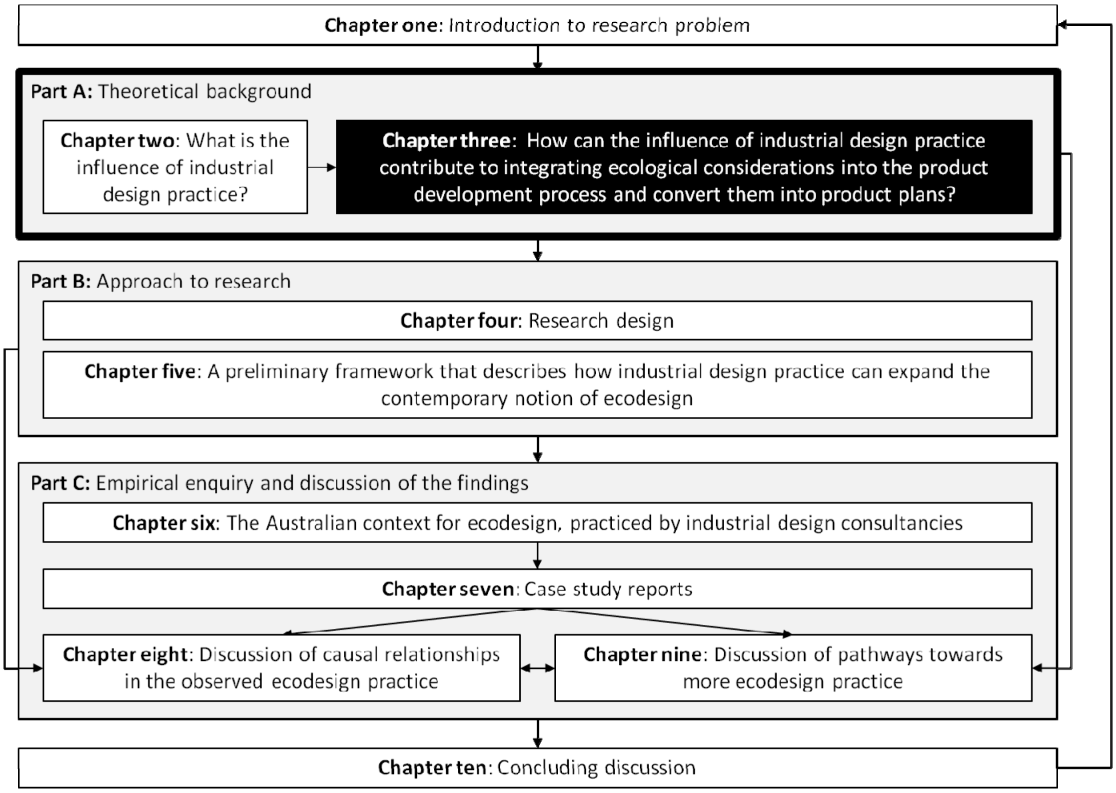
Secondly, industrial design practice can influence the technology and the meanings of a product design. The influence industrial design practice has on the product designs can be conceptualised in a two-dimensional diagram. One axis describes the technological dimension, and the other axis describes the meaning dimension. The technological dimension conceptualises the influence of industrial design practice on the technology that is embodied in a product and necessary to manufacture and distribute it. The meaning dimension describes the influence of industrial design practice on how consumers perceive and understand a product—how they make sense of it. Even though industrial designers cannot dictate the meanings consumers attach to products, they can make suggestions for certain meanings by manipulating the product-consumer interface. Both dimensions are important for developing products consumers perceive as valuable. Influencing the technological dimension is necessary to provide utilitarian and emotional functionality, whereas influencing the meaning dimension can help consumers to access this functionality.

Thirdly, Industrial design practice can facilitate a learning process that informs the goals of a product development process. The underlying logic industrial designers use to structure their practice when addressing their two agendas, *Design Thinking,* comprises problem- and solution-focused elements. Problem-focused logic follows a linear structure. It seeks to first understand the problem situation and formulate the requirements for the product designs. It then proceeds to synthesise these requirements and finally to evaluate if the results meet the initially formulated requirements. However, the problem situations that industrial designers are confronted with do not allow establishing all requirements for the product designs upfront.

How the economic and social agendas of industrial design practice are best addressed is underdetermined to varying degrees, and can only be understood by engaging in a dialogue with the problem situation through developing and testing solution suggestions. Thereby these solution suggestions are not only a means to explore the problem situation but they also determine it. The solution-focused element of Design Thinking is important for achieving higher degrees of novelty in particular in regard to the meaning dimension. The learning facilitated by the solution-focused element of Design Thinking can be used strategically to inform the goals of the product development process.

These insights are used in Chapter 3 as reference point for reviewing the contemporary literature about the ecodesign idea with regard to its relevance for industrial design practice.

CHAPTER 3. INCORPORATING THE ECODESIGN IDEA INTO INDUSTRIAL DESIGN PRACTICE



This chapter engages with the literature about the idea to incorporate ecological considerations into design practice. This idea is termed the *ecodesign idea*[11] in this thesis. The major part of this chapter reviews concepts that share the ecodesign idea. The goal of this review is to articulate the theoretical potential of industrial design practice to support the integration of ecological considerations in the product development process and convert them into product designs. To meet this goal, it uses the insights about the influence of industrial design practice from Chapter 2 as a reference point. This allows the relevance of the concepts that share the ecodesign idea for industrial design practice to be evaluated. The conclusions from this review are used in this thesis in two ways. Firstly, the remainder of this chapter builds on them to examine empirical studies into the application of the ecodesign idea. This examination clarifies how far these studies already provide insights in the application of industrial design practice to incorporate ecological consideration into commercial product development processes and convert them into product designs. It also highlights the gaps these studies leave unaddressed. This provides a basis for the research design of the empirical enquiry of this thesis that is described in Chapter 4. Secondly, the conclusions from the review of concepts that share the ecodesign idea serve as basis for Chapter 5. Chapter 5 develops a preliminary theoretical framework that describes the potential of industrial design practice to support the integration of ecological considerations in the product development process and convert them into product designs. This framework is used in the subsequent chapters to structure the empirical enquiry of this thesis and to guide the analysis of the collected data.

This chapter is divided into six sections and a concluding summary.

- **Section 3.1** explains the difficulty with evaluating the relevance of concepts that share the ecodesign idea for industrial design practice. It proposes to address these difficulties by tracing three transitions within the development of the understanding of the ecodesign idea:
    - The broadening of the underlying perspective from focusing on isolated product qualities to a consideration of the entire socio-technical system (addressed in Section 3.2.)
    - The expansion of the agenda from an ecological agenda to a sustainable agenda (addressed in Section 3.3.)

[11] This term is not the same as what is traditionally understood as ecodesign. As explained in this chapter, incorporating the ecodesign idea in industrial design practice can expand this traditional notion of ecodesign.

    - A widening of the research focus from success factors for integrating the ecodesign idea into a commercial context to design within society (addressed in Section 3.4.)

- **Section 3.2** describes the underlying perspectives of the concepts that share the ecodesign idea. The understanding of the relationship between the negative ecological impact of society and the design of products has developed over time. The concepts that share the ecodesign idea take the need to reduce the negative ecological impact of society as a starting point to deduct instructions for design practice. This has also resulted in different perspectives on the role and capacity of design practice to address this impact.
- **Section 3.3** discusses the expansion from an ecological agenda to a sustainable agenda in the concepts that share the ecodesign idea. Building on this discussion and the insights of Section 3.2, it develops a typology to position the incorporation of the ecodesign idea into industrial design practice relative to the two groups of concepts, described as sustainable design and ecodesign.
- **Section 3.4** engages with the discussion about integrating ecological considerations in product development processes. Based on the conclusion from Section 3.3 that an incorporation of the ecodesign idea into industrial design practice is positioned between the two groups of concepts, described as sustainable design and ecodesign it identifies what can be learned from both groups.
- **Section 3.5** builds on the conclusions from sections 3.2, 3.3 and 3.4, and develops a suggestion for an expanded notion of ecodesign to describe the integration of the ecodesign idea into real-world industrial design practice. It also reviews publications about past empirical investigations into the integration of ecological considerations into industrial design practice in regard to how well they provide insight into a potential real-world application of the expanded notion of ecodesign.
- **Section 3.6** summarises the two key insights of this chapter. Firstly, it restates the suggestion for the theoretical potential of industrial design practice to support the integration of ecological considerations in the product development process and convert them into product designs. Secondly, it highlights again where past empirical studies have failed to develop a comprehensive understanding of the influence of industrial design practice to support the ecodesign idea.

3.1. Confusion about incorporating the ecodesign idea into industrial design practice

Addressing the ecological crisis society faces—via means such as designing products so that their associated ecological impact is minimal—is clearly worthwhile. However, the possible contribution of industrial design practice to this endeavour is ambiguous. The role of industrial designers for integrating ecological considerations into product development processes and converting them into product concepts has been acknowledged as important (Best 2010; International Council of Societies of Industrial Design 2013; Lofthouse & Bhamra 2001; Schmidt-Bleek 1994) but not explicitly articulated. The literature provides a confusing multitude of terms that describe concepts that all share the ecodesign idea, including *green design* (Mackenzie 1997), *ecodesign* (Tischner et al. 2000), *ecological design* (White, Belletire & St Pierre 2009), *sustainable design* (Keitsch 2012), *design for sustainability* (Crul, Diehl & Ryan 2009), *design for environment* (Fiksel 1996), *design for environmental sustainability* (Vezzoli & Manzini 2008), and *responsible design* (Stevenson et al. 2011). In some publications, these terminologies—or at least a number of them—are used interchangeably (see for example: Boks & McAloone 2009; Collado-Ruiz & Ostad-Ahmad-Ghorabi 2010). Other publications, sometimes even by the same authors, insist that the different terminologies also describe different but related concepts (see for example: Charter & Tischner 2001; Crul, Diehl & Ryan 2009; McAloone 2000) and that it is important to explicitly acknowledge their individual characteristics (McAloone 2000). In other words, how the ecodesign idea is interpreted and how the concepts describing the accordant design practice are termed varies.

As there is no consistent terminology for concepts that describe the ecodesign idea, this thesis needs to establish explicit definitions for how the terms it applies are understood. To some degree, the inconsistencies in the terminology may be caused by a careless use of language. A more in-depth engagement with the literature reveals that they also reflect a learning process that happened within the scholarly community. The understanding of the implications of the ecodesign idea has developed over time (Boks & McAloone 2009; Crul, Diehl & Ryan 2009; Vezzoli & Manzini 2008).

3.1.1. Ecodesign and sustainable design: the two dominant groups of concepts that share the ecodesign idea

Some authors such as Charter & Tischner (2001) propose that within the learning process that clarified understanding about the ecodesign idea, two concepts can be distinguished: *ecodesign* and *sustainable design*. However, as highlighted above, the terms are not used coherently in the literature and thus cannot readily be used for orientation. Thus it needs to be further substantiated how these authors distinguish ecodesign and sustainable design.

Charter & Tischner (2001) explain that they understand ecodesign as incorporating ecological considerations into design practice that happens in the context of a commercially-driven product development process. Sustainable design, according to Charter & Tischner (2001), differs from ecodesign in two regards. Firstly, besides pursuing an ecological agenda it also has an explicit social and economic agenda that aims at improving equity within society. These three agendas align with the three goals or 'pillars' of sustainable development (United Nations 2005): enhancing equity in economic and social development, and lowering the negative impact of society on the earth's ecosystem. The social agenda demands explicitly considering and addressing issues such as fostering democratic decision-making, community building, public health and education (Crul, Diehl & Ryan 2009; Manzini & Meroni 2007; Vezzoli & Manzini 2008). In the literature concerned with the ecodesign idea, the economic agenda is not discussed in the same depth as the social and ecological agenda of sustainable design. Some authors do not make it explicit at all. Like the social agenda it echoes, the concept of sustainable development in aiming for achieving a more equal distribution of the value that is generated in a design process (Dewberry 1996). The second aspect in which ecodesign differs from sustainable design according to Charter & Tischner (2001) is its underlying perspective. They propose that sustainable design takes a more systemic view that provides the concept with further reaching influence and allows it to achieve higher degrees of change. Applying this distinction to the concepts, described by different authors, allows them to be sorted in two different groups. For example, the concepts that are described by authors like Lewis et al. (2001), Tischner et al. (2000), White, Belletire & St Pierre (2009) and Wimmer, Züst & Lee (2004) classify as *ecodesign*. The concepts for design practice that are proposed by authors like Fry (2009), Fuad-Luke (2009),Walker (2006) and Thorpe (2010) fall within the category of *sustainable design.*

Where industrial design practice sits relative to these two groups of concepts remains unclear. Sherwin (2004) proposes that ecodesign, as practiced by industrial designers, resembles sustainable design. Opposite that, numerous authors whose concepts can be classified as sustainable design claim that the concepts they propose are either not applicable or are applicable only to a limited degree in the current commercial context of industrial design practice (Chick & Micklethwaite 2011; Fuad-Luke 2009; Walker 2006). In other words, it seems like industrial design practice can offer the potential to take the ecodesign idea beyond the concepts that are classified as ecodesign but that it has constraints with regard to embracing those concepts classified as sustainable design. The learning process that happened in transitioning from ecodesign to sustainable design has left industrial design practice behind.

3.1.2. Where was industrial design practice left behind?

It is difficult to precisely identify the point at which the learning process within the scholarly community about incorporating ecological considerations into design practice has left industrial design practice behind. The way this learning process is usually illustrated and discussed in the academic literature can be described as somewhat egocentric. It has a strong bias towards explaining the areas where researchers focused over the past and should focus in the future to progress knowledge about how ecological considerations should best be incorporated into design practice (see for example: Boks & McAloone 2009; Vezzoli & Manzini 2008). Little attention is given to the perspective of professional designers—in particular industrial designers—on the transitions in the research focus other than drawing out that the applications of the ideas that scholars propose lags behind in real-world application and education[12]. One potential explanation for the current divergence between theory and practice can be that any new knowledge needs to be learned first by real-world practitioners and educators, a process that requires time. However, as mentioned above, authors such as Chick & Micklethwaite (2011), Fuad-Luke (2009) and Walker (2006) highlight a partial to complete lack of applicability of a number of concepts that can be classified as sustainable design in the current commercial context of industrial design practice. Thus, this thesis argues that a divergence of theory and practice may also be caused by an incompatibility between the two.

To understand the role of industrial design practice in contributing to the development of products that help to reduce the ecological impact of society, it is useful to position it within the learning process that happened in the scholarly community. This thesis argues that this can be done by drawing out three transitions that happened within this learning process:

- A broadening of the underlying perspective from focusing on isolated product qualities to a consideration of the interrelationship between the product and the entire socio-technical system,
- The expansion of the agenda from an ecological agenda to a sustainable agenda, and
- A widening of the research focus from success factors for integrating the ecodesign idea into a commercial context to design within society.

These three transitions are interwoven, happened to a large extent simultaneously and cross-fertilised each other. However, for understanding the role of industrial design practice, it is

[12] This thesis does not imply that the theory development ignores or has ignored real-world product development practice. On the contrary, a lot of empirical research has been conducted. However, as will be explained in section 3.5 of this chapter, these investigations failed to fully account for the role of industrial design practice by either taking a too-broad or too-narrow focus.

useful to separate them at the theoretical level. This is because industrial design practice has inherent limitations in terms of fully embracing each of these three transitions. Thus, distinguishing them allows for a more nuanced positioning of industrial design practice with regard to the concepts that share the ecodesign idea. The subsequent sections each describe one of these transitions. Thereby, the broadening of the underlying perspective from focusing on isolated product qualities to a consideration of the interrelationship between the product and the entire socio-technical system is discussed in the highest degree of detail. The expansion of the agenda from an ecological to a sustainable agenda and the widening of the research focus from design practice to design within society are then described in relationship to the broadening of the underlying perspective over time.

3.2. The different perspectives on the *ecodesign idea*

The motivation to devote attention to the ecodesign idea is the awareness that the design of products contributes negatively or positively to the ecological impact of society. The understanding of the relation between the design of products and their associated contribution to the ecological impact of society has changed over time. This has also resulted in different perspectives on the role and capacity of design practice to address this impact. This thesis identifies three different perspectives. To differentiate them the following terms are used:

- isolated product qualities perspective
- technical perspective
- socio-technical perspective.

These terms are explained in detail in Box 7. Putting the three perspectives in a consecutive order roughly describes how the understanding within the scholarly community has developed. Thus, the socio-technical perspective can be seen as the most progressive one. However, to develop a typology that allows one to position industrial design practice in relation to the development of the understanding of incorporating ecological considerations into design practice of the scholarly community, it is necessary to discuss all three perspectives. It is important to consider the technical perspective because it is the dominant perspective from which the integration of ecological considerations into the current commercial context of industrial design practice is described (see for example: Tischner et al. 2000; Wever & Boks 2007; Wimmer, Züst & Lee 2004). Also the isolated properties perspective cannot be readily dismissed. As Sub-section 3.2.1 explains, it has been proven that it is least likely to achieve benefits from an ecological perspective. However, it still is possible that design practice to address ecological issues in real-world product development processes is guided by the isolated product qualities perspective. Furthermore, a small number of contemporary authors such as McDonough & Braungart (2002) who advocate a strict prioritisation of full recyclability adopt the isolated product qualities perspective.

Each sub-section below discusses one of the three perspectives. Finally, Sub-section 3.2.4 positions industrial design practice relative to these three perspectives.

BOX 7
On terminology: Isolated product qualities perspective, technical perspective and socio-technical perspective

The terms for the three different perspectives on the ecodesign idea used in this thesis are not shared by the reviewed literature. Thus they are briefly introduced here.

What this thesis terms as *isolated product qualities perspective* describes the understanding that was, according to researchers such as Vezzoli & Manzini (2008), underlying in particular the early stages of the development of the ecodesign idea. The term isolated product qualities perspective has been chosen to highlight that authors who adopt it tend to focus on individual qualities of a product that are perceived as having ecological significance. An example for such a quality is the biodegradability of the applied material. The ecological performance of a product is not evaluated by taking its entire life cycle into account.

The *technical perspective* is commonly referred to as 'engineering perspective' (see for example: Charter & Tischner 2001) or 'life cycle perspective' (see for example: Vezzoli & Manzini 2008). For this thesis the term *technical perspective* was chosen to express that it narrows the focus of design practice on the technological dimension of the product properties. This phenomenon is explained in more detail in Sub-section 3.2.2. The other terms to describe this perspective are not used because they are confusing. 'Life cycle perspective' suggests that a consideration of the entire life cycle in the design of a product is exclusive to this perspective. This is misleading. As explained in Sub-section 3.2.3, this approach, which is also referred to as life cycle thinking (LCT), is also shared by the socio-technical perspective. The term 'engineering perspective' inappropriately implies a compulsory link to engineering professionals. Even though this perspective has strong roots in engineering, it can also be adopted by other design professionals.

What this thesis describes as *socio-technical perspective* is usually referred to as *systems perspective* (see for example: DeKay 2012). (continued on next page)

This is misleading because it implies that the technical perspective does not take a systemic view. As will be discussed in Sub-section 3.2, the technical perspective considers the quantifiable ecological impact along a product's entire life cycle, which requires seeing the product as part of a larger system. As both perspectives—the socio-technical and the technical perspective—account for the product being an integral part of a larger system, attributing the term *systems* only to one of them is misleading. The socio-technical perspective differs from the technical perspective in that it acknowledges that the ecological impact, associated to a product not only stems from the quantifiable properties of the product itself but also from its interrelation with the wider social context in which it is positioned. Consequently the term socio-technical perspective is used in this document instead of systems perspective.

3.2.1. The isolated product qualities perspective

Throughout design history the ecodesign idea got mentioned occasionally. Perhaps the earliest documented case of raising the ecodesign idea was when Schmidt-Hellerau (1912) called for resource-efficient design in the inaugural yearbook of the German Werkbund. The beginning of a serious debate about the ecodesign idea can be dated around the 1970s (Vezzoli & Manzini 2008; Walker 2006). Walker (2006) observes that during that time, events around the world caused a global increase in ecological awareness in western society. Examples are the energy crisis, caused by the OPEC oil embargo, the publication of books such as *The limits to growth* (Meadows et al. 1972) and the circulation of photographs of the earth that were taken from outer space. This provided a fertile ground for authors such as Papanek (1971) who played a pioneering role in advocating the ecodesign idea to the wider design community.

During the 1970s and up to the early 1990s most concrete suggestions that were made to the industrial design community to respond to the ecological problem were predominantly focused on isolated qualities of products (see for example: Elkington 1986; Möller 1982; Papanek 1971). The rise of the ecological awareness made the wider public conscious of phenomena that made apparent the negative ecological impacts of today's form of development. This in turn stimulated efforts to try and change the qualities of products that were seen as responsible for the observed phenomena. One example is an increased awareness in society about the waste problem caused by an increasing amount of products being disposed of. This motivated design interventions such as the use of biodegradable materials or to increase the recyclability of products. Another example is an increased sensitivity from governments, other institutions and consumers towards the harmfulness of certain substances for the environment and/or human health. Examples for initiatives that were triggered this way are the phase-out of CFCs (Hammitt 2000) and limiting the usage of certain hazardous substances in electronic products (Goosey 2004). The consequences of the design interventions were only accounted for in regard to how well they addressed the observed phenomenon, but not in regard to the overall ecological performance of the product.

The focus of the isolated qualities perspective covers the technological and the meaning dimension of the product properties

The isolated product qualities perspective does not only focus on materials. Most of the concrete suggestions for design interventions that can be found in the publications written from this perspective address the technological dimension of the product properties (see for example: Möller 1982). However in particular Papanek also engages with the meaning dimension of the product properties (Papanek 1971; Papanek 1995). For example, he criticises industrial design professionals for designing products with inbuilt obsolescence by creating product interfaces that stimulate consumers to purchase but are quickly perceived as out-dated. Papanek also opens an in-depth discussion about the role of industrial design within society with regard to its general responsibility for the negative ecological impacts of consumerism as well as in regard to its potential to address social inequality. As Sub-section 3.2.3 explains, by considering the role of design within a social context, Papanek already anticipated crucial elements of the socio-technical perspective.

Limitations of the isolated product quality perspective

A focus on isolated product qualities only when conducting ecologically motivated design interventions can be problematic. In some cases, like the phasing-out of CFCs and other harmful substances, this approach most likely has an ecological benefit. The necessity to avoid certain substances such as CFCs is usually informed by thorough research into their negative impact (see for example: Hammitt 2000 for the case of CFCs). In other cases where decisions for or against ecologically motivated design interventions are merely led by the subjective perception of the designer or other stakeholders in the product development process, such reliable reference points are missing. A good example that illustrates the limitations of the isolated product qualities perspective can be found in the work of Victor Papanek. In his book *The green imperative*, he argues that popcorn should be used instead of polystyrene as packaging material on the basis that popcorn comes from a renewable resource and is biodegradable (for more details see p. 35 in Papanek 1995). He focuses only on these two qualities of the material and does not account for the entire ecological impact associated with providing popcorn, using it as packaging material and disposing of it at the end of its life in that purpose. Even before Papanek published his book, Jolliet et al. (1994) showed that when considering the entire life cycle of the previously mentioned alternatives for packaging, popcorn can actually turn out to be the less favourable option in terms of its ecological impact. In particular, the farming of the corn can have significant negative ecological implications. For example, the necessary irrigation consumes significant amounts of water, fertiliser is applied and farming machinery consumes petro-chemicals to operate. In other words, Papanek appears not to understand the full implications of his decisions from an ecological perspective. By focusing only on the property of the corn itself, Papanek overlooks these 'hidden' ecological impacts. Because the isolated product qualities perspective fails to account for ecological impact of a product along its whole life cycle, it has two limitations.

Firstly, the isolated product qualities perspective is incapable of accounting for the full implications of ecologically motivated design decisions. Most design interventions have implications for the ecological impact of a product along the entire life cycle of the product. This is also true for those motivated by an ecological agenda. Thus, design interventions that result in a desirable ecological performance of a product at one stage of its life cycle may cause negative ecological impacts at other stages, nullifying or even outweighing the benefits (Klöpffer 2003). In the popcorn example, factors associated with supplying raw materials can be more significant for popcorn than for polystyrene, outweighing potential benefits from popcorn being a plant-based material. A similar situation is discussed by Lockery (2010), who describes how the best efforts to design for disassembly to improve recyclability are in vain and might even have negative effects if no thought is given to whether the product ends up in an appropriate recycling facility.

Secondly, the isolated product qualities perspective leaves unclear whether the most significant negative ecological impact of a product is targeted. The negative ecological impact of a product happens along its entire life cycle and its underlying causes are often not obvious to people who are not trained environmental scientists. Thus, it is often difficult for designers to identify the areas that need attention. This can result, for example, in an inappropriately high focus on individual properties of products just because this negative ecological impact is directly perceptible and understandable (Hauschild, Jeswiet & Alting 2004). Boks (2008) observes this phenomenon in regard to the attention given to understanding how to lower the ecological impact of products at the end of their useful life.

3.2.2. The technical perspective

The technical perspective helps to overcome the limitations of the isolated product qualities perspective by considering the quantifiable ecological impact of a product along its entire life cycle. This allows (i) identifying and addressing the most relevant ecological impact of a product and (ii) identifying and mediating trade-offs of design interventions that decrease the ecological impact of a product at one stage of its life cycle, but increase it at another stage. This approach is also termed *life cycle approach* (Manfredi et al. 2012) or more commonly, *life cycle thinking* (LCT) (Chomkhamsri & Pelletier 2010; Clift 1998). The term LCT will also be used from now on in this thesis. To practice LCT, information about the ecological performance of a product along its life cycle needs to available. Traditionally such information is derived from a method that is referred to as *life cycle assessment* (LCA) (Baumann & Tillman 2004).

The roots of the technical perspective

The technical perspective focuses on making step-by-step improvements on the technological dimension. To understand why this is the case, it is necessary to trace back how it came about. The technical perspective has its roots in the efforts to integrate LCA into the product development process. Vezzoli & Manzini (2008) explain that in the 1990s in particular, significant effort was directed towards integrating information derived from LCA into product development processes to inform decision-making for or against design interventions. LCA does not directly originate from a product design background. The first LCA studies date back to the 1960s and were mainly concerned with manufacturing decisions around beverage containers (Hunt, Franklin & Hunt 1996). In its original and most common application, LCA is a comparative method that allows to identify how a function is best provided from an ecological perspective (Klöpffer 2003). For this purpose, a functional unit is defined. A product or service ‘may have a number of possible functions and the one(s) selected for a study depend(s) on the goal and scope of the LCA. The functional unit defines the quantification of the identified functions (performance characteristics) of the product.’ (International Organization for Standardization 2006, p. 12). Because LCA is a quantitative method, the functional unit can only capture the utilitarian functionality of a product or service, as emotional functionality is qualitative. For example, the previously cited LCA study of Jolliet et al. (1994) that compared popcorn and polystyrene as two alternatives for packaging defined a certain volume of padding as the functional unit. After defining the functional unit, LCA assesses the associated ecological impact for each solution to provide the functional unit. This assessment covers the entire life cycle, ranging from resource extraction over manufacture, distribution and use to the final disposal. It results in ecological impact profiles for each solution and thus allows their comparison.

The traditional ecodesign process and the link to the engineering profession

Even though LCA is traditionally used as a comparative method, it can also be used to generate impact profiles of reference products or product groups that show their most relevant ecological impact (Millet et al. 2007). This information can then serve as an orientation when making design decisions to either improve the ecological performance of the reference product or to design similar products with an optimised ecological performance. At the end of the process, LCA can be used again to evaluate the ecological improvements that were achieved. This was also the way how LCA was used in demonstration projects such as the EcoReDesign™ Program at the Royal Melbourne Institute of Technology (RMIT) that were undertaken to showcase how to design ecologically improved products (Sweatman & Gertsakis 1997).

The underlying logic of this approach is problem-focused. It applies the steps analysis, synthesis and evaluation in a consecutive order. This aligns well with the prescriptive models for the design process, introduced in Sub-section 2.2.1. Thus, integrating LCA into the product development process also bears the risk of imposing this prescriptive structure. This can be observed in particular in the literature about the ecodesign idea from the 1990s and early 2000s. Most of it shows a strong bias towards structuring the design process according to prescriptive models of the design process (see for example: Brezet & Van Hemel 1997; Fiksel 1996; Lewis et al. 2001; Tischner et al. 2000; Wimmer, Züst & Lee 2004). Some authors such as Fargnoli (2009) even explicitly articulate this preference. They all describe what is commonly referred to as an *ecodesign process*. Such a traditional ecodesign process is shown in Figure 18.

As discussed in Chapter 2, engineering professionals in particular favour this way of organising their design practice. In this thesis it is proposed that this may explain why, after overcoming the isolated product property perspective, the ecodesign idea was predominantly taken up by the engineering profession (Charter & Tischner 2001).

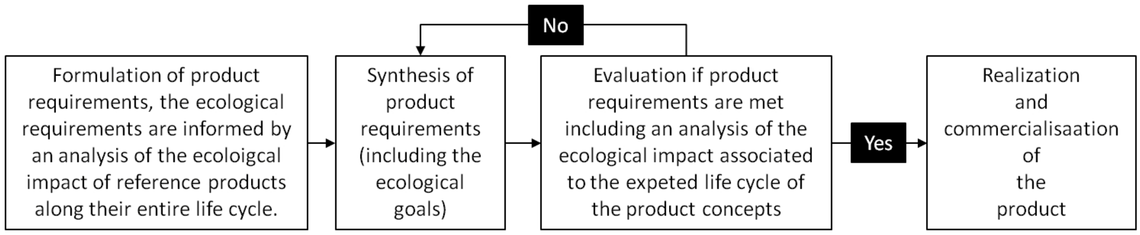


Figure 18: The structure of a traditional ecodesign process
(Source: created for this research)

The link to the engineering profession offers one explanation why the technical perspective does not devote much attention to emotional functionality or the meaning dimension of product properties. The technical perspective focuses on influencing the technological dimension of the product properties when converting ecological considerations into product designs. The extent to which authors who adopt the technical perspective acknowledge the possibility of influencing the meaning dimension is usually only relegating to the fact that products need to be acceptable (Charter & Tischner 2001) or attractive (Tischner et al. 2000) to consumers. Another reason for the neglect of these aspects may be the prominence LCA gives to the utilitarian functionality of a product through the necessity to formulate the functional unit.

In order to explain the nature of the technical perspective, it is important to introduce LCA and explain its role in the development of the understanding of the ecodesign idea. The topic of LCA will also be taken up again when discussing the tools that are available for industrial designers to practice LCT under Sub-section 3.2.4. However, as explained in Box 8 this thesis does not extensively engage with the debates of the research community around LCA.

BOX 8
Engagement with LCA in this thesis

Even though the logic of LCT builds on LCA, and information to practice LCT is often derived from LCA, this thesis does not expect that industrial designers actively engage in conducting a full LCA. Many researchers have highlighted that conducting LCAs is beyond the specialised knowledge of product development professionals (Millet et al. 2007; Ryan 2004; Tischner et al. 2000). Thus, LCA-based knowledge to support LCT in a product development process can be expected to be provided either through LCA experts or through tools that allow industrial designers to access this information themselves. Consequently, most critical decisions in LCA that cause debate in the LCA community are more important for tool developers and experts than for industrial designers. (continued on next page)

For example, the selection and prioritisation of impact categories is considered difficult (Millet et al. 2007; Reap et al. 2008) but is largely pre-empted in the design of the tools that are available to industrial designers. The choice of impact categories for assessment depends on the goal and scope of the LCA. Common (but not binding) impact categories include: the contribution of a product to global warming, ozone layer depletion, acidification, eutrophication, photochemical oxidants and abiotic resource depletion (see for example: Wimmer, Züst & Lee 2004). An LCA that compares two solutions may reveal that one solution has a lower ecological impact in one category, but a higher impact in another category. To make a decision for or against one of the two solutions, it is necessary to weigh the importance of the impact categories. The selection of the impact categories and their weighing are inherently subjective (Millet et al. 2007) and can significantly change the conclusions that are drawn from an LCA. Tools that have been developed to allow industrial designers to assess the ecological impact of a product along its entire life cycle (such as Sustainable Minds, Product Ecology Online and SolidWorks Sustainability /Sustainability Express) already pre-determine most of these decisions. They do not allow for the choosing the impact categories. Also, the decisions regarding weighting are mostly made by the tool developers. Sustainable Minds, for example, already computes the impact categories that the developers of the tool identified as most relevant into one single indicator (Sustainable Minds 2013). Product Ecology Online (WSP 2010) and Solid Works Sustainability / Sustainability Xpress (SolidWorks 2013) provide insights into three or four indicators, respectively. While this still requires the designers to make a subjective decision, the scope of this decision is reduced compared to conducting a full LCA.

For further reference about LCA:

- A detailed procedure for how to conduct a full LCA can be found in the ISO 14040 (International Organization for Standardization 2006) and in various manuals (see for example: Baumann & Tillman 2004; Guinée et al. 2002; Wimmer, Züst & Lee 2004).
- For an overview of unresolved problems with LCA, see in particular: Reap et al. (2008).

Limitations of the technical perspective

The technical perspective has helped to achieve quantifiable improvements of the ecological impact of individual products. However, authors such as Vezzoli & Manzini (2008) and Fletcher & Goggin (2001) question if it provides a satisfactory explanation for how ecological considerations should be integrated into design practice. Two points of critique are raised.

Firstly, literature written from a technical perspective has a strong bias towards understanding products only as technological solutions to provide utilitarian functionality. However, as explained in the next sub-section in more detail, the ecological impact associated with a product not only results from the technology that is embodied in the product and used to manufacture and distribute it. The ecological impact associated with a product also depends on its interrelation with individual consumers and its role in the wider societal context (Fry 2009; Schulze 2002). The focus of the technical perspective (on the technological dimension of the product properties and on assessing the quantifiable ecological impact associated with the physical embodiment of the product) does not allow these issues to be taken into account. Particularly, it ignores the less tangible, emotional functionality of a product and the role of the product within the wider societal context. As explained in more detail in Sub-section 3.2.4, this thesis proposes that the capacity of industrial design practice to manipulate product meanings by influencing the product-consumer interface offers a possibility to address this shortcoming.

Secondly, the degree of novelty achieved by the technical perspective is seen as insufficient (Halila & Horte 2006; Vezzoli & Manzini 2008). Higher degrees of novelty are also associated with higher degrees of change, and also offer greater potential for improvement of the ecological impact. However, the traditional ecodesign process (shown in Figure 18) has difficulties in achieving high degrees of novelty. Its linear structure implies that only those product requirements formulated in the beginning can be considered by the design practice and have a chance to be reflected in the final product design. This has led to the belief that it is best to formulate ecological requirements as early as possible in the ecodesign process and to do so with the highest degree of detail (Dewulf, Wever & Brezet 2012; Tischner et al. 2000). However, it can be questioned if this is generally true. In the past, this has led to product designs that orient themselves closely on the reference solutions that were assessed to formulate the ecological goals in the beginning of the ecodesign process—so-called *redesigns* (Dewberry & de Barros 2006).

The difficulty of the traditional ecodesign process to achieve higher degrees of novelty has also been recognised by authors who adopt the technical perspective. In response to this issue, these authors have made a range of suggestions. Examples are ‘Front Loading’ (Front Loading aims for a complete problem definition as early as possible even if it is associated to uncertainty. For a detailed description see: Dewulf, Wever & Brezet 2012), multi-criteria selection approaches (see for example: Tischner et al. 2000) and models of the fuzzy front end[13] (Wever & Boks 2007). However, none of these approaches moves beyond a problem-focused logic, suggesting a linear design process. Consequently, they have difficulties in explaining how to overcome the necessity of having a well-defined starting point from which step-by-step improvements can be planned. As explained in more detail in Sub-section 3.2.4, this thesis proposes that the capacity of industrial design practice to draw on the solution-focused element of Design Thinking offers a possible pathway to overcome this lock-in to only incrementally improve existing product concepts.

3.2.3. The socio-technical perspective

The socio-technical perspective also embraces the concept of LCT. However, the socio-technical perspective does not have an exclusive focus on the technological dimension of the product properties and the quantitative ecological impact of the individual product. It acknowledges that besides looking at the ecological impact of a technology, it is also important to consider the wider 'impacts and social transformations' of an innovation (Geels 2004, p. 898). In other words, it conceptualises innovation within a socio-technical system (Geels 2004)—hence the name chosen for use in this thesis. This expansion is important because the interrelation of a product with its surrounding social context plays a significant role for its associated ecological impact. This is true for the direct relation between the products and the consumers, as well as for the role of products in the wider societal context.

Obvious examples that demonstrate the importance of considering the relation between products and consumers to design are the attitudes and behaviours of individual consumers associated to the product they interact with. For instance, the emotional relationship between a product and a consumer can prevent or stimulate perceived obsolescence (Chapman 2005; Van Hinte 1997; Van Hinte 2004). Perceived obsolescence may lead consumers to discard a product well before the end of its useful life. This not only causes avoidable waste but may also lead to an unnecessary increase in consumption when consumers replace the discarded products. Consequently, a number of researchers have focused on using design to influence the attitude and behaviour of individual consumers (see for example: Lilley 2009; Wever, van Kuijk & Boks 2008). Other scholars highlight that the role of products within their broader social context is important to consider with regard to the ecological impact of society (Fry 2009; Thorpe 2010; Wahl & Baxter 2008). In particular, Fry (2009) points out that design plays an active role in shaping values and perceptions in society which can be utilised for (and

[13] Models of the fuzzy front end are conceptualisations of the innovation process that follow a problem-focused logic but try to accommodate for change beyond incrementally improving existing product concepts by describing the early stages of an innovation process as more iterative and explorative (see for example: Koen et al. 2001).

against) sustainable development. The socio-technical perspective also demands the consideration of potential rebound effects as consequences of design decisions (Vezzoli & Manzini 2008). The *rebound effect* describes the phenomenon when an ecologically improved solution leads to an increased the level of overall consumption to an extent that ultimately outweighs its ecological benefits. These rebound effects can be direct or indirect (Hertwich 2005). For example, a *direct rebound effect* can be caused by the increased use of an energy-efficient device. An example for an *indirect rebound effect* is when monetary savings, facilitated through an energy-efficient device increase consumption elsewhere, causing negative ecological implications.

Because the socio-technical perspective expands the focus of design practice beyond the individual product to its role in society, it also allows questioning of whether this role can be fulfilled differently. This is necessary to overcome the lock-in of the technical perspective on incrementally improving pre-existing products. The literature that is written from a socio-technical perspective is also much more diverse in terms of what is designed. Some publications even leave this completely open and discuss the possible contribution of design practice to the ecodesign idea at a very general level (see for example: Fry 2009; Wahl & Baxter 2008; Young 2010). Others focus on the professions of product service systems design, which are closely related to industrial design (see for example: Manzini & Vezzoli 2003) or interaction design (see for example: Blevis 2007). Still, some authors direct their main attention towards physical objects, whilst also acknowledging the influence of design on the role of the object within its social context (see for example: Walker 2006).

BOX 9
Are there different types or levels of innovation?

The literature about the ecodesign idea tends to distinguish between different types or levels of innovation that are associated with different degrees of novelty and can achieve different scales of ecological impact reduction. The probably most widely-used conceptualisation is the one by Brezet (1997). He distinguishes four different levels and allocates the lowest improvement potential to redesigning existing product concepts for eco-efficiency, and the highest potential to innovations at a system level. Brezet (1997) further argues that higher levels of innovation require more time to develop and unfold (see Figure 19).

(continued on next page)

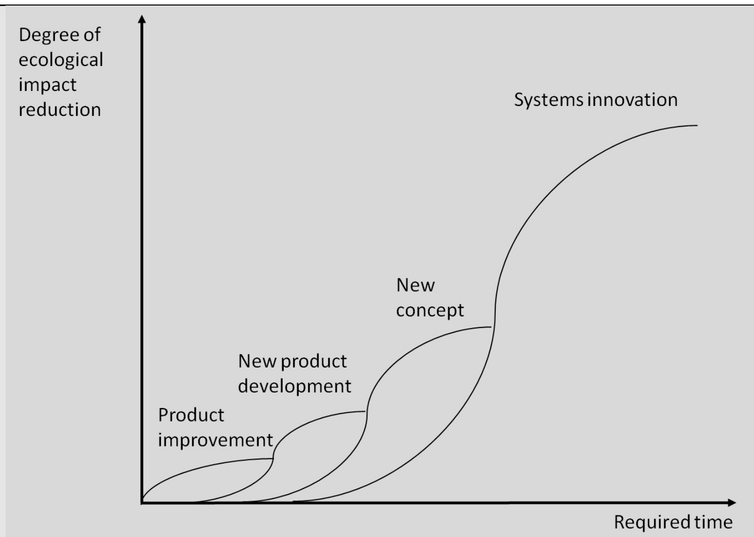


Figure 19: Types of innovation, associated time required and impact reduction potential (Reproduced from: Brezet 1997)

While product improvements are seen as essential, only system innovations are seen as having sufficient potential to reduce the ecological impact of society in order to achieve sustainable development (Berkhout 2002). Andersen (2008, p. 320) describes system innovations as ‘eco-innovations which are so radical and systemic in character that they involve complementary changes in production and consumption patterns, often involving considerable institutional change.’ The model of Brezet (1997) can be useful in several ways. One is to conceptualise the possible contributions of an innovation to the reduction of the overall ecological impact reduction of society. It is used in this way by several authors such as Bhamra et al. (2001), Crul, Diehl & Ryan (2009) and Gaziulusoy (2010).

However, even though Brezet (1997) builds his model on empirical experiences, his proposition can be challenged. The distinction between different levels is merely conceptual—in particular, the split-off of a system innovation. Innovations always happen within a wider context. For example, as discussed in Chapter 2, any change to a product that can be recognised by the consumer also influences a product’s meaning and thereby brings along change that goes beyond the physical tangible object itself. Even discrete changes on the technological dimension of products may have further, potentially far-reaching implications. For example, low impact materials may require changes in the supply chain and in the production methods. Consequently, ‘there is no dichotomy between systemic and in-house/stand-alone innovations’ (Andersen 2008, p. 323). Another example of a potential weakness of the model of Brezet (1997) are the time-frames he proposes. It remains unclear if they generally apply. (continued on next page)

The pace of innovations can vary significantly (Grossman & Helpman 1993), and it does not always have to be the case that more radical innovations require more time than less radical ones.

Distinguishing between different ‘levels’ or types of innovation is not useful when trying to understand the role of industrial design practice for integrating ecological considerations into product development processes and converting them into product designs. This is because different types of innovation also propose that different processes are necessary to achieve them. However, as explained in Sub-section 2.4.3, this does not apply from the perspective of industrial design practice. Thus, as this thesis focuses on industrial design *practice* rather than an assessment of the *outcomes,* it does not use a distinction between different types or levels of innovation.

3.2.4. Positioning industrial design practice relative to the different perspectives

As a conclusion from the three preceding sub-sections, it can be said that the focus of design practice from an isolated product qualities perspective only addresses individual aspects of products when converting ecological considerations into product designs. It does not account for the full consequences of this practice from an ecological perspective.

Design practice from a technical perspective does account for the quantifiable ecological impact along the entire life cycle of a product. However, it focuses only on the technological dimension of the product properties and prioritises problem-focused logic to structure the product development process. This has led to a strong tendency of authors adopting this perspective to concentrate on technical solutions when suggesting how to convert ecological considerations into product designs.

Design practice from a socio-technical perspective also accounts for the ecological impact of the products it designs along their entire life cycle. The socio-technical perspective moves beyond looking only at the technological dimension of the product properties; it also considers the role of a product in its direct and wider societal context. This view also allows questioning whether this role can be fulfilled differently. It even goes as far as allowing for the questioning of the role a product plays in society in the first place. When converting ecological considerations into product concepts, design practice from a socio-technical perspective not only seeks to improve technological solutions but also to achieve social change. Even though these three perspectives evolved over time and the socio-technical perspective can be seen as the most progressive, not all authors have adopted it. As Sub-section 3.3.2 and Section 3.4 discuss in detail, the integration of ecological considerations into design practice in the context of commercial product development processes is still associated with the technical perspective.

The three perspectives that this thesis distinguishes in the development of the understanding of the *ecodesign idea* are shown in Figure 20. Figure 20 highlights the requirements for transitioning from one perspective to another. Figure 20 also shows the perspective that can be adopted when incorporating ecological considerations into industrial design practice as proposed in this thesis. It is argued in this thesis that incorporating the ecodesign idea into industrial design practice allows going beyond the technical perspective, but has limitations in fully incorporating the socio-technical perspective. As explained below, this suggestion is partially informed by the conclusions that were drawn in Chapter 2 about the influence of industrial design practice, and partially by observations that were made by Sherwin (2000; 2004) and Bakker (1995).

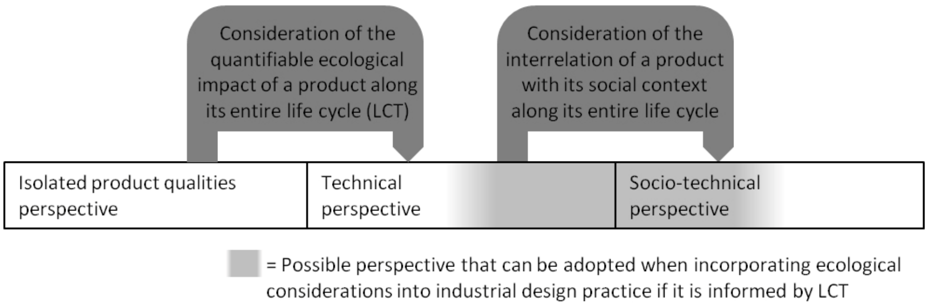


Figure 20: The three perspectives that this thesis distinguishes in the development of the understanding of the ecodesign idea, the requirements to transition between them and the perspective this thesis proposes for incorporating ecological considerations into industrial design practice
(Source: created for this research)

It is argued in thesis that if it is informed by LCT, the influence on the technological dimension of the product properties allows industrial design practice to comply with the technical perspective. Beyond this it is proposed that industrial design practice can also incorporate aspects of the socio-technical perspective. Chapter 2 concluded that industrial design practice not only influences the technological dimension of the product properties, but also their meaning dimension. The role of industrial design practice to manipulate the meanings consumers can attach to products brings along two implications. Firstly, it requires that industrial designers consider the interrelation of a product with its social context. Secondly, it allows them to exert influence on the product-consumer relationship and the immediate social context of the product through design interventions that impact on the product interface. This thesis assumes that industrial designers can use this capacity when converting ecological considerations into product designs. This would also allow them to address the claims of researchers such as Moreno, Lilley & Lofthouse (2011), who stress the importance of considering user-related aspects for eco-innovation. Industrial design practice can furthermore draw on the solution-focused element of Design Thinking, which—through its capacity to explore and determine a problem situation—can achieve higher degrees of novelty than when relying solely on problem-focused thinking. These qualities can allow industrial design practice to incorporate aspects of the socio-technical perspective.

The proposition of this thesis that industrial design practice can (i) influence the product-consumer relationship and (ii) achieve higher degrees of novelty than what can be explained by the technical perspective when converting ecological considerations onto product designs is supported by the research of Sherwin (2000; 2004) and Bakker (1995). Both observed settings in which industrial designers were asked to consider ecological impacts in their design practice. These industrial designers were also provided with ecological information that allowed them to practice LCT. Sherwin (2000) found that the industrial designers he supported in a pilot-project at Electrolux sought to influence consumer perception and behaviour through the way they designed the product interface when converting ecological considerations into product designs. He also found that the results of ecologically motivated industrial design practice often has a degree of novelty that is beyond step-by-step improvements of existing product concepts (Sherwin 2004). That industrial designers do not only apply problem-focused logic and also break away from reference solutions provided by drawing on the solution-focused element of Design Thinking is also supported by the report of an experiment conducted by Bakker (1995).

While the perspective proposed by this thesis for incorporating ecological considerations into industrial design practice overlaps with the socio-technical perspective, it has limitations in fully incorporating it. The focus of industrial design practice and the socio-technical perspective differ in terms of where within the socio-technical context they direct their attention. In the case of the socio-technical perspective, this is the entire socio-technical context whereas in case of industrial design this is the individual consumer-product relationship. As explained in Section 2.1, this focus of industrial design practice is prescribed by its commitment to create value for individual consumers. Consequently, the capacity of industrial design practice to directly address ecological issues that are connected to the role of the product within the wider social context (such as the rebound effect) has limitations.

The available support for LCT

LCT is required when incorporating ecological considerations into industrial design practice. Otherwise the isolated product qualities perspective cannot be overcome (see Figure 20). The necessary information for LCT is usually derived from LCA. The particular efforts during the 1990s to integrate LCA into the product development process showed that it is usually not feasible to conduct full LCAs in this context. The necessary time, effort and level of expert knowledge conflict with the cost- and deadline-driven environment of commercial product development processes. In response to these challenges, various LCA-based tools have been developed. These 'analytical tools' (Lewis et al. 2001, p. 41) allow designers to access the ecological impact that is associated with a product's life cycle more easily and quickly. To highlight their connection to LCT, they will be called *analytical LCT tools* in this thesis.

Besides reducing the effort associated to gaining relevant ecological information about the life cycle of a product, the development of the analytical LCT tools also sought to address a general design paradox. This paradox describes that the capacity to influence a product design is maximal at the beginning of the product development process, but information that is available to direct this influence is minimal at that point in time. This is because this information is only generated during the progress of the product development process. In order to also cater to ecological information needs at the early stages of a product development process, the analytical LCT tools that have been developed proceed to different levels of detail.

The more detailed analytical LCT tools are *streamlined LCAs*—computer programs that use databases with predefined materials and processes to reduce the time and effort involved in conducting an LCA and represent the information in a form that does not require expert knowledge (see for example: Austrian Ecodesign Information Platform 2001; SolidWorks 2013; Sustainable Minds 2013; WSP 2010). The necessary simplifications of streamlined LCAs negatively impact the accuracy of their results. Streamlined LCAs are consequently not appropriate for making exact claims about the ecological impact of a product. However, the information required to formulate an ecological agenda for improving a product is not always required to be 100% accurate, but rather more directional in nature. Even though streamlined LCAs are less accurate than full LCAs, they still provide sufficiently detailed information to identify the most relevant impacts of a product to help decide on appropriate ecodesign interventions (Yang 2007).

Progress has also been made in providing tools that supply information to support LCT at a more general level. Collections of these less-detailed analytical LCT tools can be found in how-to manuals such as the ones written by Lewis et al. (2001), Tischner et al. (2000), White, Belletire & St Pierre (2009) and Vezzoli & Manzini (2008). For example, they cover guidelines, material lists, process trees and sets of structured questions or matrix-based approaches that help designers to think through ecological issues along the expected life cycle of a product concept. Also, collections of examples showing principles of low-impact solutions that can deliver input at the very beginning of a product development process are available (see for example: Benyus 2002; Fuad-Luke 2010).

The availability of this more general ecological information is of high relevance for the application of LCT by industrial designers. Bakker (1995) and Lofthouse (2006) both found that industrial designers require more directional ecological information when they creatively generate solution suggestions, and only require more detailed analytical LCT tools afterwards to evaluate these concepts relative to one another. Collado-Ruiz & Ostad-Ahmad-Ghorabi (2010) observed that providing too-detailed ecological information early in a product development process can even forestall creativity.

Is the available LCT support sufficient?

In the 1990s, tool development for LCT received much attention by the scholarly community. Much progress has been made to provide tools that can be applied at different stages of the product development process for LCT. However it remains unclear whether the developed analytical LCT tools are sufficient to overcome the isolated product qualities perspective in real-world product development processes. Access to accurate ecological information is still seen as a barrier for incorporating ecological considerations into real-world design practice (Mawle, Bhamra & Lofthouse 2010; Stevenson et al. 2011). Scholars like Le Pochat, Bertoluci & Froelich (2007) still see the effort and complexity of the available analytical LCT tools as too high and the information that they deliver as not relevant enough. Others like Vezzoli & Manzini (2008) find that the application of LCT in real-world product development processes has made good progress—but only when associated with the traditional notion of ecodesign. Furthermore, Boks (2006) believes that further tool development is not the most important thing that needs to be addressed. He proposes that other barriers, such as the use and communication of ecological information, are more important to address. He suspects that the call from academia for more tools can in some cases also be the attempt of scholars who work on tool development to justify allocating more funds to that research area.

3.3. A transition from an ecological to a sustainable agenda

The second transition that this thesis seeks to draw out is the transition from an ecological to a sustainable agenda. Sub-section 3.1.1 explained that the group of concepts that can be described as sustainable design not only share an ecological agenda but also seek to address a social and economic agenda. Other than the social and economic agenda inherent to industrial design practice (see Section 2.1), which prioritises the interests of the industrial designers, their clients and individual consumers the social and economic agenda of sustainable design seeks to enhance equity in society. The social agenda demands explicitly considering and addressing issues such as fostering democratic decision-making, community building, public health and education (Crul, Diehl & Ryan 2009; Manzini & Meroni 2007; Vezzoli & Manzini 2008). The economic agenda seeks to achieve a more equal distribution of the value that is generated in a design process in society (Dewberry 1996).

The transition from an ecological to a sustainable agenda happened more or less in parallel with the transition from the isolated product qualities perspective to the socio-technical perspective. With exceptions like Papanek (1971), the main focus of authors adopting the isolated-product qualities perspective was to incorporate ecological considerations into design practice (see for example: Elkington 1986; Möller 1982). An explicit social and economic agenda for design practice that accompanied the ecodesign idea is also largely absent from most publications that adopt the technical perspective and are classified as ecodesign (Lewis et al. 2001; Tischner et al. 2000; Wimmer, Züst & Lee 2004). The absence of the economic agenda can be explained by the circumstance that ecodesign is commonly understood as integrating ecological considerations into the environment of commercial product development processes (Karlsson & Luttropp 2006). This environment already has its own economic agenda (which is to create financial revenue for the client and the industrial designer) and a social agenda (which is to meet the demand of individual consumers). The absence of an explicit social agenda in the technical perspective beyond meeting the demand of individual consumers can also be rooted in the focus of the technical perspective on quantifiable product performance. The difficulty of quantifying and measuring social equity may be one factor that prevented the engagement of the technical perspective with broader social issues and impacts.

The desire to address a broader social agenda beyond meeting individual consumer needs can also be seen as the main driver for the transition from the technical to the socio-technical perspective. The socio-technical perspective allows understanding the bilateral relationship between the design of products and their social context. This understanding is also a prerequisite for using design to address social issues. Thus, authors adopting a socio-technical perspective also commonly pursue a sustainable agenda (see for example: Fry 2009; Wahl & Baxter 2008; Walker 2006).

BOX 10
Social life cycle assessment (SLCA)—an attempt of the LCA community to address the social agenda of sustainable development

Even though attempts to integrate the concept of a *social life cycle assessment* (SLCA) into consumer product design have not yet matured, it deserves mention in light of the shared history of LCA and product design.

The focus of traditional LCA on quantifying the ecological implications of a design along its life cycle does not allow for understanding social implications. This limits LCA as a tool to support sustainable development. In response the LCA community developed the concept of a social LCA or SLCA. SLCA suggests expanding the concept of LCA from analysing only the ecological impact to include the social impact of a product (Benoît & Mazijn 2008). It is unclear how appropriate and applicable the concept is to social factors, which are by nature more qualitative and ill framed. While not dismissing the general concept of SLCA, Clift critiqued that it usually results in a 'checklist mentality' where social impacts are regarded in isolation to (instead of as required in) their wider context (Clift, personal communication 2010).

The concept of SLCA is not discussed in further detail in this thesis, as the concept has yet to mature and has not yet played a significant role in commercial consumer product design.

3.3.1. The capacity to integrate a sustainable agenda into industrial design practice is limited

The publication *Transitions in sustainable product design research* by Boks & McAloone (2009) suggests that the shift from an ecological agenda to a sustainable agenda happened not only in the academic spheres but also in corporate practice. They find that the way companies report their business activities increasingly includes the progress of their endeavours to address ecological and also social aspects. However, the extent to which this reflects any change in the *design practice* of these companies remains unclear.

As explained in Section 2.1, industrial design practice has an inherent economic and social agenda: it seeks to create economic value for the industrial designers and their clients, and personal value for consumers. This limits the capacity of industrial design practice to adopt the social and economic elements of a sustainable agenda, as this would require the creation of social and economic value not only for individual stakeholders but also for wider society. While the capacity to comply with these two aspects is limited, this thesis does not mean to imply that it is not existent. Still, as the social and economic aspects of a sustainable agenda can conflict with the inherent goals of industrial design practice, this thesis proposes that it is useful to understand how ecological considerations can be incorporated into industrial design practice first. Industrial design practice does not have an inherent ecological agenda that can directly conflict with seeking to minimise the negative ecological impact associated with the products that are designed. However, as was explained in Section 3.1, how ecological considerations can be incorporated into industrial design practice has not yet been fully understood. Thus, addressing this less complex issue first can provide a valuable foundation for further research, addressing the more complex issue of understanding how best to integrate a sustainable agenda into industrial design practice.

BOX 11
The overt and the hidden social agenda of industrial design

Industrial design has an overt social agenda and a hidden one. Its overt social agenda has been discussed in Section 2.1 as prioritising the needs of the individual consumers. This social agenda is meant in this thesis when referring to the social agenda of industrial design. Its hidden social agenda is embedded within the economic paradigm currently underlying the commercial context in Western capitalist society. This paradigm assumes that economic growth leads to social benefits for the entire society. This assumption justifies prioritising the financial needs of the industrial designers themselves, their clients and the demand of individual consumers over the needs of the whole of society in the design of a product.
The concept of economic growth is highly contested with regard to sustainability. Authors such as Daly (1992) question if the concept actually holds its promise to benefit the wider society in the long term.

Even though the researcher is aware of this debate and shares concerns about shortcomings of the economic growth paradigm, this discussion is not the focus of this thesis. This is for the following reasons. The vast majority of industrial designers work within a context that is governed by the current economic paradigm, and they do not have the influence to directly change this paradigm. Their professional practice is not concerned with redesigning the economic system. As at least in the near future the current economic paradigm will still dominate the context within which industrial designers work, it is important to understand their possible contribution to designing lower impact products in order to progress towards reducing the negative ecological impact of society at the present moment.

3.3.2. Integrating ecological considerations into industrial design practice—an expanded notion of ecodesign?

Figure 21 shows two transitions along two axes: the shift from the isolated product qualities perspective to the technical perspective and ultimately to the socio-technical perspective, and the expansion of the underlying agenda of design practice from an ecological to a sustainable one. The positioning of industrial design practice that is proposed in this thesis is visualised by the grey field. Within this map, a number of authors are placed that express recommendations for how ecological considerations should be integrated into design practice. This clearly shows the two groups of concepts, classified as *ecodesign* and *sustainable design* after Charter & Tischner (2001) in Sub-section 3.1.1. It also shows that none of the authors overlaps with the positioning that this thesis proposes for industrial design practice.

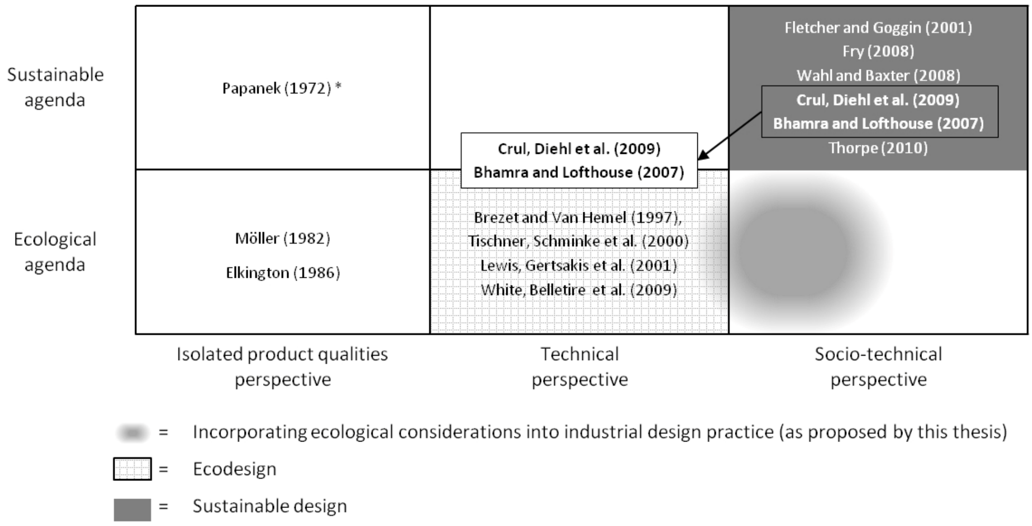
Figure 21 further illustrates an interesting phenomenon that is explained here, using the UNEP manual 'Design for Sustainability' by Crul, Diehl & Ryan (2009) as an example. Some parts of the manual, such as the two introductory chapters by Crul (2009) and Crul, Diehl & Lindquist (2009) and the chapter about Product Service Systems (PSS)[14], written by Tischner, Ryan & Vezzoli (2009) adopt a socio-technical perspective and advocate a sustainable agenda. However, as the suggestions that the manual makes for actual design practice become more concrete, two trends can be observed:

1. The prominence given to the ecological agenda increases while the extent to which the social and economic agenda is incorporated and discussed in detail decreases;
2. The extent to which the interrelationship between the products and their social context is considered decreases.

Furthermore, the models of the product development process and the innovation process discussed by the manual have a prominent linear structure. In other words, they have an underlying problem-focused logic. Crul, Diehl & Ryan (2009) mention that there also is the possibility of more explorative approaches with an underlying solution-focused logic. They acknowledge that, in particular when seeking to achieve a high degree of novelty, it is possible to apply approaches where goal setting emerges from experimentations rather than 'at the onset of' a product development process (Crul, Diehl & Ryan 2009, p. 79). However, the authors do not give these approaches much prominence or elaborate on them in detail. Consequently, it can be said that the more the manual is concerned with recommendations for design practice that can be transferred into real-world product development processes, the

[14] A Product Service System (PSS) is generally 'a system of products and services (and related infrastructure) which are jointly capable of fulfilling client needs or demands' (Tischner, Ryan & Vezzoli 2009, p. 95) For more details on PSS, see section 5.2.3. and Tukker & Tischner (2006a).

more it adopts a technical perspective and focuses only on an ecological agenda. This is visualised by the two positions of Crul, Diehl & Ryan (2009) in Figure 21, which are connected with an arrow.



(*) As already mentioned in sub-section 3.2.1, the work of Papaneck also already incorporated some aspects of the socio-technical perspective, especially in regards to the role of design in stimulating consumption. However he did not overcome the limitations of the isolated product-properties perspective by accounting for the ecological impact of a product along its entire life cycle. This is why he is positioned in the upper-left cell in this diagram.

Figure 21: Positioning industrial design practice relative to the groups of concepts classified as ecodesign and sustainable design
(note that the position of the authors within the cells does not illustrate a difference in the extent to which they adopt an ecological or sustainable agenda)
(Source: created for this research)

The phenomenon that suggestions for integrating sustainable design into a commercial context fall back on an approach that rather reflects what is commonly understood as ecodesign is not specific to Crul, Diehl & Ryan (2009). As Figure 21 shows, it can also be observed in the manual *Design for sustainability: a practical approach* by Bhamra & Lofthouse (2007), which explicitly addresses industrial designers. The potential conflict of the social and economic agendas in sustainable design may be one explanation for this phenomenon. However, it is argued in this thesis that in particular, the fall-back to the technical perspective is not mandatory. As shown in Figure 21, it is proposed that incorporating ecological considerations into industrial design practice can add to the technical perspective, traditionally associated with ecodesign. It thus represents an expanded notion of ecodesign. As explained in detail in the next section, it is further argued in this thesis that this expansion may also help to incorporate ecological considerations more readily into real-world product development processes.

3.4. Integrating ecological considerations into product development processes

As shown in Figure 21, when it comes to integrating ecological considerations into real-world product development processes, the available literature commonly falls back to describing an ecodesign process. This creates a link between explanations for integrating ecological considerations into the context of commercial product development processes and the technical perspective. This link is problematic for understanding the capacity of industrial design practice to contribute to integrating ecological considerations into real-world product development processes and converting them into product designs. The technical perspective has an inherently problem-focused logic and only suggests influencing the technological dimension of the product properties when converting ecological considerations into product designs. Thus, it omits the capacity of industrial design practice to also draw on the solution-focused element of Design Thinking and its ability to influence not only the technological dimension of product properties but also the meaning dimension. The socio-technical perspective adopted by sustainable design conceptualises products and also design practice within the wider socio-technical context. This would better allow for the accommodation of the qualities of industrial design practice. However, as shown in Figure 21, incorporating ecological considerations into industrial design practice does not equal sustainable design. Thus, to improve the understanding of how the influence of industrial design practice can support the integration of ecological considerations into commercial product development processes and convert them into product concepts, it is important to understand two things.

Firstly, what can be learned from literature adopting the technical perspective about the success factors for integrating the ecodesign idea into a commercial environment? Secondly, what aspects can industrial design practice adopt from sustainable design with regard to the capacity of design practice to integrate the ecodesign idea into a product development process?

3.4.1. Success factors for integrating the ecodesign idea into a commercial environment

The ambitions of the research community around the ecodesign idea to diffuse the idea into a commercial environment necessitated an understanding of the success factors for applying the ecodesign idea within this context. In a literature review, Johansson (2002) consolidates the success factors that scholars had identified for integrating the ecodesign idea into the environment of commercial product development. He concludes that success factors can be sorted into three groups. The first group comprises general success factors for a product development process. Examples of such success factors include: the availability of resources that allow for the conducting the necessary activities; the willingness and capacity of a company to internalise the solutions that have been achieved in a product development process; and a general innovation-friendly climate. The other two groups of success factors, competency and motivation are specific to the incorporation of the ecodesign idea. They are discussed below in detail. Table 2 summarises the three groups of success factors for integrating the ecodesign idea into a commercial environment.

Table 2: Success factors for integrating the ecodesign idea into a commercial environment
(Table created for this research based on: Johansson 2002)

<table>
<tr><th colspan="3">Success factors for integrating the ecodesign idea into a commercial environment</th></tr>
<tr><td rowspan="2">Group 1: General success factors for a product development process include:
The availability of resources that allow conducting the necessary activities;
The willingness and capacity of a company to internalise the solutions that have been achieved in a product development process;
An innovation friendly climate</td><td colspan="2">Specific success factors for incorporating the ecodesign idea into a product development process</td></tr>
<tr><td>Group 2: Competency The availability and applicability of ecological information to practice LCT</td><td>Group 3: Motivation The goals and drivers for integrating the ecodesign idea into the product development process can be identified</td></tr>
</table>

The second group comprises factors that are important for the competency to convert ecological considerations into product designs so that they have quantifiable eco-benefits. Sub-section 3.2.4 explained that this competency to practice ecodesign particularly hinges on the availability and applicability of ecological information to practice LCT and that progress has been made to provide this information through analytical LCT tools. While some authors still see the available analytical LCT tools as insufficient and argue that this represents a major barrier for ecodesign (Le Pochat, Bertoluci & Froelich 2007), others such as Boks (2006, p. 1355) propose that 'there is already enough information about how to do ecodesign'.

This links to the third group of success factors in Table 2. A lack of LCT can also be a symptom of a lack of motivation. The application of analytical LCT tools and the use of the resulting information in the product development process require time and effort. Including ecological considerations into the product development process increases the complexity of the decisions that need to be made (Åkermark 2003). Furthermore realising and commercialising the ecologically optimised products may be associated with higher effort (Hall & Clark 2003)[15]. For example, low impact materials as well as cleaner production technologies may be more expensive. This creates a tension with the imperative to minimise the required resources, arising from the economic agenda of the commercially driven context for industrial design. This circumstance explains why ecological considerations cannot be expected to be included in

[15]Even though the outcomes of an ecodesign process may be more expensive to realise and commercialise this is not always the case. In some cases LCT may even identify opportunities for lowering these costs as described by (see for example: Plouffe et al. 2011).

commercial product development processes solely because of their ecological benefit (Van Hemel & Cramer 2002).

The literature formulates numerous drivers which are believed to incentivise companies to integrate ecological considerations into their product development processes (Brezet & Van Hemel 1997; Crul, Diehl & Ryan 2009; Tischner et al. 2000; Wimmer, Züst & Lee 2004). It is usually differentiated between company *internal* and *external* drivers (Brezet & Van Hemel 1997; Crul, Diehl & Ryan 2009).

- Examples of external drivers are: ecological improvements prescribed by legislation, the presence of respective norms and standards, and consumer demand for eco-friendly products (how the term eco-friendly product is used and understood in this thesis is explained in Box 12).
- Examples of company internal drivers are: a general ecological consciousness of staff within the company, in particular managers, the possibility to seize monetary saving potentials which also bring along an ecological benefit or an opportunity to reach new consumer groups who consider ecological criteria in their purchasing decisions.

Besides the presence of drivers that stimulate the development of eco-friendly products, researchers such as Wever, Boks & Bakker (2008) point out that it is also important that the integration of ecological considerations into the product development fits within the company portfolio. In other words, a company is only likely to act on drivers if they create business opportunities that align with the company strategy.

BOX 12
On terminology: The use of the expressions 'eco-friendly products', 'products with a low ecological impact' and 'products with a lower ecological impact' in this document

In this thesis, the outcomes of design practice in which the ecodesign idea was applied are referred to as eco-friendly products or products with a low or lower ecological impact. To avoid a misinterpretation of these expressions, this section explains how they should be understood in this document.

Strictly speaking, integrating the ecodesign idea into design practice can only achieve a reduced ecological impact. It is inevitable that a product has some form of ecological impact associated with its life cycle. Almost all of today's products consume non-renewable or scarce resources and contribute to the generation of waste. Some authors such as McDonough & Braungart (2002) argue that the ecological impact of a product does not necessarily have to be negative. (continued on next page)

They propose that efforts should be directed towards closing material loops and eliminating the concept of waste. According to McDonough & Braungart (2002), if all materials used for products can be taken from and returned to either a technological material cycle or a biological material cycle products without or even with a positive ecological impact are possible. This suggestion is problematic as it does not account for the limited rate at which the earth's ecosystem can absorb material flows. Carbon dioxide for example is a substance that can be readily absorbed by the ecosystem – however not at the rate at which humanity currently emits it into the atmosphere. The rising level of carbon dioxide in the atmosphere causes various kinds of ecological problems, most importantly climate change (IPCC 2013) and increasing acidification of the oceans (Doney et al. 2009). Hence, as a product has in any case an ecological impact it can only be attempted to reduce this impact as much as possible and focus on the areas which are most problematic by practicing LCT. Because integrating the ecodesign idea into design practice can only achieve a reduced ecological impact adjectives that describe the ecological performance of a product as absolute can be misleading. Nevertheless such expressions are still used in the literature. For example Abele, Anderl & Birkhofer (2005) write about 'environmentally friendly products'. A more accurate expression would be environmentally friendlier products.

Relative expressions such as environmentally friendlier products raise the question about a reference against which this friendliness is assessed. However in some cases describing this reference involves a considerable amount of effort. In a design process multiple dynamic reference points may exist. This can in particular be the case when the product design has a high degree of novelty. As explained in detail in sub-section 2.5.3 from the perspective of industrial design practice the degree of novelty of a product design can be described on a continuum, ranging from product redesign to new product development. The more a design classifies as a redesign of an existing product concept the easier it is to clearly identify a single reference point to compare the ecological performance of a design against. In some cases a reference point may also be available in the case of a product design that is allocated at the new product development end of the continuum. Such a comparison is only possible if the new product fulfils an identical function as an existing product (or possible and plausible combination of existing products). An example for such case is the comparability of books with electronic readers in regards to providing access to readable material (see for example: Lloyd 2011). (continued on next page)

The ecodesign idea can also be applied in the development of products with functionality that consumers did not have access to before the new product gets available. In such cases orientation can only be gained through assessing tentative prototypes, in particular different concepts that are generated in the course of a product development. Because prototypes and different concepts are often only accessible in the course of a product development process it is difficult to make explicit reference to them when the ecological performance of a product is described. This makes it difficult to find a general expression describing the outcome of the application of the ecodesign idea whilst covering the entire possible continuum, ranging from product redesign to new product development and highlighting that ecological benefits are always relative.

In response to the difficulties above the terms eco-friendly product or product with a low ecological impact are used in this thesis to describe outcomes of the application of the ecodesign idea covering the entire possible continuum, ranging from product redesign to new product development. These expressions do not explicitly highlight that the ecological benefits of a product are relative but communicate clearly that ecological considerations played a role in the design of this product. Only if a clear reference is available the expression product with a lower ecological impact is used.

The identification of goals and drivers for ecodesign from a technical perspective

As illustrated in Figure 21, the literature that discusses the ecodesign idea in a commercial context has a strong tendency to adopt the technical perspective. The associated problem-focused logic and preference for structuring design practice according to prescriptive models puts industrial design practice in an operational role. It responds to goals and drivers that have been identified prior to the product development process through research into the status quo. This is visualised in Figure 22 with the white arrows.

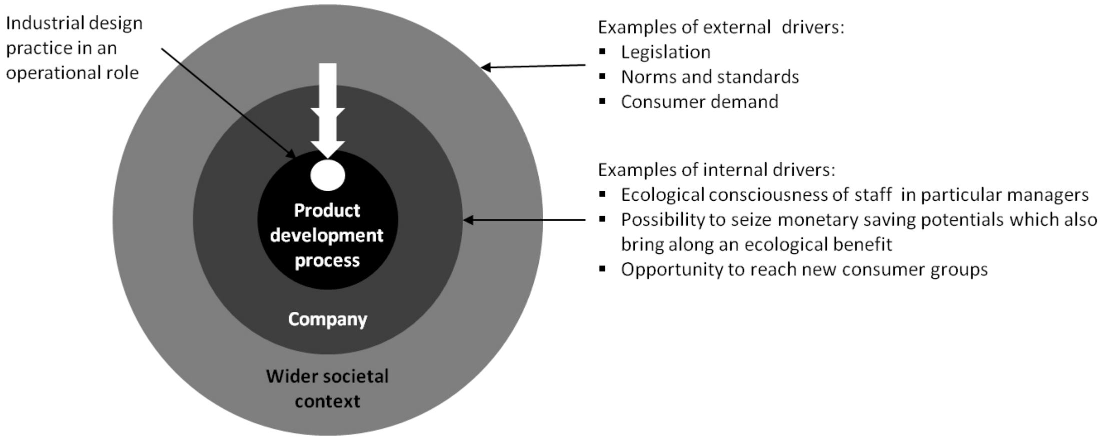


Figure 22: The technical perspective on the identification of drivers for integrating ecological considerations into the design process and the role of industrial design practice
(Source: created for this research)

Figure 22 also indicates whether the drivers for including ecological considerations into the product development process can be classified as internal or external drivers. To guide the research into the status quo to identify goals and drivers for ecodesign, it is usually suggested to amend traditional management tools for product development to include ecological considerations. In particular, the SWOT analysis and the Anshoff growth matrix are seen as useful (Wever & Boks 2007). Other examples of such amended management tools are the *house of environmental quality* suggested by Tischner et al. (2000) and *life cycle costing* (LCC) as described by Giudice, La Rosa & Risitano (2006)[16].

Authors such as Tischner et al. (2000) and Crul, Diehl & Ryan (2009) highlight that companies can and should be pro-active in integrating ecological considerations into the design process. This may allow them to gain advantages from a business perspective if they can anticipate upcoming changes that either create or strengthen drivers for ecodesign, such as legislation that demands eco-friendly products or increased consumer sensitivity towards ecological issues. However, they do not allocate an active role to industrial design practice in surfacing or stimulating such drivers.

3.4.2. The role of design in society and the sustainable design process

The previous sub-section explained that a consideration of ecological issues always needs to be justified by the potential of increasing the value created in a design process for the client of the design service. This is not always possible. Thus, the context of a commercial product development process brings along not only the risk to marginalise social and economic issues that are not of direct interest to the client of design services, but it can also crowd out

[16] LCC after Giudice, La Rosa & Risitano (2006) assesses the entire life cycle of a product to specify its ecological impacts and its financial costs. This allows the identification of areas where ecologically motivated activities can also result in a financial benefit.

ecological considerations. Consequently, a number of authors see the current context for industrial design practice as inherently prohibitive for making progress towards addressing the social, economic or ecological agenda of sustainable design (Chick & Micklethwaite 2011; Fuad-Luke 2009).

As a response, authors such as Morelli (2007) and Wahl & Baxter (2008), who adopt a socio-technical perspective and write about sustainable design, commonly discuss design practice in a new context. This new context positions designers so that they are directly accountable to all stakeholders affected by the outcomes of their practice. Some authors like Young (2010) do not explicitly contrast this new context with the current context for industrial design practice, while others such as Morelli (2007), Chick & Micklethwaite (2011) and Fuad-Luke (2009) do. In the new context for design practice that these authors write about, designers no longer provide their service exclusively to a client that seeks to industrially manufacture and commercialise the outcomes of the design practice by selling them to individual consumers. Thus, these authors usually do not refer to industrial designers, but to designers in general. The new context can be seen as an extrapolation of the concept of co-design (Fuad-Luke 2009). In its most radical form, this means equally addressing the views and values of all stakeholders affected by the economic, ecologic and social consequences of the outcome of the design practice. This prevents the marginalisation of social, economic and ecological issues that occur along the expected life cycle of the solution.

To include the views and values of all stakeholders who are affected by the solution that is designed the socio-technical perspective also draws on the solution-focused element of Design Thinking[17]. It acknowledges that design problems are partially underdetermined and that design practice plays an important role in exploring and determining them (Scott, Quist & Bakker 2009; Wahl & Baxter 2008). The socio-technical perspective claims that design practice is not only concerned with the quantifiable product properties but that it also influences their cultural context. Blevis (2007) believes that the personal views and values of those executing the design practice are important. He proposes a hierarchy between the values of those who execute the design practice, the practice they apply and the solutions they can achieve. This implies that designers can only propose solution suggestions that explore and determine the problem situation in regard to eco-friendly solutions if the designers themselves are conscious of ecological issues.

[17] However the extent to which this is explicitly discussed by different authors, adopting the socio-technical perspective varies.

A shift towards co-design also changes the nature of the problem situation that the designers confront. In a radical co-design scenario, the role of the designer becomes a facilitator and integrator within the network of stakeholders. This allows the use of design to create equal value for all stakeholders affected by the entire life cycle of a product. This scenario is shown in Figure 23.

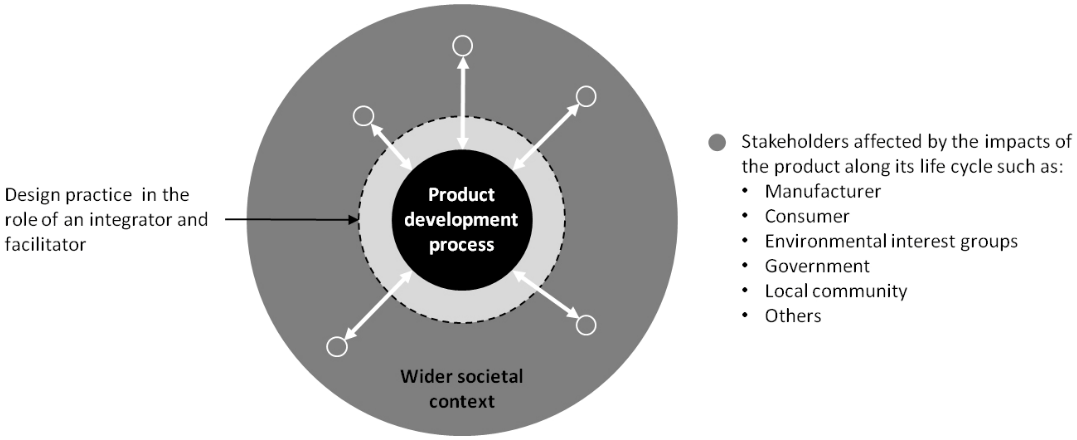


Figure 23: A new context for design practice to prevent a marginalisation of social, economic and ecological issues (Source: created for this research)

It needs to be noted that even though the arrows connecting the individual stakeholders directly connect to the field in the conceptualisation of the design process, the individual stakeholders do not necessarily actively contribute to this process. Some scholars such as Walker (2006) still discuss sustainable design as being somewhat authored by the designer. Other scholars propose *co-creation*—an active stakeholder contribution to the design activity—as a promising way to integrate their views and values (Maase & Dorst 2006; Scott, Quist & Bakker 2009).

BOX 13
On Terminology: Design activism

A question that remains largely unaddressed in the literature is the driving force behind sustainable design practice for the individual designers. While the concept of sustainable design is desirable from a socio-political perspective, it remains particularly unclear why individual designers should practice sustainable design, as it has not yet been clarified how it helps them to meet their personal needs. (continued on next page)

The concept of *design activism* explicitly formulated by Thorpe (2008) and Fuad-Luke (2009) suggests that sustainable design activities are solely driven by the personal ideals of the designers themselves. While design activism is not the primary focus of this thesis, the term activist approach will be used in the report of the empirical data, collected by this thesis to describe design practice that is driven only by the individual values of the industrial designers.

3.4.3. Can industrial design practice play an active role in the identification of goals and drivers for ecodesign?

Authors adopting a technical perspective and applying problem-focused logic to identify goals and drivers for ecodesign suggest that this is a valid pathway to integrate ecodesign into the context of commercial product development processes. This thesis proposes that allowing industrial design practice to adopt a strategic role offers another possible pathway. As explained in Chapter 2, the capacity of industrial design practice to draw on the solution-focused element of Design Thinking can help to reveal and/or stimulate drivers for including ecological considerations into the design process that are not yet explicit. This expands the possibilities to identify opportunities for ecodesign beyond traditional research in the status quo. It allows for exploration of the context that is designed for specifically with regard to opportunities for ecodesign that have not yet surfaced. Thereby, industrial design practice cannot comply with sustainable design and integrate the views and values of all stakeholders affected by the outcomes of their practice. Industrial designers are bound to prioritise the generation of value only for their client, the consumer of the product. This narrows the group of stakeholders that are considered by industrial design practice. However, there is still an opportunity to apply solution-focused thinking to reveal and/or stimulate drivers for including ecological considerations into the design process within that context. This is visualised in Figure 24. It shows industrial design practice in a strategic role. Both bidirectional arrows show the capacity of industrial design practice not only to explore but also to contribute to determining the problem situation for which they design. Figure 24 specifically draws out consumers within this context because it is the traditional role of industrial design practice to integrate the consumer perspective into the product development process.

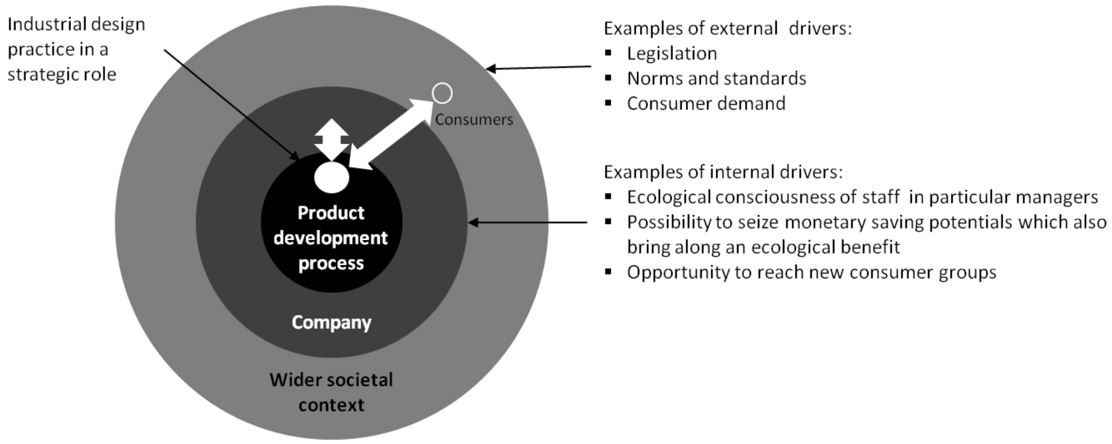


Figure 24: Industrial design practice in a strategic role to reveal and/or stimulate drivers for ecodesign (Source: created for this research)

This thesis assumes that personal ecological awareness and motivation of those who execute industrial design is beneficial (but not essential) to reveal and/or stimulate drivers for ecodesign through solution-focused thinking. Compared to industrial designers who are not ecologically aware and/or unmotivated industrial designers who are ecologically aware and motivated can be expected to more readily generate eco-friendly solution suggestions. This allows intentionally directing the reflective conversation that the designer leads with the problem situation towards an enquiry about opportunities for such solutions. However, it is assumed in this thesis that a discovery of drivers for ecodesign within this reflective conversation can also happen through what has been introduced in Chapter 2 as 'surprises'. Also, the 'back-talk' of the problem situation to solution suggestions that are not necessarily eco-friendly may trigger a response that reveals opportunities for ecodesign.

3.5. A lack of insight into the real-world practice of industrial designers

Summarising the conclusions from the preceding three sections, this thesis proposes that incorporating the ecodesign idea into industrial design practice allows expanding the traditional notion of ecodesign in two ways.

1. Drawing on the solution-focused element of Design Thinking can aid in overcoming the lock-in of the current notion of ecodesign that leads to only incremental improvements of existing product concepts. The capacity of industrial design practice to explore the context for which it designs offers another way to identify goals and drivers for integrating ecodesign into a commercial product development process. This goes beyond the traditional notion of ecodesign, where goals and drivers were identified only through research into the status quo.

2. Industrial design practice allows progression beyond merely the technological dimension of product properties when converting ecological considerations into product designs. It also allows for the manipulation of the meaning dimension of the product properties for this purpose.

The expanded notion of ecodesign that this thesis proposes is shown in Figure 25. It already incorporates important elements of sustainable design. Thus, this thesis argues that improving the understanding of how to facilitate incorporating ecological considerations into industrial design practice may serve as a bridge between the two concepts. This is shown by the arrows, marked (1) and (2).

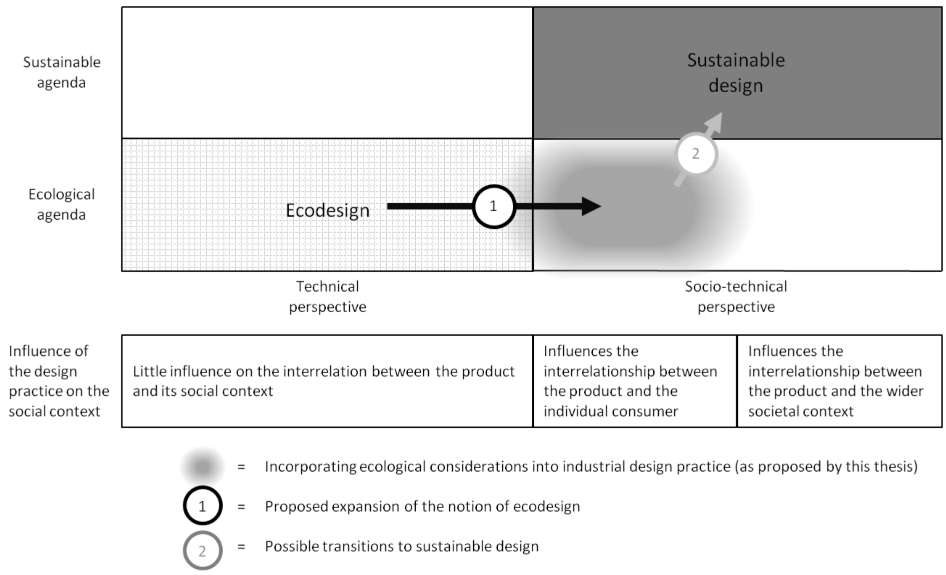


Figure 25: Incorporating the ecodesign idea into industrial design practice—an expanded notion of ecodesign as a possible transition towards sustainable design
(Source: created for this research)

The suggestion of an expanded notion of ecodesign as plausible is also supported by the insights provided by Sherwin (2000; Sherwin 2004) and Bakker (1995). As explained in Sub-section 3.2.4, these authors observed that when industrial designers are motivated to integrate ecological considerations into their practice and provided with ecological information that allows them to practice LCT, they can go beyond the traditional understanding of ecodesign. However, these observations were made in an experiment (Bakker 1995) and a pilot study (Sherwin 2000). Both environments differ from real-world product development processes. The industrial designers were externally motivated and did not have the same time and budget pressures that they would face in their usual work environment.

Incorporating the ecodesign idea into industrial design practice can, under some circumstances, reflect the expanded notion of ecodesign. However, it remains unclear how far this applies to the commercial product development processes, the context of the practice of most industrial designers. Critique on real-world ecodesign highlights that it 'never really managed to escape the purely technical engineering spheres' (De Leeuw 2006, p. 9). Why this is the case and if this generally applies is unclear. Most empirical studies which seek to understand real-world ecodesign processes focus on barriers and success factors at a company level; they do not fully itemise the roles of individual stakeholders (see for example: Boks 2006; Johansson 2002). A general shortcoming of those few studies that go to a level of detail where they provide insight into the integration of the ecodesign idea into industrial design practice is that they usually only capture the perspective of the industrial designers (see for example: Mawle, Bhamra & Lofthouse 2010; Stevenson et al. 2011; Ueda, Shimitsy & Sato 2003; Ugas & Kohtala 2011). This is problematic because industrial design practice does not happen in isolation. In particular, their client plays an essential role through funding the product development process and thus needs to agree to the decisions the industrial designers make in their practice. Not capturing their perspective on the work of the industrial designers delivers an incomplete representation of the problem situation. Besides only accounting for the perspective of the industrial designers on their practice, the available studies also fail to develop a comprehensive image of the influence of industrial design practice. The underlying reasons are that empirical investigations into real-world ecodesign practice usually either:

a) apply a framework to guide their enquiry that orients itself on the traditional notion of ecodesign and sees industrial design practice in an operational role or
b) do not establish a framework upfront to guide their enquiry and lose a focus on industrial design practice.

These two groups of studies are discussed below.

3.5.1. Studies applying the traditional notion of ecodesign as a guiding framework

The first category describes studies that apply criteria to assess the integration of the ecodesign idea into real-world industrial design practice that are based on the traditional notion of ecodesign. Some of these studies, for example Ueda, Shimitsy & Sato (2003), White et al. (2004) and Dewulf, Wever & Brezet (2012) explicitly focus on the practice of industrial designers. Others such as Knight & Jenkins (2009) do not make a distinction between industrial designers and engineers or ignore industrial designers completely. This undifferentiated view can be explained by the observations that were described in Sub-section 3.2.2. The traditional notion of ecodesign only covers the influence of design practice on the technological dimension of product properties. Even though industrial designers commonly do not go to the same degree of detail as engineers when influencing the technological dimension of product properties, this is an area where both professions overlap. Thus, when adopting the traditional notion of ecodesign, there is little difference between the two professions. However, this is an incomplete representation of the influence of industrial design practice. It misses the potential to manipulate the meaning dimension of product properties. Thus, this group of studies provides little insight about if and how this capacity is used by industrial designers to convert ecological considerations into product designs.

Using the traditional notion of ecodesign as a framework further limits the possibility to develop an understanding of the application of the solution-focused element of Design Thinking by industrial designers when incorporating the ecodesign idea into their practice. The traditional notion of ecodesign implies a preference for structuring design practice in a problem-focused logic. This brings along that industrial designers are merely in an operational role, seeking to comply with previously set requirements that were established through research into the status quo. This has led to two focus areas of these studies. Researchers such as Dewulf, Wever & Brezet (2012) direct their attention to how far upfront ecological goals are established in product development processes. Studies like the one conducted by Knight & Jenkins (2009) mainly investigate the availability and applicability of LCT support in form of analytical tools. However no attention is given to the capacity of industrial design practice to contribute to identify goals and drivers for ecodesign by drawing on the solution-focused element of Design Thinking.

3.5.2. Studies without a guiding framework

The second category of studies does not apply any guiding framework to structure the enquiry into the role of industrial designers for addressing ecological issues in a product development process. Such a broad and explorative approach, for example, is followed by Mawle, Bhamra & Lofthouse (2010) and Stevenson et al. (2011). They develop extensive lists of factors and potential interrelationships that can influence the work of industrial designers. Even though all of these may play a role for the integration of ecological considerations into the practice of industrial designers, this group of studies thus far has not improved the understanding of how the specific influence of industrial design practice can support this process.

3.6. Concluding summary

This chapter has reviewed the literature about incorporating ecological considerations into design practice. This review addressed two goals. Firstly it sought to position industrial design practice relative to how design practice is represented within concepts that share the ecodesign idea. Secondly, it sought to clarify how far past empirical studies have developed a comprehensive understanding of the role of industrial design practice to develop product designs with a low ecological impact in a commercial context.

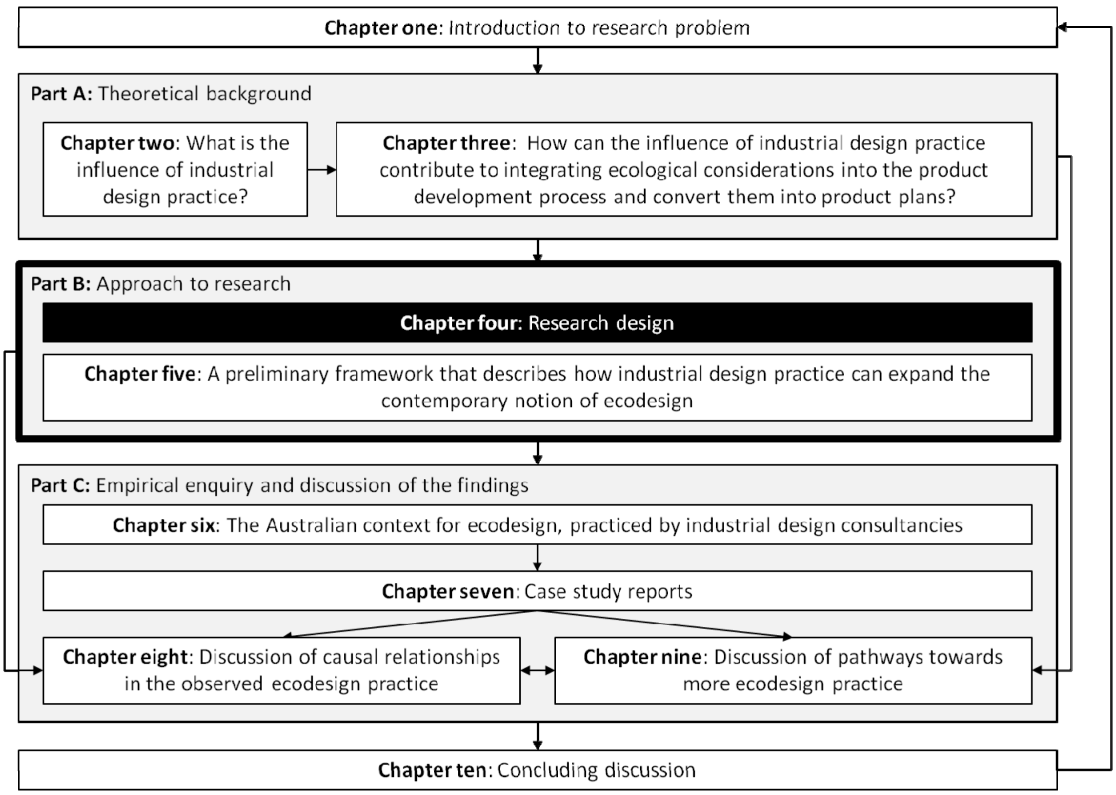
The reviewed concepts that share the idea to integrate ecological considerations into design practice, or ecodesign idea*,* do not fully account for the influence of industrial design practice. The concept of ecodesign disregards the capacity of industrial design practice to manipulate the meanings consumers attach to a product. It also fails to acknowledge the ability of industrial design practice to explore and determine a problem situation by drawing on the solution-focused element of Design Thinking. Ecodesign favours applying a problem-focused logic in structuring design practice. This limits its capacity to achieve novelty, to step-by-step improvements of contemporary product concepts. Sustainable design, on the other hand, accounts for the possibility to influence the social context within which a product is positioned through design practice. Sustainable design also acknowledges the capacity of industrial design practice to explore and contribute to determine a problem situation. However, besides an *ecological* agenda, sustainable design has an inherent *economic* and *social* agenda. These elements limit its compatibility with the current commercially driven reality for industrial design practice. As this context is integral to industrial design practice, its capacity to fully comply with sustainable design is limited.

Both the concepts of ecodesign and sustainable design highlight the necessity to consider the entire life cycle of a product for selecting and conducting interventions to develop product designs with a low ecological impact. This approach, termed *life cycle thinking* (LCT), is also relevant for incorporating ecological considerations into industrial design practice.

While current commercial industrial design practice cannot fully comply with sustainable design, it can theoretically expand the notion of what is traditionally understood as ecodesign in two ways. Firstly, industrial design practice can draw on the solution-focused element of Design Thinking. This can help to achieve higher degrees of novelty than what can be expected from relying on problem-focused thinking only. Even more importantly, drawing on the solution-focused element of Design Thinking can also facilitate going beyond having to rely on drivers for ecodesign that are explicitly articulated in the status quo and that can be identified by conventional research that follows a problem-focused logic. This is because the solution-focused elements of Design Thinking can help to reveal and/or stimulate drivers that were not explicitly articulated in the status quo. Secondly, industrial design practice can influence the meaning dimension as well as the technological dimension of the product properties. This allows for the manipulation of how a product is perceived and understood in order to achieve solutions associated with a low ecological impact rather than relying on technological improvements alone. In other words, it allows for influencing the individual social context in which a product is positioned when converting ecological considerations into product designs.

Thus far, empirical investigations have failed to deliver a comprehensive understanding of the integration of ecological considerations into the real-world practice of industrial designers. They have either taken a too-broad or too-narrow focus and thus do not shed light on all aspects that need to be understood to articulate the role that industrial design practice currently plays for applying the ecodesign idea in commercial product development processes. Thus, it also remains unclear how far incorporating the ecodesign idea into industrial design practice currently reflects the expanded notion of ecodesign. Further, it is not clear where barriers for industrial designers in embracing the expanded notion of ecodesign lie and how they can be overcome. A design for an empirical enquiry to address these knowledge gaps is presented in Chapter 4.

CHAPTER 4. RESEARCH DESIGN



This chapter describes the research design that was used for the empirical enquiry in this thesis. Chapter 3 has clarified that the integration of the ecodesign idea into the real-world practice of industrial designers has not been sufficiently explored thus far. This is true for theoretical and empirical investigations. Chapter 3 has addressed this research gap at a theoretical level by highlighting how industrial design practice can expand the traditional notion of ecodesign. However, it remains unclear how far real-world industrial design practice reflects the expanded notion of ecodesign where key barriers lie. Addressing this research gap through an empirical enquiry as outlined in this chapter is important in order to meet the goal of this thesis: to identify pathways for industrial designers to better utilise their influence to contribute to the development of consumer products with a low ecological impact. This chapter is structured in four sections.

- **Section 4.1** formulates the research questions that this thesis sought to answer empirically and reiterates the limitations of past empirical studies in providing answers to these questions.
- **Section 4.2** introduces *Adaptive Theory* (AT) as the approach used to guide the collection of the empirical data and its analysis. An AT approach was chosen for this thesis to overcome the limitations of the approaches of past studies into real-world ecodesign practice.
- **Section 4.3** presents and justifies case study research as the most appropriate form of enquiry for the empirical investigation of this thesis.
- **Section 4.4** describes the research design that was applied in this thesis. It explains why this thesis saw selecting case studies from the ecodesign practice of industrial design consultancies (IDCs) and their clients as the most suitable method to gain the required insights, and describes the sampling process. This section also describes the methods this thesis used to collect and analyse the empirical data.
- **Section 4.5** reflects on the usefulness of an adaptive theory (AT) approach in this research.

4.1. The research questions and limitations of past empirical studies

Chapter 3 concluded by suggesting that incorporating the ecodesign idea into industrial design practice can expand the traditional notion of ecodesign in two ways. The first expansion is linked to the capacity of industrial design practice to draw on the solution-focused element of Design Thinking. This can allow industrial designers to (i) achieve higher degrees of novelty in product designs and (ii) identify goals and drivers to integrate ecodesign into commercial product development processes. The second expansion is linked to the ability of industrial design practice to influence not only the technological dimension of the product properties but also their meaning dimension. This expands the focus of traditional ecodesign on achieving impact reductions only through technological innovations. It also facilitates the manipulation of the product-consumer interrelationship when converting ecological considerations into product designs.

While proposed on a theoretical level in Chapter 3, it was untested regarding whether the expanded notion of ecodesign facilitated by industrial design practice also applied to the commercial environment of real-world product development processes. The suggestion that industrial designers can expand the traditional notion of ecodesign is to some extent supported by investigations into a pilot study (Sherwin 2000; Sherwin 2004) and an experiment (Bakker 1995). However, this pilot study and the experiment was undertaken in an environment somewhat removed from the reality of real-world industrial design practice.

Because the proposition that industrial design practice can expand the traditional notion of ecodesign has not been explicitly formulated previously, the attempt of this thesis to explore it empirically also held an underlying assumption. It assumed that industrial designers do not need to be explicitly informed that they can use the entire influence of their practice to incorporate the ecodesign idea. Consequently, this assumption needed to be tested first. This gave rise to the following question:

> *Research question 1: Is there empirical evidence for the suggested expanded notion of ecodesign in commercial industrial design practice?*

The expanded notion of ecodesign proposed in Chapter 3 widens the scope of influence of ecodesign practice when converting ecological considerations into product designs. This should be visible in the design interventions that are applied for that purpose—termed *ecodesign interventions* in this thesis—as well as in the generated outcomes. The expanded notion of ecodesign also allocates strategic influence to ecodesign practice that can allow industrial designers to contribute to the identification of goals and drivers for an ecodesign processes. Thus, research question 1 can be divided in two sub-questions:

> *Research question 1a: How do industrial designers convert ecological considerations into product designs?*
>
> *Research question 1b: What influence does industrial design practice have to identify goals and drivers for ecodesign processes?*

Besides suggesting that industrial design practice can expand the notion of ecodesign, Chapter 3 also highlighted that this practice needs to be guided by life cycle thinking (LCT). Thus, an additional question is added to this group.

> *Research question 1c: How far do industrial designers apply LCT to identify the most relevant ecological impacts and to inform their decisions for or against ecodesign interventions?*

The real-world application of ecodesign practice by industrial designers appears to remain limited in most cases (De Leeuw 2006). Answering the research questions 1a–1c allows an evaluation of how far the current practice of industrial designers reflects an expanded notion of ecodesign. While this step is methodologically necessary, it does not directly address the overarching goal of this research, which is to identify pathways for ecologically motivated industrial designers to better utilise their influence to design consumer products with a low ecological impact. To do so, it is necessary to ask two further research questions:

> *Research question 2a: What limits the ecodesign practice of industrial designers?*
>
> *Research question 2b: How can industrial designers progress their ecodesign practice?*

Only then can the overarching research question be answered:

> *Where should industrial designers direct their efforts to improve the integration of ecological considerations in the product development process and to strengthen their capacity to translate them into product concepts?*

4.1.1. Limitations of past empirical studies

The review of published research into real-world ecodesign practice in Section 3.5 revealed two groups of studies that both fail to provide insight into the potential application of the expanded notion of ecodesign by industrial designers. One group applies the traditional notion of ecodesign as a guiding framework to structure the empirical enquiry (see for example: Dewulf, Wever & Brezet 2012; Ueda, Shimitsy & Sato 2003; White et al. 2004). This does not allow for the capture of expansions to the ecodesign concept that are possible when drawing on the full influence of industrial design practice. The other group of studies does not draw on any explicit guiding framework that is established before the engagement with the research context. This explorative and open approach followed by Stevenson et al. (2011) may help to develop a more inclusive appraisal of the incorporation of the ecodesign idea into real-world industrial design practice. However, such studies thus far have failed to capture a comprehensive image of the application of the influence of industrial design practice to the ecodesign idea. They predominantly deliver insights about aspects and factors within the real-world context for industrial design practice that may potentially influence the incorporation of the ecodesign idea into this practice. However, they provide little insight into the actual interrelationship between these factors and the practice of the industrial designers—with particular regard to the potential of this practice to influence its context. A possible explanation for this lack of focus on industrial design practice may be that this practice is often somewhat oblique (Cross 2011). Thus, a study that is not guided by a framework may be distracted by more obvious and explicit phenomena and shift its attention away from industrial design practice.

Consequently, a detailed explanatory framework of the expanded notion of ecodesign would be helpful to ensure that the research does not lose its focus. However, no such framework is readily available because contemporary theory concerned with the ecodesign idea fails to fully acknowledge the potential influence of industrial design practice. To address this difficulty, this thesis followed an Adaptive Theory approach after Layder (1998).

4.2. Adaptive Theory (AT)

The Adaptive Theory (AT) approach established by Layder (1998) draws on existing theory and preliminary theoretical propositions as a reference point to guide and structure an empirical enquiry. This PhD research project drew on the theoretical proposition of the expanded notion of ecodesign that was developed in Chapter 3 as a preliminary guiding framework. This framework is described in detail in Chapter 5. At the same time AT demands that the researcher responds to new insights gained through the investigation to adapt the initial reference point if necessary. As an approach to research, AT can be described as being situated between Strict Hypothesis Testing (SHT) and traditional Grounded Theory (GT) (Layder 1998).

4.2.1. Strict Hypothesis Testing (SHT)

The approach to scientific research that is described as Strict Hypothesis Testing (SHT) is attributed to have been first explicitly formulated by Popper (1935) (Layder 1998). The underlying logic of SHT is referred to as *deduction*. Informed by contemporary theory about a research problem, it identifies a gap in the current body of knowledge and formulates a hypothesis to close this gap. This hypothesis is then supported or rejected by testing it against empirical evidence. Popper (1935) highlights that a hypothesis can never be generally verified as there may always be other empirical evidence that disproves it. To structure the enquiry to collect the necessary data, SHT uses existing theory as a framework to identify the relevant variables for testing the hypothesis. This permits a focus on only those aspects that are considered important to understand in order to be able to support or falsify the hypothesis.

4.2.2. Grounded Theory (GT)

The concept of Grounded Theory (GT) was first formally introduced by Glaser & Strauss (1967). Traditional GT suggests that the researcher approach the empirical data completely free of preconceived ideas about the research problem. GT assumes that empirical data has inherent themes and structures. GT researchers should seek to uncover these inherent structures and themes. This then allows for theoretical contributions that are highly relevant for understanding the observed phenomenon, as they are 'grounded' in its real-world context. Using any previously established general theory about the observed phenomenon (to narrow the enquiry or filter the collected data) is seen as risk to reduce the openness necessary for a full appraisal of the empirical data. The underlying logic of GT to derive theory from empirical observations is also referred to as *induction*.

4.2.3. The benefits of an Adaptive Theory approach

In their extreme and pure forms that are described above, both the approaches of GT and SHT have limitations with regard to their usefulness to inquire into complex social phenomena. SHT may lack the necessary flexibility and openness to develop a full appraisal for a research problem, while GT may be inefficient and also bears the risk of missing the most relevant aspects of a phenomenon under investigation.

SHT sees the theoretical frameworks that underpin the research as a rigid structure that needs to be stringently applied in the enquiry. This is problematic because theoretical frameworks are generalised descriptions of events, situations or processes. They make simplifications that may not be appropriate for the investigated context. Thus, SHT is limited in terms of its capacity to capture and respond to factors and causal relationships that are specific to the investigated phenomenon or generally not captured by the applied theoretical framework. These shortcomings of SHT are used as justification for the claim of GT to approach empirical investigations without preconceived ideas (Glaser & Strauss 1967).

Also, GT has limitations regarding its capacity and efficiency to inquire into complex social phenomena (Layder 1998). Approaching an enquiry in a completely open fashion bears the risk of focusing on the most explicit and not necessarily the most relevant factors and causal relationships that determine a social phenomenon. Layder (1998, p. 54) further sees it as impossible to approach research with a 'clean slate', as proposed by pure GT. Researchers always bring their own perspectives, perceptions and prior knowledge about the investigated phenomenon to the research process. GT addresses this inherent bias of the researcher by highlighting the necessity of making these factors explicit in order to create awareness for them on the side of the researcher and make any possible influence of them transparent for peers. However, only acknowledging the preconceived ideas of the observed phenomenon that are formed prior to an empirical investigation misses out on the possibility of using them constructively (Layder 1998). Trying to be as open as possible has been observed as being labour-intensive and potentially inefficient (Allan 2003).

Layder (1998) proposes that utilising initial assumptions of the researcher and established theory can help to make the enquiry more effective and efficient, an approach he coined as Adaptive Theory (AT). To adequately capture the specific characteristics of the investigated problem, AT demands that researchers should see a theoretical framework as a flexible guide that can be altered according to the insights gained through empirical enquiry. In other words, AT 'provokes a creative dialogue between orientating theories, research rigour and action' (Bessant & Francis 2005, p. 109) 'with the aim of adapting theories, developing new theories or extending understanding of the applicability of theories' (Bessant & Francis 2005, p. 93). This dialogue of AT and its positioning between SHT and GT is shown in Figure 26.

More progressive interpretations of GT acknowledge the usefulness of a theoretical framework as a starting point to structure an empirical enquiry and resonate with the suggestions made by Layder (1998) (see for example: Charmaz 2006). In order not to confuse the approach followed in this thesis with the original form of GT, this thesis uses the term AT. The underlying logic of AT draws on deduction as well as on induction—a hybrid way of reasoning that is also termed *abduction* (Layder 1998; Steinke, von Kardoff & Flick 2004).

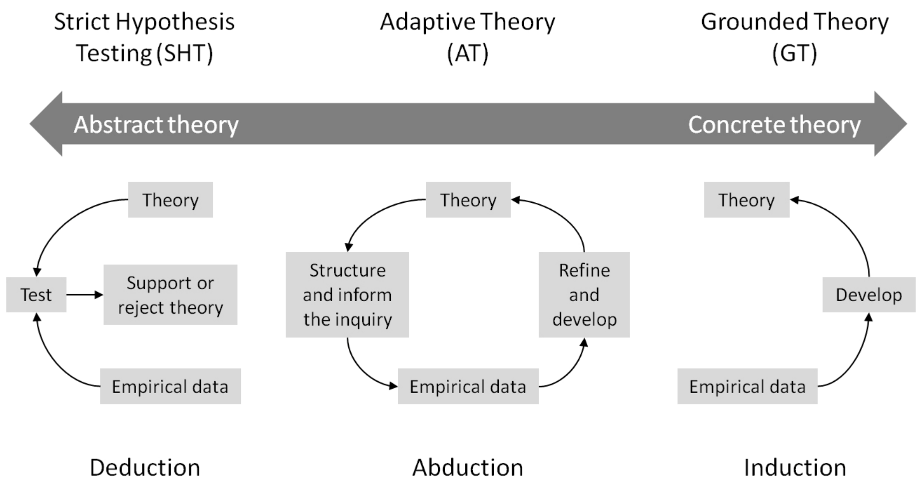


Figure 26: Adaptive Theory (AT), contrasted with Grounded Theory (GT) and Strict Hypothesis Testing (SHT) (Source: created for this research)

In this thesis abduction describes the logic underlying the research design. The term also gets applied by some researchers who write about design thinking (Cross 2011; Dorst 2010) but is not used in this thesis in this context to avoid confusion. The use of the term abduction by the social research scholarly community and design thinking researchers is discussed in Box 14.

BOX 14
On Terminology: Abduction

Figure 26 shows that the logic of AT, which Layder (1998) called *abduction*, is an iterative learning process. It starts with some *a priori* structure, provided by existing theory and assumptions and refines and challenges this theory by engaging with real-world situations. This logic strongly resembles Design Thinking. This explains why the term *abduction* is also applied in the Design Thinking literature to describe the underlying logic of the concept (Cross 2011; Dorst 2010). Like AT, Design Thinking draws on some initial knowledge about a problem situation and tries to respond to insights that are gained through enquiry into that problem situation. Because the design process generates knowledge about a problem situation while resolving it in a satisficing way, it can be regarded as a form of research—as research through design (Zimmerman, Forlizzi & Evenson 2007).

Even though AT and Design Thinking both draw on a form of reasoning that is commonly referred to as abduction, the two concepts are not identical. An AT approach to research and Design Thinking differ in two regards:

1. The sought-after outcome: while an AT approach to research seeks to generate new knowledge, Design Thinking seeks to generate value.
2. An AT approach does not necessarily imply an active engagement of the researcher to try and resolve a problem situation. However, for some research methodologies such as Action Research, this may be the case. In Action Research, the understanding of a problem situation is sought to be achieved through the active contribution of the researcher in resolving it (for a detailled description of action research see for example: Whitehead & McNiff 2006). In this case, a clear distinction between Design Thinking and an AT approach becomes difficult. This is because research is usually conducted to understand problem situations that are seen as valuable to resolve.

It can be concluded that Design Thinking represents a specific application of abduction. In order not to confuse this specific application with the broader use of the term in social research (Layder 1998; Steinke, von Kardoff & Flick 2004), this thesis does not apply the term of abduction in the discussion around Design Thinking.

Addressing risks of using an Adaptive Theory approach

Figure 26 illustrates that AT is an iterative process. An initial theoretical proposition is used to structure and inform the enquiry. The insights into the observed phenomenon are then used to challenge, refine and further develop the theoretical proposition. This refined theoretical proposition can then be used again for a more targeted and nuanced empirical enquiry. Bessant & Francis (2005, p. 110) point out that this iterative nature of AT bears the risk of 'the development of an intellectually closed system where a researcher's perceptions gain a stature they do not deserve'.

To overcome this risk, it is necessary to make the initial theoretical proposition explicit, to provide comprehensive insight in the empirical evidence that was collected, and to discuss how and why the initial theoretical proposition was adapted. This also necessitates explicitly considering rival explanations for the observed phenomenon and arguing for or against each possible explanation. Only then are the theoretical contributions of a study retraceable for peers, and it can be assured that the research has been conducted rigorously. These requirements were met by this research as follows:

By highlighting where industrial design practice can expand the current notion of the concept of ecodesign, Chapter 3 has laid the foundation for the theoretical proposition this research used to provide direction to the empirical enquiry. This expanded notion of ecodesign served as a basis for formulating a first description of its implications for industrial design practice. This is documented in Chapter 5 as the preliminary framework that was used to structure and guide the empirical enquiry. Chapter 7 reports the findings of this empirical enquiry. To assure that all collected evidence is reported fairly, these reports were then double-checked with the research participants who provided the empirical data. Furthermore, wherever possible and appropriate, direct quotes provide insight into the original data. This is to make the foundations of the discussions and theoretical contributions of Chapter 8 and Chapter 9 transparent and retraceable.

4.3. Case study research as the selected form of enquiry

Answering the research questions for this thesis requires deep insight into the practice of industrial designers in their real-world environment. This section introduces case study research as the most appropriate form of enquiry for this purpose. Case study research examines a phenomenon within its real-life environment (Simons 2009). It thereby 'tries to illuminate a decision or set of decisions, why they were taken, how they were implemented and with what result' (Schramm 1971 in Yin 2008, p. 17). Other approaches to develop an understanding of causal relationships and factors that determine the nature of a phenomenon, such as experiments, tend to divorce 'a phenomenon from its context' (Yin 2008, p. 11). Industrial design practice is inherently linked to its real-world context, and its interrelationship with this context ultimately determines the influence industrial designers can have. Thus, case study research, with its ability to capture these aspects, was particularly well suited for the enquiry conducted in this thesis. Case study research is compatible with an AT approach as it can be applied for inquiries that seek to test a hypothesis as well as for explorative inquiries that seek to generate theory, in line with traditional GT (Simons 2009).

Because the interrelationship between the ecodesign practice of industrial designers and the context for this practice are not well understood, it was decided to investigate multiple cases of ecodesign practice. This allowed for the observation of the ecodesign practice in different contexts. Investigating multiple and possibly different cases better permits the identification of factors that determine a phenomenon (Flyvbjerg 2006). The uncertainty about real-world ecodesign practice was also the underlying reason for researching completed cases of ecodesign practice. The other option would have been to attempt to identify cases that allowed the observation of ecodesign practice in real time. However, the uncertainty about which circumstances are beneficial or even essential for ecodesign practice would have implied selecting cases with the risk of not being able to observe the phenomenon that this research chose as a focus.

4.3.1. The application of case study research to investigate design practice

Cross (2011) identifies case study research as one of the most well established forms of enquiry used to gain insight into design practice. Various publications discussing industrial design within its real-world context draw on case study research to investigate and also to illustrate the influence and capabilities of industrial designers (see for example: Brown 2009; Feldman & Boult 2005). They provide valuable insight into the influence of industrial design practice in its real-world environment.

However, in regard to fully exploring the associated design practice, case study research has limitations. The messy real-world environment makes it impossible to conduct a detailed analysis of the internal thinking process of industrial designers in arriving at the ideas they develop. Research into design practice commonly gains these insights through the analysis of protocols[18] from controlled experiments with industrial designers (see in particular: Cross, Christiaans & Dorst 1996). Such protocols are commonly not available for real-world design projects. This is partly because they are not generated and partly because they require a rather

[18] These protocols are detailed records of a design process that aim at making the reasoning behind the creative process explicit in a very detailed step-by-step manner. The most common form of these records is notes that capture the verbal explanations of designers, describing their own thought process while designing. They can also be supplemented by video and audio recordings and other data collection methods.

strict experimental setup. Modifying a real-world design project to generate protocols would mean shifting the form of enquiry from a case study to an experiment which again does not fully capture the phenomenon under investigation in its real-world context.

The difficulty of gaining insight into how industrial designers draw on Design Thinking for their ecodesign practice was addressed in the design of this research as follows: Interviews were the main source of information. The design of these interviews sought to capture how the industrial designers drew on Design Thinking for their ecodesign practice in two ways. Firstly, the research participants were asked to provide insight into the product development process of a specific project of their choice where they had applied ecodesign in a chronological order. They were asked to explicitly talk about the learning during this process and about how the requirements in the project were formulated. This allowed the extent to which problem-focused or solution-focused thinking dominated in identifying goals and drivers for the ecodesign integration to be identified. Secondly, a diagram showing the iterative nature of design practice was used to support the discussion with the industrial designers how far they saw their practice as exploring and determining the problem situation they work on. The diagram is attached in Appendix 1.

4.3.2. Generalisations from case study research and theory building

There is debate within the scholarly community about the extent to which it is possible to derive more generally applicable claims from case study research. Case study research, by definition, describes an investigation in only one or a limited number of cases to understand the causal relationships within a phenomenon. This has led to criticism of the approach. The main point of critique is that due to the small sample size, the conclusions that can be drawn from a case study are usually not fit for assessing their wider applicability through statistical tests. Thus, some authors see the capacity of case study research to contribute to more general theory building as limited (see for example: Campbell & Stanley 1966). Flyvbjerg (2006) argues that statistical tests are not necessarily the only or most appropriate way of establishing the relevance of case study research beyond the investigated context. Easton (2010) claims that when selected strategically, the insights that can be gained from investigating one case can already be enough to draw more general conclusions.

The goal of this empirical enquiry was to identify pathways for industrial designers to better utilise their influence to design consumer products with a low ecological impact. This implies the ambition to aim for some generalisability of the insights of this research for industrial design practice. To allow for drawing conclusions that are relevant beyond the investigated cases, this thesis applied a threefold strategy.

- Firstly, this thesis sought to identify and investigate cases that can be expected to deliver the most insight in terms of finding answers to the research questions. This is commonly referred to as *relevance sampling* or *purposive sampling* (Flyvbjerg 2006; Silverman 2009). The relevance of the cases was established with a staggered approach to sampling that is described in detail in Section 4.4.
- Secondly, this staggered approach to sampling not only helped to identify promising cases but also generated information about the context in which these cases were situated. This information, together with background literature, was used to 'nest' the findings within the broader context (as proposed by Yin 2008). This provided a robust basis for discussing how far the context the phenomenon was observed in can be regarded as unique.
- Thirdly, this research investigated multiple cases. This allowed for the discussion of the individual cases relative to each other. This strategy is also proposed by Flyvbjerg (2006). He explains that in situations where the factors and causal relationships that determine a phenomenon are not fully known and when there is uncertainty with regard to their relevance, it is useful to select several, different cases and to contrast them against each other. The sampling process is described in detail in Section 4.4.

4.4. Case study design

This section describes the research design that was applied in this thesis. It is divided into four sub-sections. Sub-section 4.4.1 argues for selecting the investigated cases from the context of industrial design consulting. Sub-section 4.4.2 explains the approach to sampling and provides an overview of the overall research design including the data collection methods. Sub-Section 4.4.3 describes the use of semi-structured interviews as main data source. Sub-section 4.4.4 provides insights into the analysis of the data.

4.4.1. A focus on the environment of industrial design consulting

This thesis selected case study research as the form of enquiry because it allows the researcher to gain insight into a phenomenon in its real-world environment. The most common environment for industrial designers is to find employment either in an in-house design department or in an industrial design consultancy (hereafter abbreviated IDC) (Best 2010). For this research, it was decided to collect the necessary empirical data about the ecodesign practice of industrial designers who work in IDCs. The reasoning for this decision is described below.

In this research project it was expected that collecting data from IDCs allowed access to a broader variety of cases and more readily allowed for the identification of insightful cases of ecodesign practice by industrial designers. Even though some degree of specialisation is observed among IDCs (Tennity 2010; Vanchan 2007), they are confronted with a much wider range of clients than in-house industrial designers. This allows them to draw on a more diverse experience of applying industrial design practice and potentially also ecodesign in different projects. Because the interrelationship of ecodesign practiced by industrial designers and its context is not understood in detail, this research assumed that access to a broader variety of cases increased the likeliness of identifying insightful cases.

In this research project it was assumed that investigating the ecodesign practice of IDCs better facilitated a focus on industrial design practice. Organisational, political and cultural aspects within a company can play a significant role in determining if the overall context is fertile or hostile for ecodesign (Boks 2006). Even though these factors are relevant for in-house designers and IDCs alike, they were not the primary concern of this research. To understand the role of industrial design practice for integrating ecological considerations into the product development process and converting them into product concepts, it was necessary to be able to focus on this practice while still taking these other factors into account. In this research it was assumed that this could be done more easily in the context of industrial design consulting, as it was anticipated that the relationship between industrial design consultants and their clients is more formalised than that of in-house design teams. This extracted the industrial design practice somewhat from the company context. This is shown in Figure 27.

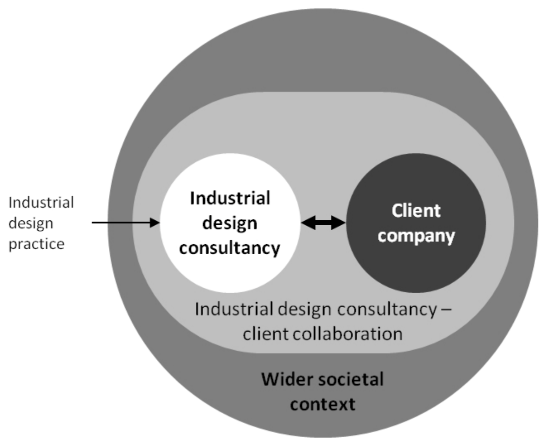


Figure 27: The context of industrial design consulting more easily allows for focusing on the contribution of industrial design practice to ecodesign
(Source: created for this research)

As argued in Chapter 2, the general nature of the industrial design practice and the influence it can exert is identical, whether industrial designers work in in-house design departments or in IDCs. However, this is not true for the relationship-specific influence of the individual industrial designers. The actual influence that industrial designers can exert is a combination of both of them: the relationship-specific influence of the individual industrial designers and the influence they can acquire through their practice. It is contested which environment provides industrial designers with better opportunities to have influence on the product development process and on the product. Von Stamm (2010) assumes industrial designers who work in-house have more influence over the product development process and the concepts they design. In contrast, Mawle, Bhamra & Lofthouse (2010, p. 13) observe that industrial designers who work in consultancies 'seem to have much more opportunity to influence strategic decisions than those in larger companies.' While it remains unclear if in-house industrial designers or those that work in IDCs generally have a higher potential to influence the product development process and the product, this debate is not the focus of this thesis. However, it illustrates the necessity to focus on those IDCs that are likely to take a more strategic role. This was addressed by this research by the approach to sampling.

4.4.2. Approach to sampling and overview of the research design

In this research project a staggered approach to sample the investigated cases was used. In this approach, each step was building on the collected data of the previous step. Consequently, in order to describe the sampling process, it is also necessary to refer to associated steps in the data collection, the methods that were used and how they were used. In other words, through explaining the approach, this sub-section also provides an overview of the research design.

The approach to sampling followed three consecutive steps. Firstly a content analysis of commercial websites of IDCs identified a pre-selection of promising cases. Secondly, interviews with ecodesign experts refined this pre-selection. Thirdly, in semi-structured interviews with representatives of the IDCs, the selection of cases that were used for this thesis was finalised. The overall research design, including the staggered approach sampling and data collection is shown in Figure 28. Figure 28 also shows the kind of information that was derived from each data collection method and how this information relates to the research questions. The thickness of the arrows highlights the significance of the data collection methods for the information that was used to address the research questions. The research questions that are linked to the information derived from the website content analysis are greyed out, as this research method only provided insights into how the IDCs *communicated* ecodesign practice, and not how they actually *conducted* it. The remainder of this sub-section provides a detailed description of the approach to sampling as well as the website content analysis and the expert interviews. The semi-structured interviews with representatives from selected IDCs and representatives of client companies of these IDCs were the main source of data. Thus, the application of this method in this research is discussed in more detail in Sub-section 4.4.3.

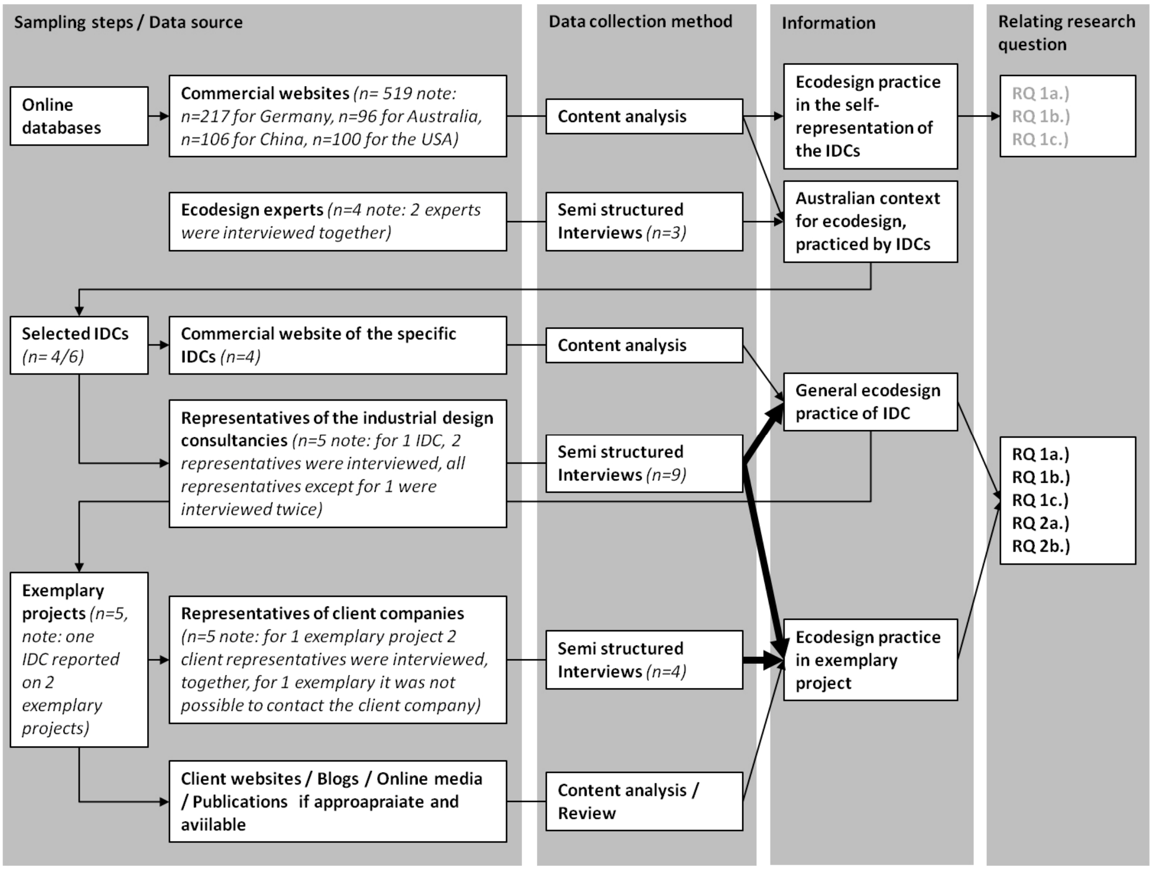


Figure 28: Overview of the research design
(Source: created for this research)

Research question 1a: How do industrial designers convert ecological considerations into product designs?

Research question 1b: What influence does industrial design practice have to identify goals and drivers for ecodesign processes?

Research question 1c: How far do industrial designers practice LCT to identify the most relevant ecological impacts and to inform their decisions for or against ecodesign interventions?

Research question 2a: What limits the ecodesign practice of industrial designers?

Research question 2b: How can industrial designers progress their ecodesign practice?

A website content analysis to pre-select promising cases

The staggered approach to sampling was necessary because the ecodesign practice of industrial designers (and specifically IDCs) has thus far been underexplored. Consequently, the available literature did not provide sufficient information to practice purposive sampling. To address this issue, the first step of the empirical investigation of this research was to conduct a content analysis of 519 commercial websites of IDCs in Australia, Germany, the USA and China. The commercial websites of the IDCs were identified through freely available online directories (Core77 2010; Design Australia 2010; Design Institute of Australia 2010; Verband Deutscher Industrie Designer 2010; Yellow Pages 2010). Four papers were written about this first explorative step of the research (Behrisch, Ramirez & Giurco 2010a; Behrisch, Ramirez & Giurco 2010b; ; Behrisch, Ramirez & Giurco 2011a; ; Behrisch, Ramirez & Giurco 2011b). While it was initially planned to select promising cases from several countries, it was decided, after having conducted the website content analysis, to select the case studies only from Australia. The reasoning behind this decision is described in Chapter 6, which also outlines the Australian context for ecodesign practiced by IDCs.

The goal of the website content analysis was to use the self-representation of the IDCs to evaluate how far ecodesign was integrated in their practice. It was sought to gain at least preliminary answers to the research questions 1a–1c. The website content analysis was mainly theory-led and partly thematic. The theory which led the website content analysis was an earlier version of the preliminary framework, describing the expanded notion of ecodesign that is presented in Chapter 5. This early version was still mainly built on traditional ecodesign theory with an underlying technical perspective as introduced in Chapter 3. It was hoped to gain insights into if and how industrial designers can expand the notion of ecodesign through a thematic analysis of their self-representation, using the research questions as a guide. The procedure of the website content analysis can be found in Appendix 2.

The website content analysis did not deliver sufficiently detailed insights to make claims directly about the ecodesign practice within the IDC community. It only allowed the development of an understanding about the extent to which ecodesign is included in the self-representations of IDCs. This limited insight into their practice was mainly due to a lack of detailed information on the websites of the IDCs. It was also partly due to the shortcomings of the way the content analysis was designed and conducted. Content analysis can either be used as a quantitative method (see for example: Rourke & Anderson 2004) or as a qualitative method (see for example: Hsieh & Shannon 2005). However, this distinction is rather fluid as any content analysis requires the interpretation of the content by the researcher (Krippendorff 2004). The application of content analysis for this research was mainly led by pre-established criteria to assess the ecodesign practice that is communicated on a large sample of commercial websites of IDCs. This approach is therefore rather quantitative in nature and allowed only limited insights into the complex, incompletely understood phenomenon of ecodesign as practiced by industrial designers.

Despite its limitations, the website content analysis identified several Australian IDCs that communicated ecodesign practice in a way that indicated that their practice expanded beyond the traditional notion of ecodesign. They showed products in their portfolios with a high degree of novelty where, besides the technological dimension, the meaning dimension of the product properties was also influenced in order to address ecological considerations. This allowed for the pre-selection of potentially promising cases to launch a more in-depth investigation into the ecodesign practice of the IDCs. The findings of the website content analysis were also used by this thesis to illustrate the context for ecodesign practice by the Australian IDCs. This is documented in Chapter 6.

Interviews with ecodesign experts to refine the case selection

The second step in the sampling process / data collection comprised interviews with four Australian ecodesign experts. Two of them were interviewed together. The experts were selected based on their contribution to training and supporting professional industrial designers in ecodesign. They were contacted via telephone and email with the request for an interview. After they agreed to participate, they were provided with an information letter about the research project and the interview questions prior to the interview. This background material can be found in Appendix 3. More details about the expert interviews can be found in Appendix 4.

The interviews had two purposes. First of all, they provided a basis to discuss the list of pre-selected cases that was generated from the website content analysis. Informed by the feedback of the experts, the selection of the IDCs who were approached with the request to participate in this research project was finalised. The resulting list counted six IDCs. Of those six IDCs, five were from the list that was generated from the website content analysis, and one was included solely based on the recommendations of the ecodesign experts.[19] Secondly, the

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[19] Based on the recommendation of another Australian ecodesign expert (not interviewed for this thesis) this research also interviewed two companies that provided industrial design as a service but had their main focus on graphic design and architecture/interior design. The ecodesign expert recommended these companies because the expert saw them as exceptionally proficient in influencing the meaning dimension. These interviews were very insightful about the application of the solution-focused element of Design Thinking and the capacity of design practice to influence the meaning dimension in other contexts but the development of consumer products. With regard to the incorporation of the ecodesign idea into industrial design practice in the context of a consumer product development process, they did not provide more substantial insights than the interviews that this research conducted with the IDCs. Thus it was decided not to include the results of these two additional interviews in this thesis.

interviews sought to capture the perspective of the experts on the Australian context for ecodesign, practiced by IDCs. These insights are used together with the findings of the website content analysis and a review of the available literature used to illustrate the context that the investigated cases were situated in.

In-depth interviews to finalise the case selection and identify exemplary projects

The third step in the sampling process was based on the data that was collected from the IDCs. The six IDCs were contacted via email and telephone with the request for participation in the research project. Their participation required agreeing to an in-depth interview with representatives of the IDC that could provide insight into their ecodesign practice, a potential follow-up interview and providing a contact of a client company with whom they collaborated on an ecodesign project. The interviews collected data about an exemplary project that the IDCs had conducted for a client and about their general experience with practicing ecodesign. The role of the exemplary project for the research design was twofold. Firstly, guides to case study research agree that in order to develop a comprehensive understanding of the phenomenon under investigation, it should be attempted to capture the perspectives of all relevant stakeholders (Simons 2009; Yin 2008). Next to the IDCs, the clients in particular play an active role in determining the ecodesign activities of the IDCs, as they have to fund and commission the work of the latter. Thus, using exemplary projects was seen as the most promising way to identify these contact persons and to gain insight into their perspectives. Secondly, the exemplary projects played an important role in the interview design as described under Sub-section 4.4.3. Even though the client company could have been approached directly, it was seen as necessary to do so only with the consent of the IDC in order not to jeopardise the business relationship of the IDC with this client. After agreeing to participate, the representatives of the IDCs were supplied with a one-page background information document and the interview questions. These documents can be found in Appendix 3.

All six IDCs that were contacted agreed to participate in the research and were interviewed. However, not all the IDCs were able to talk about an exemplary project where they had designed a consumer product for a client and included ecological considerations. The collected data did not allow for analysing of the underlying reasons of this circumstance. However, it seemed that these IDCs either had not worked on developing any consumer products recently where ecological considerations received a high degree of explicit attention, or that confidentiality constraints did not allow them to report on them. Thus, in the interviews they rather talked about ecodesign more generally or reported about projects where they developed products other than consumer products. Examples were public furniture, machinery and packaging. As Sub-section 4.4.3 explains, this exemplary project played an essential role in the approach of this research to develop an understanding of the ecodesign practice of the IDCs. Thus, the interviews with two of the six IDCs were not included in the analysis of this research.

The remaining four IDCs all provided exemplary projects, which could be used as reference points to discuss their experience with practicing ecodesign. It was left to the IDC to select a project they would put forward as specifically positive, negative or generally representative of their experience with ecodesign. One IDC chose to provide insight into two projects, one as an exceptional project that allowed much focus on ecodesign and the other one as representative for their general experience with ecodesign. The latter project was the only one where an IDC had concerns with approaching the client company with the request for an interview. Thus, for this project, only the perspective of the IDCs was captured. Due to the missing insight into the client perspective, it was initially considered to exclude this project. However, as it was found to illustrate the general experience with ecodesign that was also reported by the other IDCs, it was decided to include it despite the lack of capturing the client perspective.

Recruitment of the interview participants

The IDC–client interaction is usually handled via one or several contact persons on both sides (Ingols 1996). On the side of the IDC, this is commonly the brand owner or a senior designer who also manages the project. As it was expected that these individuals could provide the most detailed information about the ecodesign practice of the IDC and in the exemplary project, it was specifically requested to interview them when approaching the IDCs. If, during the course of the interviews, it became apparent that other staff from the IDC might be able to provide an additional insightful perspective on the ecodesign practice of the IDC, this person was also interviewed. This was the case for one IDC. Also on the side of the client company, it was sought to interview the contact person of the IDC for the exemplary project. Chapter 7 reports the findings from each IDC individually. In the beginning of each report, the interview participants are introduced and their role in their respective company is described. In total, nine interviews were conducted with representatives from the IDCs and four interviews were conducted with representatives from client companies. Five representatives from IDCs and four representatives from client companies participated in the interviews.

4.4.3. Semi-structured interviews as the main source of data

Partially informed by the experience of the limitations of the quantitative website content analysis (described in Sub-section 4.4.2), a more qualitative form of enquiry was found to be better suited to gain insights into the social processes and causal relationships that determine ecodesign practice. This research used semi-structured interviews with representatives from the IDCs and their clients as main data source to gain insight into the general ecodesign practice of the IDCs and the ecodesign practice that was conducted in an exemplary project. For the exemplary projects, the insights provided by the representatives of both companies made it possible to retrace the entire chain of events of the product development processes. Furthermore, the interviews also captured a description from both perspectives of the final product and how far the goals and requirements were seen as successfully materialised.

Where appropriate and possible the interview data was supplemented with additional data from three sources. One was the websites of the IDC and the client company; the second was published information about the exemplary projects; the third was documentation of the exemplary projects that the research participants drew upon to illustrate their reports. It was expected that some outcomes that were generated during the product development process were available at the participant's work place such as briefing documents, slideshow presentations, emails and prototypes. To give the research participants the opportunity to draw on this material if they felt that it allowed them to better illustrate the points they wanted to bring across[20] the interviews were conducted at their work place.[21]

Adaptive Theory (AT) in the interviews

The decision for semi-structured interviews is in line with the use of AT in this thesis. The theoretical foundation on which AT suggests to build for guiding an empirical enquiry is provided by the proposition that the influence of industrial design practice allows for the expansion of the traditional notion of ecodesign. To make this proposition more usable to structure the enquiry, Chapter 5 provides a more detailed preliminary framework. This background knowledge served as a basis for formulating the first set of interview questions. While AT draws on existing knowledge to structure and guide the enquiry, it demands openness towards new insights that emerge from the data. Five measures were taken in the interview design to achieve this openness.

[20] This material was not collected and included in this document as some of the projects are not on the market and thus are confidential.
[21] This was possible for all but one interview.

Firstly, the interview questions were seen and presented to the participants as starting points for a discussion rather than a checklist. This premise was also explicitly highlighted to the research participants in the beginning of the interview. The course of the interview—and the order in which the interview questions were addressed—was largely determined by how the conversation developed. This allowed for the flexibility of deepening the enquiry in response to the aspects and causal relationships that the research participants brought forward as particularly important.

Secondly, after conducting each interview, the interview questions were revised with regard to their usefulness in delivering insights to the research questions. This revision was based on notes and reflections on the interview process. In some cases, the research participants also provided feedback that was also considered in revising the interview questions. The revisions of the research questions increased their efficiency in helping to focus the conversations on the practice of the IDCs rather than on their outcomes. The final version of the interview questions can be found in Appendix 3.

Thirdly, some new insights (which raised further questions) only became apparent after a preliminary analysis of the interview data. This was particularly the case regarding research questions 2a and 2b:

> *2a: What limits the ecodesign practice of industrial designers?*
> *2b: How can industrial designers progress their ecodesign practice?*

In the case of three IDCs, the first set of interviews provided too little insight into the activities of the IDCs influencing the meaning dimension of the product properties and in practicing solution-focused thinking. These two qualities of industrial design practice underlie the proposition of Chapter 3 that the notion of ecodesign can be expanded. To develop the necessary understanding of how far these two qualities of industrial design practice are generally embraced by the IDCs and why their application to ecodesign remained limited, a second round of interviews was conducted. The follow-up interviews focused specifically on these two points. They were more open and used a presentation of the preliminary findings of the research as basis for discussion. To specifically discuss the application of solution-focused thinking, a representation of an iterative design process with a divergent and a convergent element was used. This representation is can be found in Appendix 1. The full presentation of the preliminary findings that was given to the representatives of the IDCs can be found in Appendix 5.

Fourthly, even though the interviews were initially scheduled for one hour for the representatives of the IDCs and for 45 minutes for the clients, they continued until the information that could be derived from the interview participant by the researcher was exhausted. This point was reached when no more new insights were brought forward by the research participants. Thus, the individual interviews varied in length, with the shortest one around 30 minutes and the longest one a little more than three hours.

Fifthly, the previously described staggered approach to sampling and recruitment made sure that all relevant interview partners were identified and that their perspective on the investigated phenomenon could be captured.

The role of the exemplary projects in the interviews

Besides creating the opportunity to identify a client, the exemplary projects played a central role in the interview design in three regards. First, they helped to gain insight into how the goals and drivers for the ecodesign practice were identified. Industrial designers are observed to have difficulties talking explicitly about their underlying thinking process when reporting about their work; they usually rather talk about the outcomes that they achieved (Cross 2011). This difficulty was addressed in the interview design by asking the interview participants to report the exemplary project step-by-step. This allowed them to retrace when and how goals and drivers were identified and to draw out the contributions of the IDC and the industrial design practice. While it did not provide detailed insights into the creative thinking process of the industrial designers, it helped to capture how problem-focused and solution-focused thinking influenced the product development process and the final outcome. Secondly, as all the exemplary projects had a tangible outcome, they allowed for the evaluation of how far the ecodesign practice helped to convert ecological considerations in the final outcome of the product development process. Thirdly, the exemplary projects served as reference points for the IDCs when providing insights into their general ecodesign practice. It was anticipated in the design of the interviews that such a reference point could be beneficial to develop more comprehensive insights. In the course of the interviews and the analysis, it proved to be essential to have this reference point for deriving meaningful insights from the interviews. This was because when reporting about their general experience with practicing ecodesign, most representatives of the IDCs talked about a range of contexts. As they often did not make the different contexts explicit, it was sometimes difficult to derive a clear understanding from the insights they provided if these insights were seen in isolation. This essential role of the exemplary project for making sense of the interviews was also the major reason why those IDCs that could not provide insight in an exemplary project were excluded from the sample.

Addressing risks of using interviews as the main source of data

Interview data can have limitations for comprehensively reconstructing past events. The interview participants may have forgotten aspects over time, which makes it difficult for them to recall the event (Yin 2008). Furthermore they are only capable of reporting from their perspective. This prescribes which aspects are perceived as relevant and may vary between individual research participants. Thus, it is not possible to uncover the 'true' way things have happened, but that it is only possible to document different perspectives and interpretations on a given process. These issues were addressed in this research in four ways.

1. By collecting insights from representatives of the client companies and from the IDCs, it was ensured that the two relevant perspectives of the IDC-client collaboration were captured. This also allowed for the crosschecking of insights provided from each perspective. In some cases, the information provided by the research participants was contradictory. In those cases, the report in Chapter 7 gives equal prominence to both perspectives presented.
2. Asking the interview participants to chronologically report the product development process helped the research participants to recall the process step-by-step and reduced the risk of missing important issues.
3. Drawing on additional data sources (websites, documentation and published information) to supplement or validate the data collected in the interviews allowed the development of a more comprehensive image of each case.
4. Follow-up interviews specifically focused on closing gaps in the collected data.

The second issue with interviews that needs consideration is the role of the interviewer and the potential bias s/he introduces in the interview situation (Hermanowicz 2002). S/he has to guide the participant through the questions without imposing her or his own opinion or discouraging the participant to speak freely. While this is more important when participants are interviewed about personal issues, it still plays a role in interviewing professionals about their work and therefore is relevant for this research. The researcher has a personal background in industrial design. It is acknowledged that in particular, this personal background most likely had an influence on the interviews (Singer, Frankel & Glassman 1983). The professional experience of the researcher brought an attendant risk of bias toward premature conclusions, consequently preventing the researcher from asking more detailed questions to further explore the aspects of the cases under investigation. To minimise this bias, the interview questions were carefully designed with the goal to gain rich descriptions about the investigated cases instead of quick answers. Care was taken not to interrupt the research participants and not to express the personal opinion of the researcher on ecodesign during the interviews. While having personal experience in design practice brought along difficulties as described above, it also permitted the researcher to take deep interest in the interviewee's perspective. This approach helped in gaining more detailed information during the interviews than if the researcher had no professional experience in industrial design.

The use of terms to describe the ecodesign idea

The representatives from the IDCs and the client companies were approached, explicitly asking them about their experience in integrating ecological considerations into the product development process and converting them into the products they designed. In all written and verbal correspondence with them, the term *ecodesign* was used coherently when referring to the incorporation of the ecodesign idea into design practice. This also comprised the interview questions and the background information about the research project that were sent to the research participants prior to the interviews.

While conducting and analysing the interviews, the researcher made the observation that the majority of research participants used different terms interchangeably for incorporating ecological considerations into their design activity. This was true for the representatives from the IDCs and for those from the client companies. The following terms were applied to varying degrees for incorporating ecological considerations into design practice: *ecodesign*, *design for environment*, *sustainable design* and *design for sustainability*. None of the representatives from the IDCs and client companies communicated potential differences between the individual concepts. Even research participants who used the terms *sustainable design* or *design for sustainability* reported only about pursuing an ecological agenda in their design practice. They did not make any statements about using design practice to directly address an explicit social or economic agenda that was in line with sustainable development.

That the interviewees used varying terms when describing the incorporation of the ecodesign idea into their design practice needs to be considered when reading the report of the empirical enquiry in Chapter 7. It frequently draws on direct quotes from the research participants to give prominence to their voices. As explained above, these direct quotes do not always use the term *ecodesign* for describing the use of design activity to apply the ecodesign idea within a commercial product development process. In order to minimise the distortion of the reported data, it was decided to leave the terms applied by the research participants in the quotes unchanged while coherently using the term *ecodesign* in the report where no direct quotes were used. Consequently in the report in Chapter 7, all terms used by the interviewees when referring to the incorporation of the ecodesign idea into their design practice are treated equally.

4.4.4. Analysis—from data to information

This sub-section describes the process that was applied in this research to make the step from the collected data to information. Insights, gained from empirical data are reported in Chapter 6 and Chapter 7. Chapter 6 draws on the preliminary investigations into the application of ecodesign through expert interviews and the website content analysis. Chapter 7 reports the results of the semi-structured interviews that were conducted with the representatives from the IDCs and the client companies.

The criteria for deriving valid information from quantitative data (such as that gathered through the website content analysis) are different from deriving valid information from qualitative data, such as that obtained from the semi-structured interviews (Silverman 2009). The validity of information that is derived from quantitative data is established when the procedure of collecting and analysing the data can be reproduced with the same result. Securing and demonstrating the validity of information derived from qualitative methods is more complex (Krefting 1991). Collecting and analysing qualitative data has an inherent element of subjectivity. Social events such as interviews are impossible to repeat in the exact same way. Making sense of words and sentences that were used in an interview relies to some extent on the interpretation of the researcher. Different researchers may interpret the same data differently. These circumstances can cause difficulties with the reproducibility of information that is derived from qualitative research. Thus, for establishing rigour in qualitative research, Mays & Pope (1995) propose to provide rich information about the context in which the data was collected and to make the step from data to information retraceable and understandable for peers. This way, it can be demonstrated that the available data has been analysed rigorously.

This sub-section first describes the efforts to establish reproducibility of the website content analysis and how it was tested. It then goes on to describe handling of the interview data and the procedure of the analysis of this data. Finally, it provides insight into how this research assured that all data was represented fairly.

Reproducibility of deriving information from the website content analysis

For the website content analysis, the step of collecting the data and deriving information from it was one and the same. A detailed procedure was established, which provided a checklist to evaluate the individual websites. Applying this checklist already filtered the data that was collected only to capture the sought-after information. The key criteria that were investigated were as follows:

- Did the IDC offer services that helped to design products with a low ecological impact? If so, did the IDC advertise that these services were guided by LCT?
- Did the IDC advertise that its services could provide strategic input in the product development process?

The website content analysis was conducted at an early stage of this research. For this document, only the findings about the criteria above were used, but the enquiry also covered other aspects. Examples include portfolio size, accreditations the IDC held, and further details about how ecodesign services were communicated. The full procedure of the website content analysis and the detailed list of criteria after which the websites were assessed can be found in Appendix 2.

To assure the reproducibility of the website content analysis, the procedure was carefully designed to be unambiguous. The researcher applied this procedure to the websites of the Australian IDCs and the German IDCs. The websites of the Chinese and American IDCs were analysed by two undergraduate students from UNSW. As different persons had applied the same procedure, it was possible to test its robustness by 'triangulation by observer' (Marby 2008, p. 222). The researcher picked random websites from the sample that these two undergraduate students had investigated. Without looking at their results, the researcher applied the same procedure. The obtained results were then compared to the ones the undergraduate students had generated. The results were identical, which was seen as a confirmation that the procedure designed to analyse the websites was unambiguous and reproducible.

Handling the interview data

With the consent of the research participants, all interviews were digitally recorded. The audio files were then transferred to a computer and imported into NVIVO 10. The interviews were fully transcribed. To have the opportunity to not only read the transcripts but also to be able to return to the original audio files, they were linked to the transcripts. Following each interview, detailed field notes were taken. These notes helped the researcher to recall aspects that were not captured by the audio recordings. These aspects included, for example, conversations before and after the audio recording, the use of project documentation material by the interview participants, and the initial reflections of the researcher on the interview process and the obtained data. The field notes also captured preliminary ideas the researcher had about how the data could be interpreted.

Procedure of the interview analysis

In line with AT, this research not only applied the framework presented in Chapter 5. It also pursued an open approach to the data to identify inherent themes. This allowed not only for the capture of aspects covered by the preliminary framework, but also for the accommodation of new insights that facilitated supplementing the preliminary framework in areas where it did not provide sufficient explanatory power. The openness was particularly important for the analysis of the first round of interviews. The procedure of analysing them, including the endeavours to secure the necessary openness, is shown in Figure 29. It is divided into two parts. The first part aimed at establishing a coding structure that was iteratively refined in the second part. Both parts are explained below.

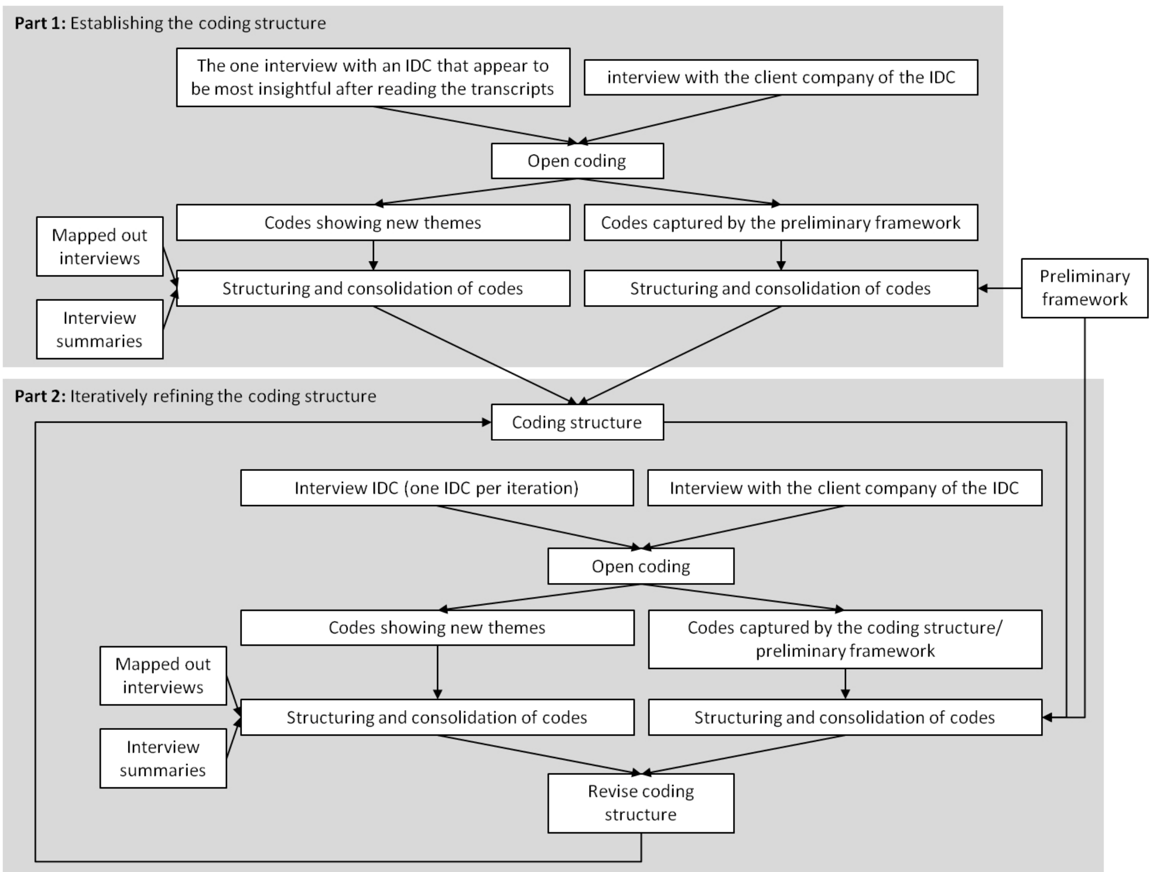


Figure 29: Procedure of analysing the first set of interviews
(Source: created for this research)

Part 1—Establishing the coding structure: After reading through all the transcripts the interview that appeared most insightful with a representative from an IDC was selected for open coding in NVIVO 10. All data was coded and sorted under descriptive topics. The same procedure was conducted with the interview of the representative of the client company of the IDC.

This resulted in two sets of codes:

1. codes that were captured by the preliminary framework, and
2. codes that showed new themes.

The preliminary theoretical framework was used to revise and consolidate the first set of codes. To revise and consolidate the second set of codes, a twofold strategy was applied. First, the interviews were summarised. This activity required drawing out the key messages of the research participants. Comparing these key messages with the codes helped to define them more clearly and also showed where codes could be merged. Next, the interviews were mapped out. At this second stage the preliminary codes with their descriptive topics were written into individual boxes that were connected with lines, illustrating causal relationships. Also, reflections by the researcher about the causal relationships were included in these maps. To distinguish these reflections from the codes and their descriptive topics, they were highlighted in grey. An example of such a map can be found in Appendix 6. Visualising the causal relationships this way helped to further consolidate the codes by grouping them. This provided a first version of a coding structure.

Part 2—Iteratively refining the coding structure: In this part the remaining interview pairs were analysed one after the other, each time followed by a refinement of the coding structure. The first step was again open coding, which resulted in two sets of codes:

1. codes that were captured by the coding structure/preliminary framework
2. codes showing new themes.

The first set of codes was revised and consolidated by applying the coding structure and the preliminary framework. For revising and consolidating the second set of codes, the same two-fold strategy described above was applied. This allowed for an iterative refinement of the coding structure.

In the analysis of the second set of interviews, no more open coding was used. The established coding structure was applied to the interviews. However, care was taken to still stay alert to new themes that could emerge from the data. If new themes were identified, the coding structure was revised to include them. This procedure is shown in Figure 30.

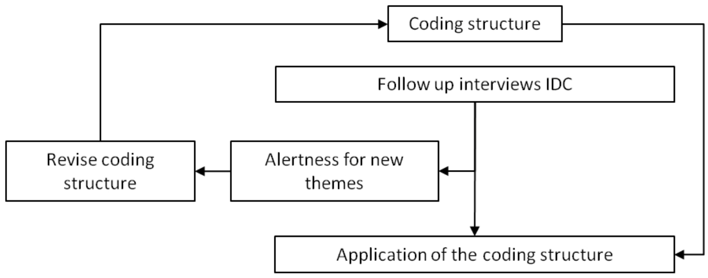


Figure 30: Procedure for analysing the second set of interviews
(Source: created for this research)

Analysis of the expert interviews

Only the interviews with the representatives of the IDCs and the client companies were analysed in this amount of detail. For the expert interviews only open coding was applied. They played more of a role in informing the orientation of the research and provided some quotes to illustrate the Australian context for ecodesign, practiced by IDCs.

Assuring a fair representation of the interview data

This research followed a twofold strategy to assure that the interview data was represented fairly in the results reported in Chapter 7. Firstly, it reaffirmed with the interview participants that they felt that they were understood correctly. This was done via

1. reporting the preliminary findings back to the research participants from the IDCs[22] in a detailed presentation, which was given to them before the second round of interviews. This presentation can be found in Appendix 5.
2. offering them the possibility to provide feedback on the sections of the final report, which referred to the information they had provided.
3. in reporting the findings from the cases, it was sought to use direct quotes wherever possible and appropriate. This approach was used because it gave the voices of the research participants more prominence in the reporting of the findings.

For the exemplary projects, this research captured the perspective of the client company and the IDC. In some cases, the representatives of the client companies and the IDCs had different perspectives on the project they reported about. The case study reports in Chapter 7 explicitly highlight inconsistencies in the insights provided by the IDCs and the client companies where they were encountered.

[22] Due to time constraints, this was only possible for three of the four IDCs.

4.5. Reflecting on the usefulness of Adaptive Theory in this research project

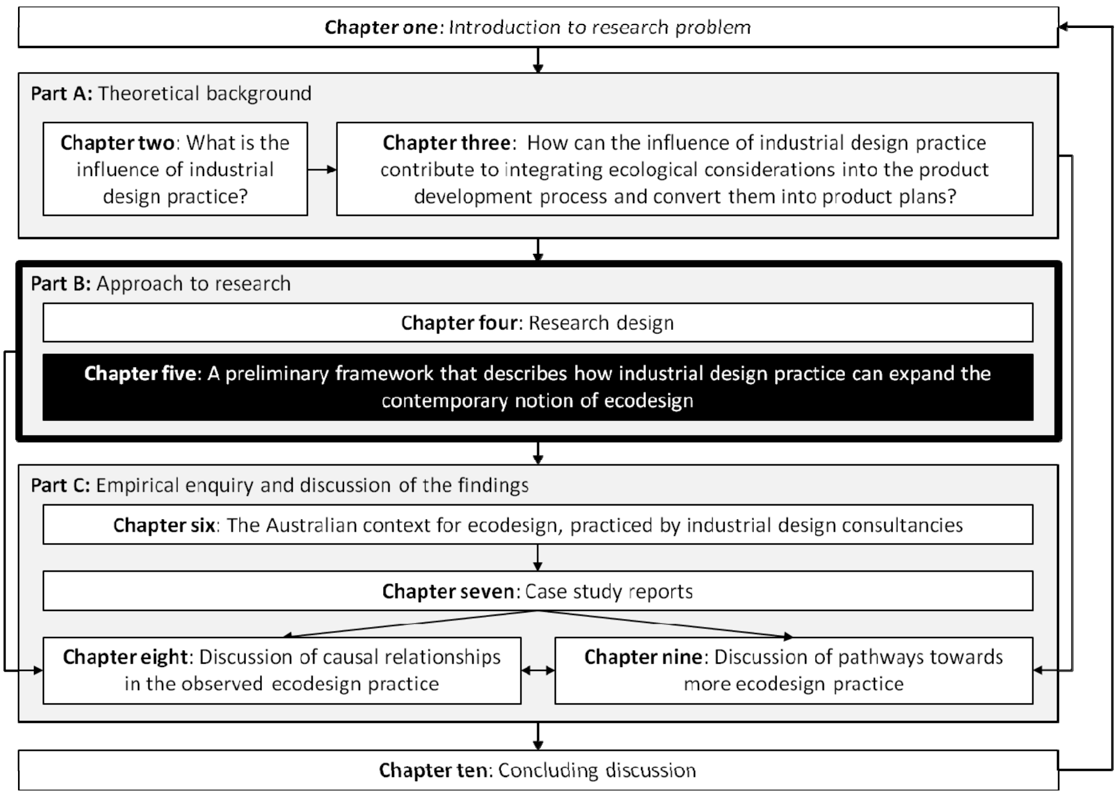
In hindsight an adaptive theory (AT) approach proved to be fruitful in gaining insight into real world ecodesign practice. The AT approach played an important role in framing the literature review, guiding the case study research and synthesizing the rich insights, gained through the case studies into new theory.

The AT approach allowed insights from the website content analysis to frame literature review. As explained under sub-section 4.4.2 the website content analysis was guided by an early version of the preliminary theoretical framework, describing the expanded notion of ecodesign. This early version already acknowledged that industrial design practice can take the ecodesign idea beyond the traditional notion of ecodesign. However, it still was strongly influenced by the traditional notion of ecodesign and did not formulate in much detail where and how industrial design practice can expand it (for a description of the early version of the preliminary theoretical framework that was used for the website content analysis see Appendix 2). Besides the shortcomings of the website content analysis as a quantitative method in providing deep insight into the under-explored phenomenon of real world ecodesign practice, also the lack of detail of the applied framework proved to be problematic. As reported in more detail in Chapter 6 the website content analysis identified a number of IDCs that communicated ecodesign practice that expanded beyond the traditional notion of ecodesign. However, the absence of a more detailed theoretical foundation made describing and explaining this practice difficult. It became clear that industrial design practice can adopt a role that has strategic influence and that it can impact on aspects of products that go beyond their quantifiable technological properties. The websites of some IDCs communicated that these capacities were also used for ecodesign but it remained unclear how and why this was only sometimes the case. These shortcomings of the website content analyse clarified where the literature review had to be widened to develop a more comprehensive image of the influence of industrial design practice and how this influence can expand the traditional notion of ecodesign.

The theoretical proposition of the expanded notion of ecodesign provided necessary orientation in designing the interviews and analysing the data. The mechanisms underlying design practice are often oblique – even to industrial designers themselves (Cross 2011). Thus there is a risk of being distracted by surrounding factors when researching into design practice. Researchers such as Stevenson et al. (2011) for example who approached researching into the ecodesign practice of industrial designers completely openly mainly collect information about such surrounding factors. Even though the factors Stevenson et al. (2011) investigates such as the exchange of ecodesign knowledge within the industrial design community are important they do not provide deep insight into the actual ecodesign practice of industrial designers. This risk was also observed in the course of the case study research conducted for this thesis. The interviewed industrial designers tended to provide much detail about factors surrounding their practice. To get them talking more about the practice they conducted, it was often necessary to specifically trigger this conversation via strategic questions. For this purpose, as well as to target the analysis of the interviews towards gaining insight into the ecodesign practice, the preliminary theoretical framework provided valuable orientation.

It was important for this research that the preliminary theoretical framework that resulted from the literature review was seen as a working model. Whilst the data, reported in Chapter 7 did not suggest that the preliminary theoretical framework of the expanded notion of ecodesign was 'wrong' it showed that it needed to be refined to answer the overarching research question of this thesis. These refinements are discussed in detail in Chapter 8 and 9.

CHAPTER 5. A PRELIMINARY FRAMEWORK OF THE EXPANDED NOTION OF ECODESIGN



This chapter presents the preliminary framework that was used to structure and guide the empirical enquiry as part of an AT approach. This framework is presented separately and introduced in this document after the research design, to highlight the fact that even though it is informed by established theory, it represents a suggestion by the researcher about how this theory can be interpreted to address the aim of this thesis.

Chapter 3 concluded that industrial design practice could theoretically expand what is traditionally understood as ecodesign. However, the implications of these expansions for industrial design practice have not yet been described in detail. This chapter elaborates these implications. This not only provides a preliminary framework to support and guide the empirical enquiry, but it also makes explicit the underlying assumptions of this research with regard to the expanded notion of ecodesign. In describing the preliminary framework, this chapter also elaborates how it was used in this thesis. The chapter is divided into three sections.

- **Section 5.1** revisits the factors that are important for integrating ecological considerations into the product development process and converting them into product designs. It describes them from the perspective of the industrial designers. Because the empirical investigation focused on the context of IDCs, this section specifically draws out how they can influence these factors.
- **Section 5.2** describes the influence of industrial design practice in order to convert ecological considerations into product designs. It describes a categorisation of the possible design interventions that can theoretically be conducted. This categorisation specifically takes into account that industrial design practice can influence both the technological dimension and the meaning dimension of the product properties. As the general ability to influence the meaning dimension of the product properties is shared by IDCs and in-house industrial designers, this section does not explicitly distinguish between the two contexts.
- **Section 5.3** summarises the preliminary framework.

5.1. Integrating the ecological considerations in product development processes—the perspective of an industrial design consultancy

Building on the work of Johansson (2002), Section 3.4 described three groups of success factors for integrating the ecodesign idea into the context of commercial product development: general success factors; competency to practice LCT; and the motivation for integrating the ecodesign idea into a product development process. This section describes each of these factor groups with specific attention to the perspective of IDCs.

5.1.1. General success factors for a product development process from the perspective of an IDC

This thesis understands the general success factors for a product development process—which are relevant from the perspective of an IDC—as those factors that are responsible for the IDC's capacity to engage with the particular problem situation through industrial design practice. The factors influencing this capacity can be classified into two categories. The first category describes the proficiency of the IDC in practicing and applying Design Thinking. The second category describes the willingness, responsiveness and capacity of their clients to utilise the capacity of the IDC in a product development process.

Proficiency in Design Thinking

The first category of success factors describes the proficiency in practicing and applying Design Thinking within the IDC. The literature distinguishes different levels of proficiency in Design Thinking, ranging from novice to visionary (Cross 2011; Dorst & Reymen 2004; Lawson & Dorst 2009). Lower, more novice levels are strongly reliant on problem-focused logic to guide design interventions, whereas higher levels draw on both problem and solution-focused thinking (Perez, Fleming Johnson & Emery 1995). Higher levels of proficiency in Design Thinking also merge problem- and solution-focused thinking more seamlessly (Cross 2004) and are linked to a more subconscious and intuitive application of Design Thinking than lower levels (Cross 2011). Designers with a higher degree of expertise are also characterised by the capacity to strategically influence the problem situation they work on. The visionary even goes as far as developing 'new ways things could be, defines the issues, opens new worlds and creates new domains.' (Dorst & Reymen 2004, p. 3).

To account for the importance of proficiency in Design Thinking, this research sought to investigate the experience of IDCs where the level of this proficiency can be expected to be high. This was addressed in the sampling process by (i) seeking to interview renowned IDCs that also had an outstanding track record of winning design awards, and (ii) asking the ecodesign experts to recommend IDCs they saw as particularly proficient in taking a strategic role.

Client readiness—the importance of IDC-client communication

The second category describes factors that are important to allow the client to utilise the proficiency of the IDC in Design Thinking. Williamson, Kalmar & Tischler (1996) summarise these factors under the term *client readiness*. This concept suggests that the client[23]:

- Recognises a problem or an opportunity
- Is aware that the IDC can address a problem or help to create an opportunity
- Is willing to address a need or create an opportunity
- Has the necessary resources for engaging the IDC and for realising and commercialising the outcome of the work
- Has the ability to communicate with the IDC.
- Has trust in the capability of the IDC

A high degree of client readiness is more likely to allow an IDC to take a strategic role. Even though client readiness is predominantly client-internal, IDCs can contribute to its development. Feldman & Boult (2005) showed that IDCs can help to cultivate client readiness before and during the product development process in order to gain more strategic influence. Key to this appears to be an appropriate communication with the client from the side of the IDC (Williamson, Kalmar & Tischler 1996). This communication can happen through traditional channels—such as being transmitted verbally or in written form. It can also happen through the representations of the solution suggestions developed by the IDC (Best 2010). Williamson, Kalmar & Tischler (1996) find that the IDC needs to communicate its capabilities, make explicit the benefits of using its services and explain what resources are required to do so.

This research captured the perspectives of the IDC and those of the client company on the product development process along the entire collaboration of the two companies. This allowed insight into the extent to which client readiness was present within that collaboration, how it developed over the course of the project, and how far industrial design practice contributed to it. As client readiness is generally important for industrial design practice, and not specific to ecodesign, this research sought to sample IDCs that were expected to be experienced in cultivating client readiness. Thus, in the website review and in the expert interviews it was sought to identify IDCs who prominently promote themselves in a strategic role.

[23] These six points are formulated based on the work of Williamson, Kalmar et al. (1996) but are not directly quoted.

5.1.2. The competency in LCT and its application

Chapter 3 clarified that LCT is a prerequisite for the expanded notion of ecodesign that this thesis suggests. Otherwise, it remains unclear whether design interventions that seek to convert the ecological considerations into the product designs successfully reduce the negative ecological impact associated with a product. Thus, it was important for this research to account for the competency of the IDCs in LCT.

The key factors for LCT competency are access to relevant ecological information and the ability to use this information to inform decisions for or against design interventions that seek to convert ecological considerations into product designs. A lack of access to such information and a deficiency in the understanding of this information has already been identified as a potential barrier for successful ecodesign practice (Bakker 1995). Because competency in LCT has already been identified as essential for the application of the ecodesign idea, this thesis sought to identify IDCs that fulfilled this pre-condition. Consequently, the website content analysis and the expert interviews sought to identify IDCs that either had the capacity to apply analytical LCT tools and/or that collaborated with experts who could provide them with the required information.

While competency in LCT is an important prerequisite, the approach also needs to be applied in the practice of the IDCs in order to develop products with an associated low ecological impact. Thus, it was important for this research to understand the extent to which the IDCs apply LCT. For this purpose the exemplary projects played an important role. The research sought to collect data about all steps in the product development process of the exemplary projects the research participants perceived as important. This allowed for the step-by-step retracing of the decision making process for or against design interventions and the evaluation of whether the entire life cycle of the product was considered in this decision making process. This helped to understand the extent and rigour of the LCT application by the IDCs. It also enabled an estimation of whether the design process actually resulted in a product with an associated low ecological impact. This insight is also discussed in Sub-section 5.2.4, which describes how the outcome of the investigated exemplary projects was integrated into the data collection. The insight into the way the IDC applied LCT in the exemplary project also allowed for making more robust inferences about their more general application of LCT.

5.1.3. Identifying goals and drivers, stimulating the integration of ecological considerations into the product development process

As explained under Sub-section 3.5.1, it is only possible to integrate ecological considerations into a commercial product development process if this can be justified by the identification of drivers for this activity. These drivers are traditionally classified as either internal or external drivers (Brezet & Van Hemel 1997; Tischner, Ryan & Vezzoli 2009). The distinction between internal and external drivers is not clear-cut (Van Hemel 1998), but is useful from a company perspective. However, this thesis argues that, from the perspective of industrial designers or IDCs, it is more appropriate to categorise these drivers with regard to how they align with the social and economic agenda inherent to the context in which they are situated[24]. Figure 31 shows the problem situation of industrial design practice that was introduced in Sub-section 2.1.2.

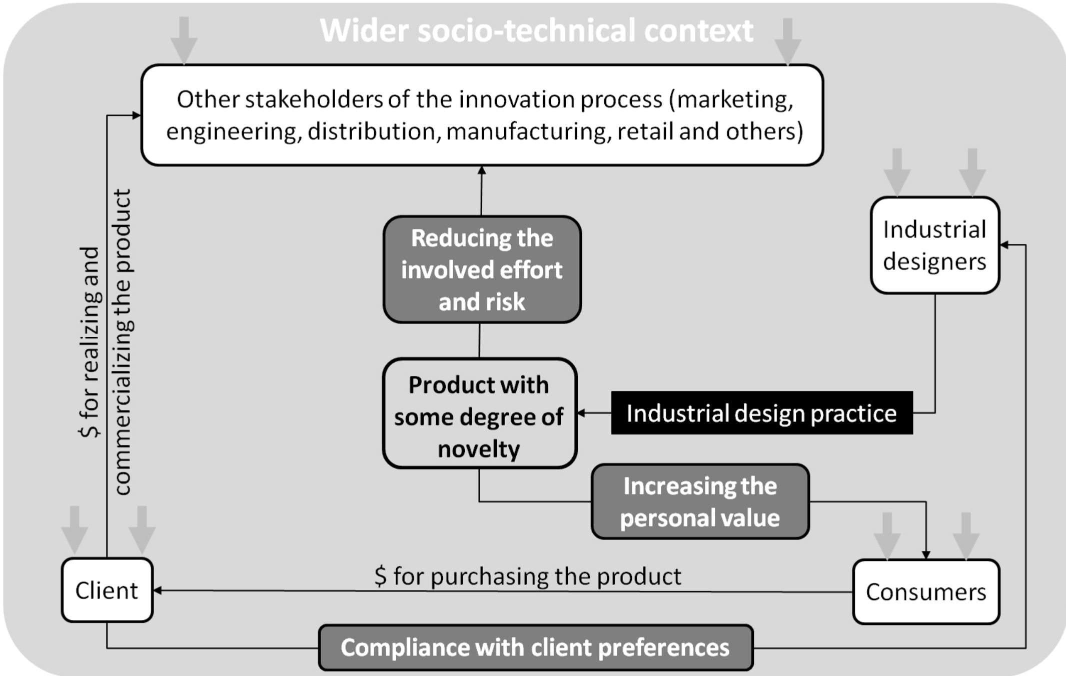


Figure 31: Categories of drivers for including ecodesign in the design process from the perspective of industrial designers
(Source: created for this research)

Within this problem situation, the industrial designers shape the product properties. This has direct impact on the associated expenses for manufacturing, distributing and commercialising the product (which they seek to minimise), and on the value that consumers potentially see in a product (which they seek to maximise). Besides that, the industrial designers may also need to consider specific preferences of the client for whom they are working. Consequently, this thesis suggests the following three categories for drivers that stimulate the integration of ecological considerations into the product development process:

[24] As introduced in Section 2.1, the economic agenda of industrial design practice demands to prioritise achieving a financial benefit for the industrial designers and their clients, while its social agenda implies prioritising the demands of individual consumers.

1. Those that allow a reduction in the involved effort and risk associated with manufacturing distributing and commercialising a product—for example, achieving both ecological and economic benefits though efficiency improvements, or avoiding extra costs or penalties by complying with ecological legislation.
2. Increasing the personal value consumers see in a product—meeting a consumer demand for products that have explicit and/or implicit ecological benefits.
3. Compliance with client preferences—responding to the self-driven motivation of a client to reduce the ecological impact of its products.

The traditional notion of ecodesign only utilises problem-focused thinking to identify goals and drivers for including ecological considerations into the product development process. Sub-section 3.4.3 proposed that industrial design practice also allows drawing on the solution-focused element of Design Thinking for this purpose. This is visualised in Figure 32.

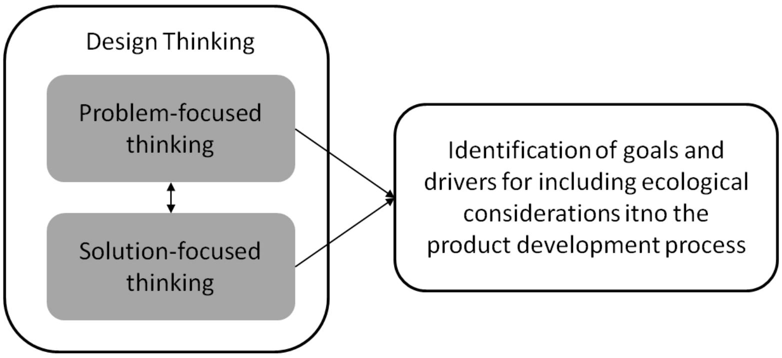


Figure 32: Capacity of industrial design practice to draw on the problem and solution-focused elements of Design Thinking to identify goals and drivers for ecodesign
(Source: created for this research)

Problem-focused thinking only uses solution proposals that are generated in the course of a project to evaluate them against previously established requirements. In contrast, when drawing on the solution-focused element of Design Thinking, representing and testing solution proposals facilitates a learning process that potentially changes or supplements the initially set requirements. Thus, the prominence of the two elements of Design Thinking for identifying goals and drivers for including ecological considerations can become visible when retracing the decisions that were made in the product development process step-by-step. Besides applying this approach to the exemplary projects, this research also asked the representatives of the companies directly about the use of more iterative and explorative approaches to identify goals and divers for integrating ecological considerations into the product development process.

A focus on ecologically motivated industrial design consultancies

This research sought to explicitly sample IDCs that expressed an inherent ecological motivation on their website and/or were recommended by the ecodesign experts as having ecological aspirations. As explained in Sub-section 3.4.3, this thesis assumed that an inherent ecological motivation of those, executing design practice increases the likelihood that the application of solution-focused thinking uncovers opportunities for ecodesign. Firstly, an underlying ecological motivation presumably can guide the industrial designers when developing solution suggestions that intentionally explore and determine the problem situation with regard to such opportunities. Secondly, it increases the likelihood that 'surprises' (unexpected reactions to solution suggestions; for more detail, see sub-sections 2.2.1 and 3.4.3) that hint towards opportunities for eco-friendly products are followed up.

5.2. Classifying ecodesign interventions from the perspective of industrial designers

This section describes and classifies the design interventions industrial designers can theoretically conduct according to the proposed expanded notion of ecodesign. The classification of ecodesign interventions that is presented in this section was used in the empirical enquiry of this research to assess how far the expanded notion of ecodesign was reflected in the practice of the IDCs and in the outcomes of this practice. In order to highlight the difference to the traditional notion of ecodesign that focuses only on influencing the technological dimension of the product properties, the importance of influencing the meaning dimension is explicitly emphasised.

BOX 15
On terminology: Ecodesign strategies, a widely-used term to describe ecodesign interventions

Traditionally the term *ecodesign strategies* has been used to describe design interventions that can help to lower the ecological impact associated with a product (see for example: Brezet & Van Hemel 1997; Lewis et al. 2001).

This use of the term *strategy* can be misleading: It commonly describes the concept of using all available resources and aligning all actions to achieve a long-term goal (Encyclopaedia Britannica 2013). In the case of ecodesign, this goal is to achieve a low ecological impact product. (continued on next page)

The technical perspective has clarified that simply conducting ecologically motivated design interventions, without considering their consequences along the entire life cycle of a product, is not necessarily successful in achieving a low ecological impact.

Making decisions for or against ecologically motivated design interventions must be informed by LCT. This thesis thus sees it as more appropriate to describe LCT as the strategy to achieve a low-impact product and the interventions (which the ecodesign literature commonly describe strategies) as individual actions that can be taken to reach this goal. Therefore, this thesis uses the term *ecodesign interventions* instead of *ecodesign strategies*.

Because design interventions that influence the meaning dimension are not widely discussed in the ecodesign literature, this section also draws on sustainable design literature. Existing classifications from both bodies of knowledge fall short of describing the full scope of ecodesign interventions that are theoretically possible from an industrial design perspective. Those from the ecodesign literature only account for ecodesign interventions that influence the technological dimension of the product properties (see for example: Brezet & Van Hemel 1997; Lewis et al. 2001; White, Belletire & St Pierre 2009). Sustainable design literature usually only discusses design interventions in more detail that go beyond traditional ecodesign. For example Bhamra, Lilley & Tang (2011) offer a typology of design interventions that seek to influence consumer behaviour in order to achieve ecological benefits but they do not expand on other ecodesign interventions. Consequently this thesis proposes a new classification of ecodesign interventions to appropriately cover the influence of industrial design practice to convert ecological considerations into product concepts.

In this thesis it is proposed that, in order to address ecological issues, industrial design practice can focus on

1. changing product technology that is applied to fulfil consumer needs—termed **product-technology-focused ecodesign interventions;**
2. accounting for and potentially changing consumer behaviour in fulfilling their needs—termed **behaviour-focused ecodesign interventions;**
3. changing the way consumer needs are fulfilled—as this can be understood as seeking new means for providing the same utilitarian and emotional functionality this category is termed **means-focused ecodesign interventions;** and
4. changing the consumer demands—termed **demand-focused ecodesign interventions.**

The four categories of ecodesign interventions are described in detail below. The section then goes on to outline the relationship between the four categories of ecodesign interventions and their impact on the product properties.

5.2.1. Product-technology-focused ecodesign interventions

These types of design interventions (such as using low-impact materials, designing for recycling or using energy-efficient components) are discussed in detail in the traditional ecodesign literature (see for example: Brezet & Van Hemel 1997; Tischner et al. 2000; White, Belletire & St Pierre 2009; Wimmer, Züst & Lee 2004). A widely cited list of product-technology-focused design interventions has been published by Brezet & Van Hemel (1997) (cited for example by: Tischner et al. 2000; White, Belletire & St Pierre 2009). The list comprises seven categories that are populated with 29 descriptions of individual ecodesign interventions. As mentioned in break-out box 15 earlier in this document, Brezet & Van Hemel (1997) use the term *ecodesign strategy* to describe what this thesis understands as *ecodesign intervention* (see Table 3).

Table 3: Product-technology-focused ecodesign interventions
(Adopted from: Brezet & Van Hemel 1997)

Overarching category (originally termed *ecodesign strategies*)	**Descriptions of *ecodesign interventions* (originally termed *sub-strategies*)**
1) Selection of low-impact materials	Cleaner materials, renewable materials, lower energy content materials, recycled materials, recyclable materials
2) Reduction of materials usage	Reduction in weight, reduction in transport volume
3) Optimisation of production techniques	Alternative production techniques, fewer production steps, lower/cleaner energy consumption during production, less production waste, fewer/cleaner production consumables
4) Optimisation of distribution system	Less/cleaner/reusable packaging, energy-efficient transport mode, energy-efficient logistics
5) Reduction of impact during use	Lower energy consumption during use, cleaner energy source, fewer consumables needed, cleaner consumables, no waste of energy/consumables
6) Optimisation of initial lifetime	Reliability and durability, easier maintenance and repair, modular product structure, classic design, strong product-user relation
7) Optimisation of end-of-life system	Reuse of product, remanufacturing/refurbishing, recycling of materials, safer incineration

The original list of Brezet & Van Hemel (1997) has an additional category which they term 'New concept development'. They treat this category as separate to the other seven, as the degree of novelty required for the ecodesign interventions within this category is much greater than for the other seven categories. This category is discussed in more detail under means-focused ecodesign interventions in Sub-section 5.2.3.

Relevance of the meaning dimension for Product-technology-focused ecodesign interventions

Product-technology-focused design interventions can in some cases be conducted without being recognised by the consumer. For example, the number of internal components of a product may be reduced without any notable changes at the product interface. Consequently, such ecodesign interventions can be expected to not have an impact on the meanings consumers attach to the product. They only require the capacity to influence the technological dimension of the product properties.

In every other case, where product-technology-focused ecodesign interventions bring along changes in the product interface and thus can be recognisable for the consumer, they potentially change the meanings consumers attach to a product. This is even true for simple amendments to a product, like using materials with visual or haptic qualities that differ from the material commonly used for this product or similar products.

Understanding and mediating these implications for the meanings consumers attach to the product is important to ensure their compatibility with a commercial product development process. This is because any change in the meanings consumers attach to a product can have positive as well as negative implications for the consumer's acceptance of a product, consequently influencing the value that industrial designers create for the consumer, their client and themselves.

5.2.2. Behaviour-focused ecodesign interventions

While not discussed in detail in traditional ecodesign literature, some authors acknowledge the possibility to foster eco-friendly consumer behaviour through the design of a product. For example Wimmer, Züst & Lee (2004) illustrate their understanding of ecodesign practice by the means of redesigning a kettle. Beside product-technology-focused ecodesign interventions, they also suggest providing feedback to the consumer about when the water has heated up. This should avoid unnecessary reheating. Other examples are the ecodesign interventions of 'classic design' and 'strong product-user relation' to avoid early obsolescence of a product in Table 3, adopted from Brezet & Van Hemel (1997).

Compared with product-technology-focused ecodesign interventions, research into behaviour-focused ecodesign interventions is still rather young (Lockton, Harrison & Stanton 2009). For example, the idea of 'scripting'—more or less forcefully making sustainable behaviour easy and unsustainable behaviour hard through the design of products—was established early in the 2000s (see for example: Jelsma & Knot 2002). More recent research also explores ecodesign interventions that sought to influence consumer behaviour beyond scripting. One example is to use conscious or subconscious nudges to move consumers towards eco-friendly behaviour patterns by making appropriate information visible and/or tangible through the experience of interacting with the product (Pierce, Odom & Blevis 2008).

Scholars have only recently started to collate and structure the different design interventions to foster sustainable behaviour (Wever, van Kuijk & Boks 2008). Wever, van Kuijk & Boks (2008) and Bhamra, Lilley & Tang (2011) suggest similar typologies of design for behaviour change strategies. As such, Bhamra, Lilley & Tang (2011) provide a more detailed description of the individual ecodesign interventions and summarise them in a table under seven different categories (adapted in Table 4).

The compilation of Bhamra, Lilley & Tang (2011) is incomplete. For example, it lacks behaviour-focused ecodesign interventions that optimise the emotional relationship between consumer and product. For instance, various ecodesign interventions can be taken to strengthen the personal attachment of consumers to their products. They range from design interventions that allow consumers to individualise their products, to design interventions that result in products that create rich user experiences which unfold over time (Van Hinte 1997; Van Hinte 2004). Examples of consumer experiences that unfold over time include offering the possibility to consumers to upgrade, repair and maintain a product themselves, or designing the product in a way that an aging process adds value for the consumer (Chapman 2005; Van Hinte 1997; Van Hinte 2004; Walker 2006). These design interventions allow consumers to develop a deeper relationship with their products. They can be used to foster various eco-friendly consumer behaviours such as not prematurely disposing of products. Many of these design interventions focus on what Chapman (2005) calls ‘emotionally durable design’. Van Nes & Cramer (2005) highlight that maximising the length of the useful life of a product is not always desirable from an ecological perspective. This is particularly true for products that require the input of energy or consumables during their use. Technological progress can decrease the impacts arising from the use phase of such products. In those cases, it may make sense from an ecological perspective to replace old, inefficient products already before they break down with newer, more efficient ones. This category of design interventions is added to the list of Bhamra, Lilley & Tang (2011) in Table 4. While not the focus of this thesis, testing (and if necessary, supplementing) this typology of behaviour-focused ecodesign interventions is a promising area of further research.

Table 4: Behaviour-focused ecodesign interventions
(Adapted from: Bhamra, Lilley & Tang 2011—design for optimised personal attachment added)

Categories / Type of design intervention for behaviour change	**Explanation provided by Bhamra, Lilley & Tang (2011)**
Eco-information—design oriented education	This category of design interventions seeks to make consumables visible, understandable and accessible to inspire consumers to reflect upon their use of resources
Eco choice—design oriented empowerment	This category of design interventions seeks to encourage consumers to think about their use behaviour and to take responsibility for their actions through providing consumers with options
Eco-feedback—design oriented links to ecologically or socially responsible action	This category of design interventions seeks to inform users clearly about what they are doing and to facilitate consumers to make ecologically and socially responsible decisions through offering real-time feedback
Eco-spur—design oriented rewarding incentive and penalty to inspire users	This category of design interventions seeks to incentivise consumers to explore more sustainable usage of a product by providing rewards/penalties to 'prompt' good behaviour or penalties to 'punish' unsustainable usage
Eco-steer—design oriented affordances and constraints to facilitate users	This category of design interventions seeks to allow consumers to adopt more ecologically or socially desirable use habits through the prescriptions and/or constraints of use embedded in the product design
Eco-technical interventions—design oriented technical intervention	This category of design interventions seeks to restrain existing use habits and to persuade or control user behaviour automatically by design combined with advanced technology
Clever design	This category of design interventions seeks to design products that automatically act ecologically or socially without raising awareness or changing user behaviour purely through innovative product design.
Design interventions for behaviour change, not included by Bhamra, Lilley & Tang (2011)	
Design for optimised personal attachment (see for example: Chapman 2005; Van Hinte 1997; Van Hinte 2004; Van Nes & Cramer 2005; Walker 2006)	

Relevance of the meaning dimension for behaviour-focused ecodesign interventions

As previously discussed for product-technology-focused ecodesign interventions, only behaviour-focused ecodesign interventions that change the product interface require industrial designers to influence the meaning dimension. Even though all behaviour-focused ecodesign interventions take consumer behaviour into account, Table 4 shows that the degree to which they change consumer behaviour varies. For example, the sub-categories 'Eco-technical interventions—design oriented technical intervention' and 'Clever design' accept current behaviour patterns. In contrast, ecodesign interventions that encourage consumers to play an active part in the maintenance of their products have a great impact on the consumer behaviour. Thus, they are also recognisable at the product interface and potentially influence the meanings consumers attach to the product. Thus, proficiency in influencing the meaning dimension of the product properties is essential for all behaviour-focused ecodesign interventions in Table 4 except for 'Eco-technical interventions—design oriented technical intervention' and 'Clever design'.

5.2.3. Means-focused ecodesign interventions

Products are a means for consumers to derive utilitarian and emotional functions that respond to their needs and that they thus perceive as valuable. This category of ecodesign seeks to develop new, more eco-friendly, means for fulfilling these needs. In order to reduce resource use, several types of design interventions to dematerialise need fulfilments have been identified. These include designing products for shared use, integrating multiple functions in one product, or creating completely new, more resource-efficient product concepts (Brezet & Van Hemel 1997). New technologies such as mp3 players, which replaced devices that needed additional physical media (such as CDs to store music) or e-book readers (that make printed books obsolete), have potential for dematerialisation. The ecological benefit of mp3s compared to CDs has been demonstrated (Weber, Koomey & Matthews 2010). Research comparing e-books with printed books concludes that the number of books read and the number of times any given book is read determines which option is preferable from an ecological perspective (Lloyd 2011).

Means-focused ecodesign interventions not only involve developing physical, tangible objects that fulfil consumer needs. They can also replace physical, tangible objects partially or completely with services. This concept that is commonly referred to as *product service system* (PSS) and is often seen as promising for dematerialisation (Tukker & Tischner 2006a). While industrial designers are likely to have a hand in developing PSSs, designing a full PSS goes beyond the capacity of industrial design practice (Tukker & Tischner 2006b). Firstly, as mentioned in sub-section 2.2.3, designing services is beyond traditional industrial Design Craft. Their contribution is likely to focus more on the physical, tangible objects that may be required for a PSS. Also, the design of an appropriate business model to offer an economically viable PSS requires additional expertise that is not typical for traditional industrial designers.

It can be concluded that means-focused design interventions can be addressed by industrial designers alone, as long as they only involve developing physical or tangible objects. In other cases—and in particular for developing PSSs—the Design Craft that can commonly be expected from industrial designers is not sufficient. In those cases, industrial designers either need to collaborate with other design professionals or acquire the required Design Craft themselves.

BOX 16
The PSS concept does not always bring along ecological benefits

A frequently cited example for a PSS is Xerox (Baines et al. 2007; McAloone & Andreasen 2002). Instead of selling copying machines, Xerox's business model is to charge their customers for the service of copying. While they still supply copying machines, these are not owned by their customers but only provided to them for a certain time. During that time, Xerox services the copy machines and takes them back when that time is over. Because the revenue is not generated by selling copying machines but from directly fulfilling the need of copying, Xerox is incentivised to facilitate this as resource-efficient as possible through a combination of physical objects and services.

Many authors see great potential for ecological impact reduction in the idea of shifting a company's business model from selling material goods towards generating revenue directly from need fulfilment (see for example: Bey & McAloone 2006; Tischner, Ryan & Vezzoli 2009). However, the PSS concept does not always bring along ecological benefits (Tukker & Tischner 2006a). If a PSS is not explicitly designed to have a low ecological impact, the capacity of the concept for decoupling resource use from revenue stream lies idle—a phenomenon Tukker & Tischner (2006a) observe for many contemporary commercial PSSs. For example, the previously described case of copying may even lead to a worse ecological impact through increased paper use within an office.The constantly replaced consumables (in particular the toner and the paper) make the copy machine users less aware of how much they copy, which results in a less conscious use of the copying machines.

Relevance of the meaning dimension for means-focused ecodesign interventions

Means-focused ecodesign interventions change how utilitarian and emotional functionality is offered[25] that responds to consumer needs. Being confronted with previously unknown or unused solutions stimulates consumers to make sense of these new possibilities that can help them to address their needs. In other words the results of means-focused ecodesign interventions trigger the construction of new meanings around them. Consumers can perceive these meanings as positive or negative, thus enhancing or diminishing the personal value of the solution to the consumer. This consequently also helps or hampers the creation of economic value from the solution for the client of the industrial designers. This places great importance on the capacity of industrial design practice to exert influence on the meaning

[25] See Sub-section 2.3 for how products offer utilitarian and emotional functionality to consumers.

dimension in order to seize potential benefits and/or mediate potential risks associated with the meanings that are potentially attached to the outcomes of means-focused ecodesign interventions.

5.2.4. Demand-focused ecodesign interventions

The three previous categories of ecodesign interventions aim to fulfil consumer demands as resource efficiently as possible. In these cases, the demands are regarded as a given and act as a starting point to describe the functionality a product that is designed should provide. Demand-focused ecodesign interventions assume that consumer demands are not predefined or static, and that they can be influenced by the outcomes of design practice. In this regard, demand-focused ecodesign interventions have a different starting point from the three previously discussed categories. Despite this different starting point, this category still represents a pathway to reduce the negative ecological impact of society. This is because the demands of consumers are a critical factor driving production and consumption, and thus are ultimately responsible for the ecological impact associated with these sets of activities (Tukker et al. 2006).

The possibility of actively influencing consumer demands to convert ecological considerations into products is mostly neglected in traditional ecodesign literature. It is only discussed by some authors who write about sustainable design and adopt a socio-technical perspective (see for example: Fry 2009; Thorpe 2010; Wahl & Baxter 2008). Fry (2009, p. 30) claims that 'everything designed goes on designing'. In other words, products can create or reinforce sustainable but also unsustainable demands in society.

Thorpe (2010) argues that the demands that can be expressed are determined by the available and known choices. She goes on to suggest that designers can influence this through 'choice editing'—only confronting consumers with products with certain characteristics (Thorpe 2010, p. 6). In other words, when an eco-friendly solution is unavailable, the possibility that consumers develop and articulate a demand for them is also limited. The same is true *vice versa*. Consequently, it is posited in this thesis that demand-focused ecodesign activities must make eco-friendly choices available and known to consumers such that the consumer can make a decision about whether or not to purchase and use them. This knowledge and the decision making process do not necessarily need to be at a conscious level. Instead, it is important that the consumer perceives and understands the product as distinct and preferable because of consciously or subconsciously received information about the ecological performance of the product. In other words, this thesis understands demand-focused ecodesign interventions as efforts to allow consumers to attach an eco-friendly meaning that they perceive as positive to a product. It is important that consumers perceive these eco-friendly meanings as positive as they otherwise would not change their needs in favour of the products to which they attach these meanings.

Sustainable design literature anticipates that using design to influence consumer demands within the current context of industrial design practice cannot deliver outcomes that are beneficial from an ecological perspective (see for example: Fuad-Luke 2009; Thorpe 2010). Historical data confirms that the capacity of industrial design to uncover and stimulate consumer demands has contributed to push consumption through premature disposal of products before the end of their useful life (Andrews 2007). Consequently, it has increased the material throughput and energy use of society and has worsened the ecological impact (Andrews 2007). Thus, demand-focused ecodesign interventions are commonly not discussed with regard to their application in the current context of industrial design practice.

However, historical data only provides insight to the use of the capacity of industrial designers to uncover and stimulate consumer demands in general. It does not allow general claims to be made about the use of this capacity with regard to uncovering and stimulating consumer demand specifically for eco-friendly solutions. Consequently, it is argued in this thesis that the possibility to practice demand-focused ecodesign interventions in a commercial environment has been dismissed prematurely. This has led to a lack of understanding regarding the potential role of demand-focused ecodesign interventions in this context. Because of the lack of engagement of contemporary theory with this topic, the description of the characteristics of demand-focused ecodesign interventions that is provided here is not exhaustive or set in stone. It rather represents a starting point for the empirical enquiry of this thesis.

Relevance of the meaning dimension for demand-focused ecodesign interventions

The capacity to influence the meaning dimension is at the very heart of demand-focused ecodesign interventions. The work of industrial designers can contribute to two channels through which they can direct effort towards communicating an eco-friendly message and thus create opportunities for consumers to attach an eco-friendly meaning to a product.

The first channel is to explicitly communicate information about the ecological performance of the product through the associated marketing material. Examples are labelling schemes or making self-declarations to consumers. While industrial designers commonly do not actively participate in marketing activities, they can contribute to generate the required information and pass it on to the marketing professionals. Traditional ecodesign literature does not acknowledge the capacity of actively changing consumer demands through making available explicit information about the ecological impact of a product. However, a number of authors from this body of literature see such activities as beneficial to reach consumer groups who either already have an explicit preference for eco-friendly solutions or are currently developing such preferences due to trends in the wider socio-technical context (see for example: Brezet & Van Hemel 1997; Tischner et al. 2000; Wimmer, Züst & Lee 2004).[26]

The second channel to communicate an eco-friendly message that allows consumers to attach eco-friendly meaning to a product is the product language that is applied in the interface. In other words, these ecodesign interventions are captured by the 'mode of use' and 'form' levers introduced in Chapter 2.

Through the 'mode of use' lever, industrial designers can influence the meanings consumers attach to a product. The experience consumers have when using a product can make the ecological performance of a product explicitly or implicitly understandable for them. An example would be a feedback mechanism making the energy consumption of an active product tangible to consumers in a way that encourages a responsible use of that product (such as the ecodesign interventions discussed by Pierce, Odom & Blevis 2008). This example shows that in some cases an intervention that designers execute may classify as behaviour-focused ecodesign intervention but also as demand-focused ecodesign intervention. This potential double classification can occur when the behaviour change, intended by a behaviour-focused ecodesign intervention brings along ecological benefits that are understandable as such by the consumer. Still, allocating the design intervention to both categories requires that these consequences were both consciously planned by the designer.

Hassi & Kumpula (2009) demonstrate that the 'form' also plays a role in determining whether consumers attach an eco-friendly or eco-unfriendly meaning to an object. This is true even for

[26] The possibility to create or reinforce consumer demand for eco-friendly products through marketing activities such as information campaigns, eco-labelling and aligning the entire brand communication to support eco-messages has received attention in the marketing literature (see for example: Belz & Peattie 2012; Ottman 2011). Some authors create a link to the design practice within the development of products (see for example: Ottman 2011, pp. 56-63). However the focus of this of this body of literature is on how to apply problem-focused thinking to gain insight into consumer demands and how to design and conduct marketing activities. Thus it provides little insight in the potential role of industrial designers and the application of solution-focused thinking in integrating ecological considerations into commercial product development processes and converting them into product designs.

products where the designers have not explicitly intended to communicate an eco-friendly or eco-unfriendly message. Some specific design interventions, such as the use of *natural* materials like bamboo (Huang & Henry 2009) or the visible applications of photovoltaic elements on a product are widely associated with an eco-friendly message. The success of other interventions, such as the use of colour or giving specific sculptural properties to communicate eco-friendliness, is more context-specific (Hassi & Kumpula 2009). In this thesis it is assumed that existing product languages are not the only pathway to trigger consumers to attach eco-friendly meanings to a product. For example, the Toyota Prius has become an icon for eco-friendly auto mobility (Ozaki & Sevastyanova 2011) without drawing on existing product languages. Arguably, the meanings consumers attach to the Toyota Prius have also been facilitated by a prominent communication of its eco-benefits through traditional marketing channels. However, the car has a distinct form without which it would be questionable if similar meanings would be attached to it.

5.2.5. The relation between the four categories of ecodesign interventions

Demand-focused ecodesign interventions can only exist in combination with one or several ecodesign interventions from the other three categories. This is because demand-focused ecodesign interventions influence only the consumer perception of a product. This perception does not necessarily overlap with a quantifiable low ecological impact of the associated product (Hassi & Kumpula 2009; Huang & Henry 2009). While such a misalignment is not desirable from an ecological perspective, it can be harmful from a business perspective. It can lead to boycotts of the product if the unjustified eco-friendly product meaning becomes public (see for example: Purkayastha & Fernando 2007).

This interrelation and the impact on the individual categories of ecodesign interventions is visualised in Figure 33, adapted from Gruendl & Mara (2010). The vertical axis represents the quantifiable ecological impact and the horizontal axis represents the extent to which an eco-friendly product meaning is offered. With regard to their quantifiable ecological impact and the use of the product form to attempt to trigger eco-friendly product meanings, Gruendl & Mara (2010) propose that most of the current products are positioned in the lower left corner. In this thesis it is assumed that this is not specific for the product form but for efforts to trigger eco-friendly meanings in general.

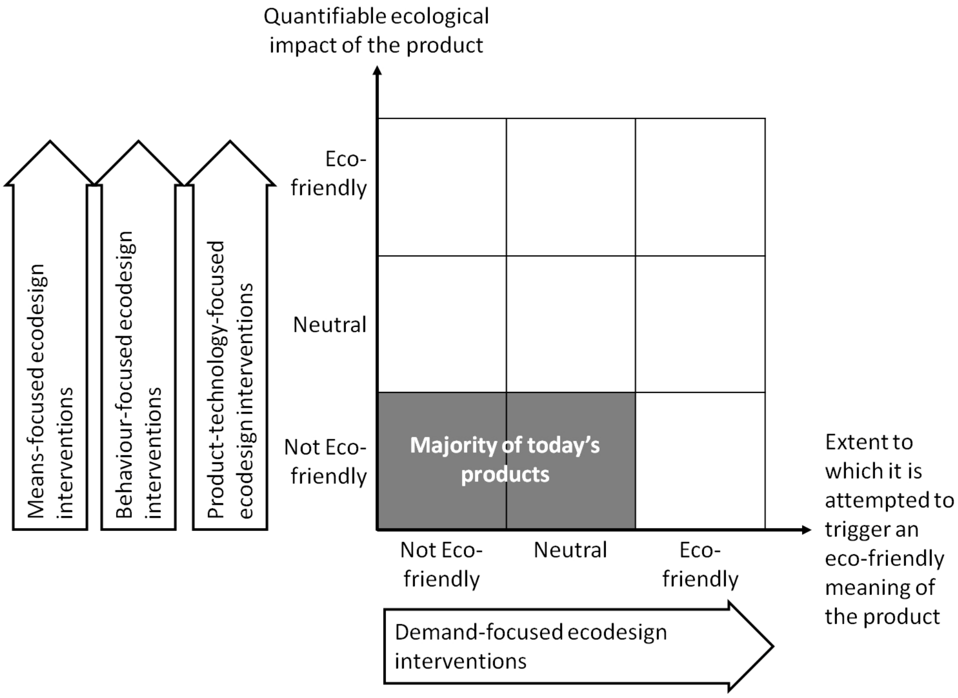


Figure 33: The impact of the individual categories of ecodesign interventions on the product properties (Adapted from: Gruendl & Mara 2010—arrows showing the levers of industrial design practice added)

The visualisation of product-technology-focused, behaviour-focused and means-focused ecodesign interventions on the vertical axis in Figure 33 should not be misunderstood as a suggestion that they can be applied interchangeably. It merely shows that these three categories of ecodesign interventions can, depending on the context, achieve a quantifiable reduction of the negative ecological impact of a product. Appropriate ecodesign interventions need to be selected context specifically.

Appropriate ecodesign interventions need to be selected context specifically

Not all ecodesign interventions are appropriate in every case. The spectrum of product-technology-focused, behaviour-focused, means-focused and demand-focused ecodesign interventions merely represents the possible room to manoeuvre that is open to industrial design practice. The selection of appropriate ecodesign interventions can vary between individual product development processes. It needs to be informed by LCT and the compatibility of the ecodesign interventions with the economic goals for the product development process. For example, eco-friendly product meanings triggered through demand-focused ecodesign interventions may not be perceived as positive by the majority of the consumers in the target market. This may be particularly the case when utilising product languages that currently trigger eco-friendly product meanings, as they are often also afflicted with other, negative meanings such as a compromised utilitarian functionality (Huang & Henry

2009). However, it remains unclear how far this also applies to new product languages that offer consumers the opportunity to attach eco-friendly meanings to products.

The allocation of executed design interventions to a category is not necessarily exclusive

The allocation of executed design interventions to the four categories, suggested in this thesis is not necessarily exclusive. Box 17 explains that establishing exclusive categories for design interventions that can bring along ecological benefits is impossible when seeking to capture the influence of industrial design practice. As highlighted in sub-section 5.2.4 some design interventions can classify as behaviour-focused ecodesign interventions but also as demand-focused ecodesign interventions. Also some design interventions that have been described as means-focused can classify as other ecodesign design interventions. For example designing products for shared use can also bring along a change in consumer behaviour. Designing more resource efficient product concepts may include design interventions that are listed under section 5.2.1 as product-technology focused ecodesign interventions. Also any design intervention that achieves quantifiable benefits from an ecological perspective and is recognisable by the consumer as such can classify as a demand-focused ecodesign intervention.

The four categories of ecodesign interventions suggested in this thesis still allow a clear description of how industrial designers use their room to manoeuvre when practicing ecodesign. The categories highlight the focus that designers can take when seeking to use their influence for achieving ecologic benefits. Thus for allocating an ecologically motivated design intervention to a certain category it is necessary to know about the intentions of the designer. For example, as explained in the previous section any design intervention that achieves quantifiable benefits from an ecological perspective and is recognisable by the consumer as such can also classify as a demand-focused ecodesign intervention. However this double allocation only occurs when the designer is aware of the implications for the quantifiable ecological impact as well as for the potential change in consumer demand triggered by the meaning of the product. An example for this is when a designer consciously uses a material because of its ecological performance and intentionally shows this material in the product interface to stimulate eco-friendly product meanings. Then this design intervention can be classified as a product-technology-focused ecodesign intervention as well as a demand-focused ecodesign intervention.

BOX 17 **The impossibility of establishing exclusive categories for the executed design interventions**
Establishing exclusive categories for design interventions that can bring along ecological benefits is impossible when seeking to capture the influence of industrial design practice. Exclusive categories would require that a design problem can be fully broken down into individual sub-problems that can be treated independently from each other. Only then is it possible to classify design interventions that only address one or several of these sub-problems. In other words exclusive categories for design interventions would require fully adopting the rational problem solving paradigm. As design thinking alternates between problem- and solution-focused logic it is governed by the rational problem solving paradigm as well as by the reflective practice paradigm. Thus describing design practice only in the light of the rational problem solving paradigm would not allow a comprehensive explanation of industrial design practice.

5.2.6. Assessing the ecodesign interventions of the IDCs

In order to assess the influence the investigated IDCs exerted to convert ecological considerations into product designs, this research drew on the four categories of ecodesign interventions as a guiding framework. It furthermore used the diagram in Figure 33 to assess how far these ecodesign interventions were embodied in the final products of the exemplary projects. To allocate the products on the vertical axis it retraced if the IDCs practiced LCT as described in Sub-section 5.1.2. If a streamlined LCA or a full LCA had been conducted by the IDC or another institution, the product was allocated accordingly to one of the three rows. If no such study was available and if LCT was not practiced rigorously, the allocation of the product was tentative based on the judgement of the researcher of the available information. To make this allocation retraceable, the decision making process is described in the report of the case studies. In order to allocate the products on the horizontal axis, the research drew predominantly on the report from the IDCs and the client companies. This clarified how much effort was directed towards allowing consumers to attach eco-friendly meanings to the product designs. As meanings are not inscribed in the product, this research also explored the way client companies communicated the product as an eco-friendly solution and, if possible, how it was discussed in online media[27].

[27] This was not possible for all exemplary products as some of them were either not yet on the market or no review of them was found in online media such as blogs and online magazines.

5.3. Summary of the preliminary framework

This section combines the individual aspects that have been described in sections 5.1 and 5.2 to provide an overview of the preliminary theoretical framework of the expanded notion of ecodesign. This overview is provided in Figure 34.

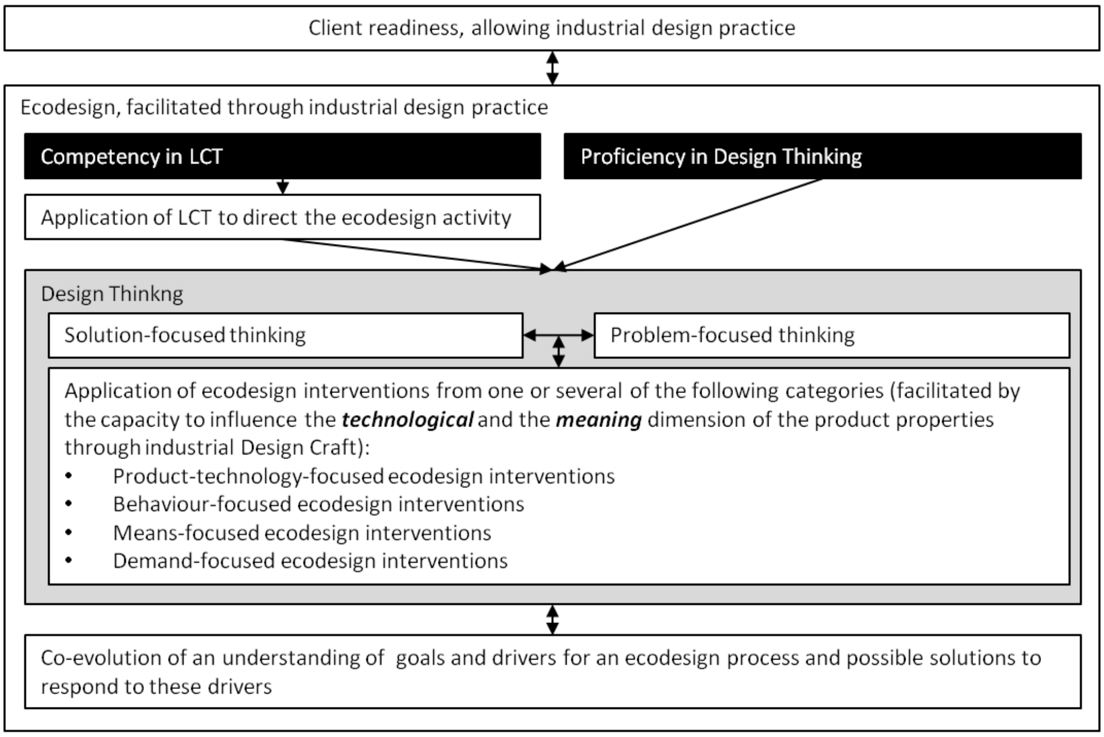
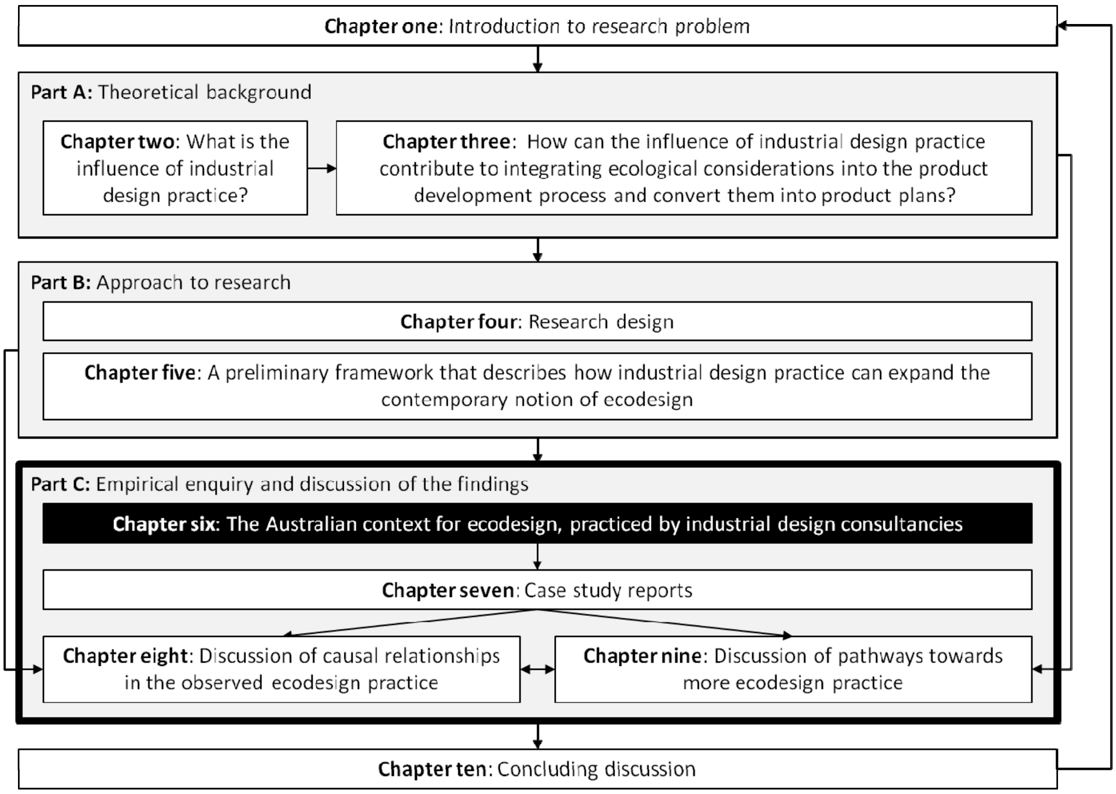


Figure 34: Preliminary framework describing the expanded notion of ecodesign
(Source: created for this research)

As explained in section 5.1, the capacity to practice LCT and proficiency in Design Thinking are prerequisites for design practice that reflects the expanded notion of ecodesign. These two factors are highlighted in black in Figure 34. The capacity to practice LCT allows applying it in the design process. All other boxes in Figure 34 are connected through bidirectional arrows. These bidirectional arrows have been used for two reasons. Firstly, as explained in the introduction of Chapter 2, the influence of design practice, its context and the way design practice is structured are all interrelated. This is expressed, for example, in the bidirectional arrows connecting the grey box (titled 'Design Thinking') and the box below, describing the 'co-evolution of an understanding of goals and drivers for an ecodesign process and possible solutions to respond to these drivers'. The second reason for the use of the bidirectional arrows is that the correlation between the individual nodes remains partly unclear. For example, Van Hemel & Cramer (2002) identify that certain constellations of stimuli and barriers for ecodesign were more successful in triggering ecodesign than others. However, they do not provide more detailed insights regarding the nature of the conducted ecodesign activity. For example it remains unclear if the resulting ecodesign practice is always guided by

LCT. Since Van Hemel & Cramer (2002) conducted their research, little subsequent effort has been invested into studying potential causal links within ecodesign practice. Thus, the preliminary theoretical framework to describe the expanded notion of ecodesign is more of a starting point for the empirical enquiry that is tested and supplemented through the collected data, rather than an exhaustive explanation of the investigated phenomenon.

CHAPTER 6. THE AUSTRALIAN CONTEXT FOR ECODESIGN: EXPERT PERSPECTIVES AND IDC SELF-REPRESENTATIONS ON WEBSITES



The researcher decided to collect empirical data from Australian IDCs. In line with this decision, this chapter provides background information about industrial design consulting in Australia. Little information about the ecodesign practice of IDCs has been published. The same is true specifically for Australia and industrial design consulting in Australia in general. In order to develop a detailed image of the environment from which this research collected the empirical data, the identified published information is supplemented with the results of the website content analysis and the expert interviews. Because this chapter draws on published information and on empirical evidence that was collected specifically for this thesis, it is positioned in this document between the research design/theoretical framework and the report of the findings from the case studies. This chapter is structured in three sections and a concluding summary.

- **Section 6.1** explains why a focus on Australian IDCs was chosen for this research.
- **Section 6.2** outlines the environment for industrial design consulting in Australia in general.
- **Section 6.3** focuses on the dissemination of ecodesign in Australia to the industrial design community.
- **Section 6.4** summarises the strengths and weaknesses of the Australian context for ecodesign practice by IDCs.

BOX 18 **Labelling of the interviewed ecodesign experts**
This report uses the labels *Expert1, Expert2, Expert3* and *Expert4* to distinguish the ecodesign experts that were interviewed for this thesis. All four experts were actively involved in disseminating LCT and ecodesign to the professional Australian industrial design community. Background information about the interview context is provided in appendix 4.

6.1. Why focus on Australia?

The decision to select only cases of Australian IDCs for the empirical investigations for this research was formed after the website content analysis had been conducted. The goal of this website content analysis was to develop an overview of the extent to which the IDCs advertise ecodesign through their online self-representations. The investigation covered the websites of IDCs in Australia, China, the USA and Germany and showed country-specific differences in how ecodesign was communicated on the websites of the IDCs. The focus on one country avoided accounting for cultural differences that may influence the empirical investigation. Several reasons for and against choosing the Australian context were considered. The most important reasons were:

- **The expected level of involvement in ecodesign by IDCs:** As reported in Section 6.2, the results of the website content analysis gave reasons to believe that ecodesign and a motivation to actively promote it to clients has disseminated further amongst Australian IDCs than amongst IDCs in the other investigated countries.
- **The likeliness of IDCs taking a strategic role in the product development process:** A report from Design Victoria (2008) finds the extent to which clients in commission IDCs in Australia to take a strategic role comparable to other countries. However this is contested. Australian IDCs did not represent themselves as frequently in a strategic role as, for example, their American colleagues. Also, the interviewed experts reported that they felt a deficiency within the Australian IDC community to gain strategic influence over the projects they work on. (See Sub-section 6.2.1.)
- **The comparability of the context for industrial design practice in the individual IDCs:** In comparison to the other three countries, the company profiles that were communicated on the websites of the Australian IDCs were the most homogenous. The website review found no IDC with more than 35 staff, and the majority of them worked for diverse clients instead of specialising on one type of client only. Furthermore, the entire sector in Australia is rather small, which decreased the effort for gaining a comprehensive overview that allowed the individual cases to be positioned relative to each other. While the homogeneity of the industrial design consulting sector is a bonus in this regard, some of the interviewed experts saw the absence of large IDCs as a potential drawback. Their perception was that large American IDCs in particular (such as IDEO or FROG) are important hubs for developing progressive ideas and attitudes within the industrial design community. On the other hand, it can be questioned again how comparable the practice of these companies is to that of an *average* IDC. IDEO or FROG are considerably larger than the majority of IDCs and employ a much more diverse staff, ranging from marketing and engineering to psychology and other scientific disciplines.
- **The accessibility of the IDCs for collecting data about industrial design practice:** The accessibility of the IDCs for collecting data about industrial design practice favoured conducting the research in either Germany or Australia. This was mainly due to the researcher's personal background of having worked as a professional designer in both countries. The website review found that comparably few German IDCs advertised ecodesign practice on their websites. While this does not necessarily imply a lack of ecodesign practice, it aligns with the personal experience of the researcher—that

> ecodesign did not receive a lot of attention within the German industrial design community. This is also reflected in the findings of Tischner & Wiedmann (2000, p. 80) that 'In German industries engineers (and not designers) are the major group of persons who deal with ecological aspects of new products.'

Considering these factors, neither the Australian context nor the context in one of the three other countries where the website content analyses had been conducted was seen as ideal. Instead, all can be expected to allow some valuable learning about real-world ecodesign practice. Ultimately, the proactive attitude of the Australian IDCs in advertising ecodesign services and the accessibility of the Australian IDCs for collecting the data were the decisive factors for Australia.

6.2. The Australian context for industrial design consulting

Compared to other industrialised countries, professional industrial design established itself rather late in Australia, after the second world war (Fry 1988). The roots of industrial design fall within the period of industrialisation in Europe during the 19th century (Bürdek 2005). The work of a number of American industrial designers such as Henry Dreyfuss, Raymond Loewy, Norman Bel Geddes and Walter Dorwin Teague are seen as crucial contributions that stimulated consumption and helped to overcome the Great Depression of the 1930s in the USA (Gantz 2010). Even though this is often seen as the birth of the profession, particularly in American literature (see for example: Gantz 2010), it can also be argued that it represents a particular style of industrial design—that of streamlining. Other designers (most of them following a more modern and architectural style such as Peter Behrens, Walter Gropius and Wilhelm Wagenfeld) also gave form to industrially manufactured goods in Europe before the 1930s (Bürdek 2005).

Fry (1988) argues that, because of its relatively recent colonial past, industrial design has not grown within the Australian society as it did in Europe and the USA, but has rather been adopted as a concept. This has led to the critique that, while having created some individual outstanding products, Australian industrial design has failed to develop its own strong identity (Bogle 2002). However, since the 1980s, with increasing globalisation of the economy and goods being internationally traded, industrial design worldwide has become generally less distinguishable between individual countries, blending into what Gantz (2010) terms 'global design'.

Today, the Australian industrial design community is best described as small but active. The first industrial design course was established at the Royal Melbourne Institute of Technology

(RMIT, at that time Royal Melbourne Technical College) in the 1950s (Bogle 2002). Today, courses in industrial design are offered by a number of Australian universities. The Design Institute of Australia (DIA), the national professional association, promotes the use of design services to industry. The Australian International Design Awards are handed out yearly to the most outstanding Australian products. The work of the best Australian industrial designers is showcased permanently in the Powerhouse Museum in Sydney and in temporary exhibitions such as the Sydney and Melbourne Design Weeks.

The Australian industrial design consulting sector is highly competitive. This is mainly caused by a small, saturated local market for design services due to limited local manufacturing (Robertson 2005). Historically, these local manufacturing companies mainly serve the comparably small market for manufactured goods in Australia and have a strong competition from imported goods (Fry 1988; Robertson 2005). This puts pressure on them to lower their cost, and increases the difficulties IDCs face in selling their services. Furthermore, a high number of firms operating in Australia are internationally owned and often source design services in other countries (Bogle 2002). In response to this highly competitive local market, Australian IDCs have started to not only work for Australian clients, but to also export their services (Design Victoria 2008).

Around 390 IDCs are believed to operate in Australia (Design Institute of Australia 2005). Australian IDCs have an average of 7.5 staff, and most of them are trained industrial designers (Robertson 2005). While this seems to be rather small compared to other businesses, it is in line with findings about the characteristics of IDCs from other countries. For example, 87% of the IDCs in the UK were found to have nine employees or fewer (Design Council 2010). The average number of staff for American IDCs was found to be 20 (Vanchan 2007).

6.2.1. Do Australian IDCs have strategic influence?

The information that was available to this thesis to evaluate if Australian IDCs can be expected to have strategic influence was contradictory. As explained in Chapter 2, strategic influence refers to the capacity of an IDC to go beyond only synthesising the requirements that are formulated in the strategy and design briefing and to also deliver input to these two other outcomes of a product development process. Reports about industrial design consulting see Australian IDCs taking such a position (Arts Queensland 2009; Design Victoria 2008). Also the website content analysis shows that almost half of the Australian IDCs represented themselves in a strategic role. This rather positive view is opposed in particular by Expert4.

A report from Design Victoria (2008) finds that clients of Victorian IDCs increasingly embrace the possibility to hire them for strategic support. The drivers for this development are the possibility to achieve higher degrees of novelty in the products they develop and to better align them with the needs of the consumers that are becoming more sensitive to good design (Design Victoria 2008). Similar drivers are also highlighted/predicted by Arts Queensland (2009) as influencing the intension to strengthen the industrial design sector in Queensland. At the same time the report from Design Victoria (2008) highlights that clients who commission IDCs to take a strategic role still only make up for a small share of the work of the IDCs. The report also compares these findings with those of reports from European countries, concluding that European countries show a similar profile in regard to how far IDCs are engaged in a strategic role (Design Victoria 2008).

That Australian IDCs can play a strategic role in the product development process is also supported by the findings of the website content analysis conducted as part of this thesis (Behrisch, Ramirez & Giurco 2010a; Behrisch, Ramirez & Giurco 2010b; ; Behrisch, Ramirez & Giurco 2011a; ; Behrisch, Ramirez & Giurco 2011b). It showed that 40% of the Australian IDCs in the sample advertised that they could assume a strategic role in a product development process. Similar proportions were observed in the IDCs from the other three countries sampled in the website content analysis. Figure 35 shows that 38% of the German IDCs, 54% of the Chinese IDCs and 58% of the American IDCs in the sample represented themselves in a strategic role.

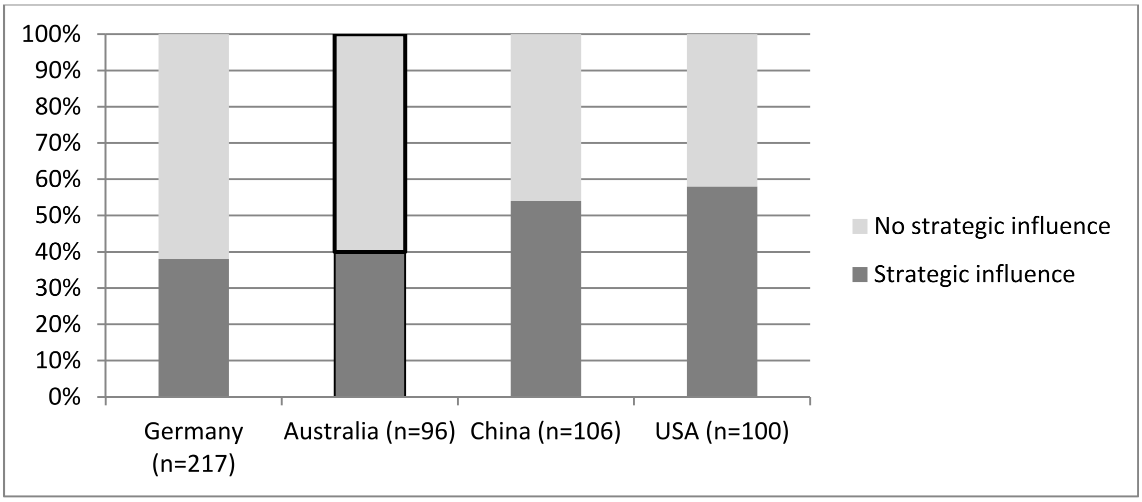


Figure 35: Percentage of the IDCs within the sample set who represented themselves in a strategic role (a strategic role comprises—beyond only synthesising the requirements formulated in the strategy and design briefing—also delivering input to these two other outcomes of a product development process) (Source: created for this research)

Even though the website content analysis found that a considerable share of the IDCs represented themselves in a strategic role, it does not necessarily mean that they filled this role in their practice. This is important to highlight, as the positive view expressed in the published reports opposes the experience voiced by the experts interviewed when selecting cases to analyse in this research. Expert1, Expert2 and Expert4 saw the capacity of most Australian IDCs to take strategic influence as very limited. They believed that one reason for this is a lower extent of design awareness in Australian society compared to Europe and the USA.

6.3. Disseminating ecodesign knowledge in Australia

Acquiring and using ecological information is an important prerequisite for practicing ecodesign. As explained in Chapter 3, this applies not only to the way ecodesign is traditionally understood, but also to the expanded notion of ecodesign suggested in this thesis. When the concept of ecodesign first became popular in the early 1990s, Australia was at the forefront of initiatives to develop and test approaches to integrate LCT into product development processes. Probably the most noteworthy initiative was the EcoReDesign™ program. It was hosted and coordinated by the Centre for Design (CfD) at the Royal Melbourne Institute for Technology (RMIT) University. Its aim was to showcase the application of LCT in product design processes (Sweatman & Gertsakis 1997). Manufacturers as well as industrial design consultants participated in the program. It successfully demonstrated that designing for a low ecological impact was not only possible but could also lead to tangible economic benefits (Sweatman & Gertsakis 1997). Despite these valuable insights, the program's capacity to demonstrate that this could be transferred to real-world environment remained limited. It was supported by government funds and most products that were developed were pilot-projects for the participating companies. Still, the EcoReDesign™ program was perceived as a success by participants and received attention in international ecodesign literature (Madge 1997; Tischner et al. 2000) as well as Australian (Lewis et al. 2001; Lewis et al. 2002; Ryan 2003).

Besides the CfD, the DIA and other institutions such as Business Victoria (2013), the Society for Responsible Design (2013) and the Australian node of the O2 Global Network (2012) also promote ecodesign in Australia. The DIA and Business Victoria provide information about designing for a low ecological impact to the design community and their clients (Business Victoria 2013; Design Institute of Australia 2004). A number of opportunities for professional designers to build up knowledge in ecodesign are available. The CfD offers short courses in LCA and LCT for professional designers and can be hired to supply advice for projects and/or conduct LCAs. Besides the CfD also other businesses such as EcoInnovators offer similar support in Australia. For several years, 'aspects of environmentally sensitive design [are] currently being incorporated in most Australian industrial design degree programs' (Ramirez 2006, p. 199). Ramirez (2006, p. 199) found that this integration only happened 'to a minor extent'. When interviewed in 2011, Expert4 reported that great progress has been made in integrating knowledge to design low-impact solutions into the curriculum of Australian industrial design students.

6.3.1. Can Australian IDCs practice ecodesign?

All experts interviewed in this research believed that the current ecodesign practice of Australian IDCs is very limited. Despite the positive development in design education, Expert4 rated the capacity of the majority of Australian IDCs to develop low-impact solutions as 'very amateurish'.

The degree to which a lack of proficiency limits the capacity of Australian IDCs to practice ecodesign is contested. Expert3 proposed that if IDCs were more proficient in practicing ecodesign, they could just integrate it into the projects they work on without even informing their clients. That IDCs can practice ecodesign without the knowledge and support of their clients is confirmed by Mawle, Bhamra & Lofthouse (2010). They investigated the ecodesign practice of UK-based IDCs and found that this is actually the approach for a lot of cases of ecodesign practice by these IDCs. However, it remains unclear if LCT is applied to inform design decisions for or against ecodesign interventions when ecodesign is practiced without an explicit involvement of the client. While Expert1 also saw the proficiency of Australian IDCs as unsatisfactory in general, he did not believe that a lack of skill within the IDCs was the main barrier for the limited practice. In particular, Expert1 described a number of young Australian industrial designers as 'switched on' to the topic, but observed that the IDCs' accountability to their clients, who often are not interested in ecological issues, as a key barrier to ecodesign in Australia. Expert1, Expert2 and Expert4 agreed that client agreement is essential to practice ecodesign and that Australian IDCs usually already fight 'an uphill battle' when trying to convince their clients to invest into ecodesign.

The position that the ecodesign practice in Australia is limited is also supported by Clune & Ramirez (2010). They analyse the entries to the Australian International Design Awards and conclude that the Australian industrial design community 'is attempting to engage' in designing eco-friendly products but that the success of these attempts is limited thus far (Clune & Ramirez 2010, p. 9).

These findings and the views expressed by the experts contrast with the comparably positive claims of a report from Design Victoria (2008). It states that close to half of Victoria's IDCs have undertaken projects where the '[m]ain objectives included sustainability outcomes' (Design Victoria 2008, p. 109). The report uses the term *sustainability outcomes* to refer to ecological impact reductions such as reducing water consumption or lowering the levels of waste. The report does not provide enough detail to determine whether LCT was practiced to inform the decisions for or against the design interventions. Thus, it remains unclear if the reported projects actually represent genuine improvements from an ecological perspective.

The website content analysis identified indications for ecodesign practice on 45% of the websites of the Australian IDCs. 12% of all investigated Australian websites[28] explicitly communicated practicing LCT to select and direct their ecodesign interventions by drawing on tools like streamlined LCA. Even though these findings do not guarantee that the IDCs actually applied their LCT knowledge, they suggest that there is the capacity to purposefully select and direct their ecodesign interventions.

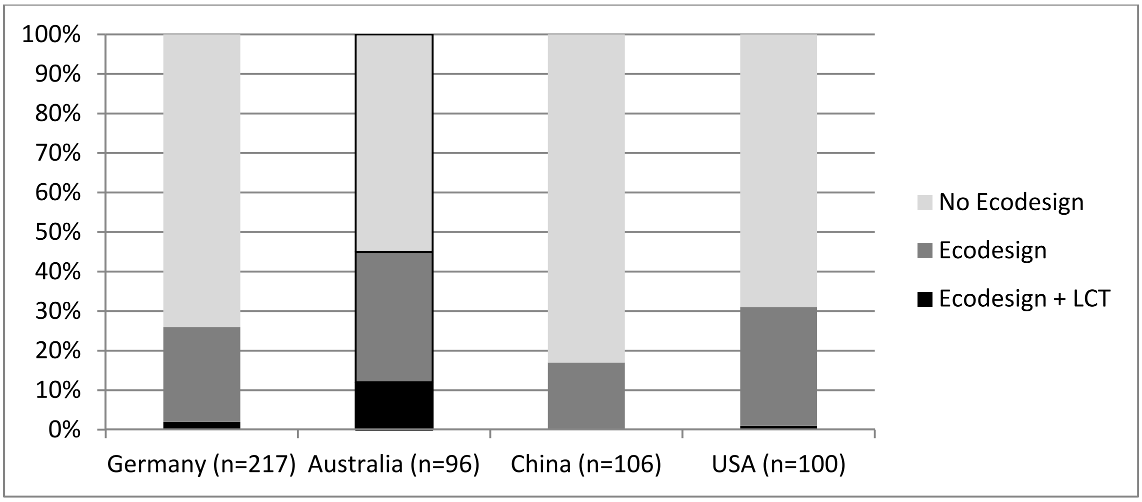


Figure 36: Communication of ecodesign services and LCT on the websites of Australian, German Chinese and American IDCs
(Source: created for this research)

None of the Chinese websites indicated a capacity to apply LCT to direct the decision making process for or against ecodesign interventions. Also in the US and in Germany, the number of IDCs that announced proficiency in LCT was much lower than in Australia: only 1%[29] of the American IDCs, and 2%[30] of the German IDCs did so. This is visualised in Figure 36, which also

[28] Representing 27% of those Australian websites that communicated ecodesign services
[29] Representing 3% of those American websites that communicated ecodesign services
[30] Representing 10% of those German websites that communicated ecodesign services

shows the extent to which Chinese (17%), American (31%) and German IDCs (26%) advertised ecodesign services on their websites.

It must be highlighted that the capacity to use the ecodesign practice, which the IDCs communicated on their website, for making claims about differences in the nature of ecodesign practice in the different countries, is limited. This is particularly true in terms of aspects that are not communicated. Nevertheless, to establish client readiness to use a service of an IDC, it should be expected that the IDC must at least communicate it. Even though their websites are not the only means to do so—the IDC can also use meetings and discussions for this means—the findings of the website content analysis suggest that Australian IDCs have the most pro-active attitude towards advertising ecodesign services to their clients.

6.3.2. Different opinions on how ecodesign practice can be progressed

Because the interviewed experts viewed different barriers as the most prominent ones for ecodesign practice in Australia, they also proposed different pathways for how this practice can be progressed. For example, Expert3 saw it as most important to improve the skills of Australian IDCs in ecodesign because this would allow them to proactively integrate it into their general practice. Because Expert1 saw the most profound barrier for ecodesign practice in the difficulties to acquire the client's agreement, he proposed that IDCs could abandon their relationship with their clients and engage themselves in entrepreneurial activities. This would provide them with more influence over the entire product development process and permit them to more readily integrate ecological considerations. Expert4 saw the capacity of industrial designers to take a proactive role in reducing the ecological impact of society as generally limited.

Expert4 stated that the influence of IDCs is small, especially if they operate on their own. He pointed out that innovation in all areas of society is necessary and that industrial design practice is only one building block that will be 'dragged along' by this transition. He did not believe that most IDCs—particularly Australian IDCs—could take a strategic role in convincing their clients to include ecological considerations in the product development process. In his experience, Australian IDCs already struggle to get their clients to use their services at all. Furthermore, he criticised the DIA for having too little political influence on the industrial design community and on the wider commercial and social context in Australia. Expert4 saw this as an important factor, limiting the capacity of the industrial design profession in Australia to lobby at a political level for an improvement of the current situation to be more favourable for ecodesign or industrial design in general.

Expert4 was of the opinion that *smart regulation* in particular was important. Smart regulation should trigger more than a mere compliance with minimal ecological standards. Expert4 believed that when drafted appropriately smart regulation can become an effective stimulus for ongoing eco-innovation and entrepreneurship. Also, the other experts expressed the hope that changes in legislation would foster ecodesign practice in Australia as well as internationally.

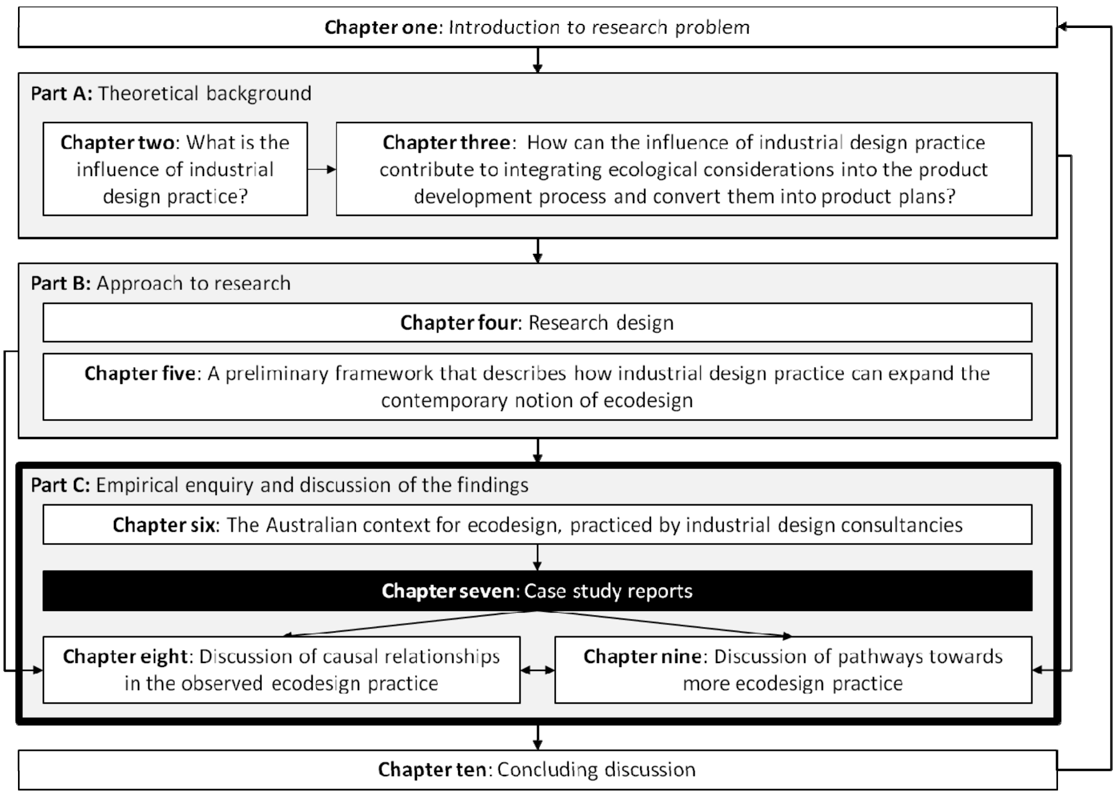
6.4. Concluding summary

The Australian context has strengths and weaknesses in regard to supporting ecodesign practice by IDCs. The expert interviews revealed that a possible lack of cultural awareness about industrial design in Australia could cause a general struggle for IDCs to be seen as relevant by their clients and society as a whole. This puts them in a weak starting position to lobby for the development for more eco-friendly products. However, it remains ambiguous how prominent this weakness affects the ecodesign practice of Australian IDCs. Design Victoria (2008) finds that the extent to which Australian companies use design services resembles other countries where industrial design has a stronger cultural foothold.

A strength of the Australian context in regard to supporting ecodesign practice by IDCs lies in the dissemination of ecodesign knowledge to the industrial design community through university and professional education and through demonstration projects. Even though the experts questioned whether this has resulted in a high proficiency by Australian IDCs to practice ecodesign, the website review indicated a higher likeliness that Australian IDCs communicated ecodesign on their websites than IDCs in Germany, the US and China. Even though this does not necessarily mean that they also incorporate it into their design practice, Australian IDCs seemed to direct more energy towards the topic than the IDCs in the other three investigated countries.

The available information about the actual ecodesign practice that can be expected from Australian IDCs is conflicting. The perceptions of individual ecodesign experts were rather negative in regard to the extent and quality of this practice. By contrast, the only published report that provides insight into the ecodesign practice of Australian IDCs paints a rather positive picture (Design Victoria 2008). It asserts that ecodesign makes up an important part of the practice of Victorian IDCs and that they successfully address ecological problems in the products they design. Also, the extent to which IDCs can practice ecodesign autonomously and how far they can progress real-world ecodesign practice on their own is contested.

CHAPTER 7. EMPIRICAL FINDINGS—EXPERIENCES FROM INDUSTRIAL DESIGN CONSULTANCIES AND THEIR CLIENTS



This chapter reports the empirical findings from the individual case studies of ecodesign practice. It is structured in five sections.

- **Sections 7.1 to 7.4** each report the insights about the ecodesign experience of one of the investigated IDCs. Each of these sections starts by providing background information about the specific IDC and the interview participant(s) at the IDC. Subsequently, the exemplary project(s) of the specific IDC are described, covering also background information about the client company and an introduction of the associated interview partner(s). Each section then proceeds to describing the general ecodesign practice of the IDC, the difficulties it encountered and the perspective of the representatives of IDCs on how ecodesign can be progressed.
- **Section 7.5** is a preliminary interpretation of the reported data and relates it back to the original research questions.

BOX 19
Labelling of the research participants

The research participants, consultancy names, exemplary projects, client companies and products were de-identified. The aliases that were used in this thesis can be found in Table 5. For IDC#2, two representatives provided information about the exemplary project. They were distinguished by using the aliases Designer#2a and Designer#2b. For IDC#3, two representatives of the IDC and of the client company were interviewed. Likewise, they were distinguished by using the small letters 'a' and 'b' after the aliases allocated to them. For IDC#4, Designer#4 provided insights into two exemplary projects. To distinguish them, the big letters 'A' and 'B' were added after the aliases Project#4, Client#4, ClientContact#4 and Product#4. As it was not possible to interview a representative of the client company for Project#4B, there is no ClientContact#4B. The roles of the research participants in their companies and in the exemplary project are introduced in the case study reports. An overview of these aspects can also be found in Appendix 4, where further information about the interviews is provided.

Table 5: Aliases, used for the research participants
(Source: created for this research)

Industrial design consultancy	Consultancy representative	Exemplary Project	Client Company	Client company representative	Product
IDC#1	Designer#1	Project#1	Client#1	ClientContact#1	Product#1
IDC#2	Designer#2a	Project#2	Client#2	ClientContact#2	Product#2
	Designer#2b				
IDC#3	Designer#3a	Project#3	Client#3	ClientContact#3a	Product#3
	Designer#3b			ClientContact#3b	
IDC#4	Designer#4	Project#4A	Client#4A	ClientContact#4A	Product#4A
		Project#4B	Client#4B	—	Product#4B

Due to confidentiality reasons the detailed case study reports have been removed from the published thesis document.

7.5. Preliminary interpretation of the empirical findings

Having documented the empirical findings of this research in the previous sections this section interprets these findings by relating them back to the original research questions. This confirms the appropriateness of the suggested expansions to the concept of ecodesign. It also highlights aspects that require a more detailed discussion in order to address the overarching goal of this research: to identify pathways for industrial designers to better utilise their influence to design consumer products with a low ecological impact.

7.5.1. Widening the applicability of industrial design practice

Before relating the case study findings back to the research questions, it is necessary to acknowledge an unexpected phenomenon that became evident in the collected data: the data indicates that not only professional industrial designers can conduct industrial design practice, but also entrepreneurial clients. Even though there are different perspectives about the extent to which the activities of individual clients contributed to the final embodiment of the products, two entrepreneurial clients in particular in the investigated projects structured their activities in a way that classifies as Design Thinking and applied industrial Design Craft.

That entrepreneurs apply Design Thinking is not surprising. As explained in Section 2.2, Design Thinking as a form of reasoning generally underlies creative problem solving activities. Entrepreneurial activity—setting up a business or institution to seize an opportunity—qualifies as such an activity. That Design Thinking underlies this activity is also reflected in the unresolved debate in the entrepreneurship literature on whether entrepreneurial activity should rather follow a problem- or solution-focused logic (for more details on this discussion see for example: Shane 2003).

What was surprising was to find two clients applying Design Thinking through industrial Design Craft to develop the design of a physical tangible product. They conducted these activities to some degree autonomously, without the support of the industrial designers. For example, they applied practices like sketching, mood boards and mock-ups to engage in a reflective conversation with the context in which they wanted to create value. Of course the clients who applied industrial Design Craft did so at a far lower level of proficiency than the investigated IDCs. Also the case study reports made it clear that the contributions of the IDCs were absolutely essential for the success of all investigated projects. However these observations raise a profound question, namely: to what extent is industrial design practice specific to professional industrial designers?

Of course, not only professional designers design as it is an activity that is inherent to human nature (Cross 2011). Also, the fact that the Design Craft distinguishing the design professions is not clearly framed and can overlap between individual representatives of the professions has been clarified (Lawson & Dorst 2009). It has been acknowledged that industrial designers are not the only ones who influence the properties of a product. One example for this is the concept of *silent design* (Gorb & Dumas 1987). *Silent designers* are stakeholders that contribute to determine the product properties via their role in the context that is designed for. Still, *silent designers* do not actively conduct industrial design practice. Even in co-creation concepts where individual stakeholders are consciously empowered to develop solution suggestions, the designer still plays a role in facilitating the creative process (Sanders & Stappers 2008). They mediate it and provide guidance and tools to develop representations of solution suggestions.

Answering the question of how specific industrial design practice generally is to professional industrial designers is beyond the scope of this thesis. Also the data, collected for this research does not allow unambiguously determining the extent to which the industrial design practice of the clients who engaged in it contributed to the development of the physical embodiment of the final product. Thus further explorations would be necessary to shed more light on the contributions of the individual stakeholders. This is particularly important as the insights provided by of some of the research participants on this issue contradicted each other.

In regard to this research project, the insight that industrial design practice can also be conducted by non-industrial designers brings along the following implications. The influence industrial design practice can have to contribute to the integration of ecological considerations into a product development process and their conversion into products has been theoretically described in an expanded notion of ecodesign. If industrial design practice is not exclusively conducted by professional industrial designers but also by other stakeholders, this expanded notion of ecodesign is also relevant to describe the activities of these other stakeholders. Because this research investigates how the influence of industrial design practice can help to progress the real-world application of ecodesign, it also needs to account for other stakeholders than just industrial designers who conduct industrial design practice.

7.5.2. Relating the empirical findings back to the research questions

Relating the empirical findings back to the research questions highlights that the suggested expansions to the traditional notion of ecodesign were appropriate. Research questions 1a and

1b searched for supporting evidence for the two regards in which industrial design practice can expand the traditional notion of ecodesign.

> *Research question 1: Is there empirical evidence for the suggested expanded notion of ecodesign in commercial industrial design practice?*
>
> *a) How do industrial designers convert ecological considerations into product designs?*
>
> *b) What influence does industrial design practice have to identify goals and drivers for ecodesign processes?*

Taking into account that industrial design practice is not necessarily conducted by industrial designers, the expanded notion of ecodesign was found to be reflected in some of the observed real-world industrial design practice. The hypothesis in Chapter 3 proposed that industrial design practice allows for drawing on the solution-focused element of Design Thinking to identify goals and drivers to integrate ecological considerations into a commercial product development process. This was confirmed in particular in Project#2 and Project#4A. Here, solution-focused thinking helped to identify opportunities for eco-friendly solutions and to develop an understanding of how to seize them. Furthermore, the hypothesis in Chapter 3 claimed that industrial design practice allows not only for influencing the technological dimension but also the meaning dimension of the product properties when converting an ecological agenda into product concepts. Again, this suggested expansion to the concept of ecodesign was demonstrated particularly in Project#2 and Project#4A. It was also present to varying degrees in the other exemplary projects, and in the general ecodesign practice reported by the IDCs.

Research question 1c further sought to understand if the ecodesign practice in the collaboration between IDCs and their clients was informed by LCT.

> *Research question 1c: How do industrial designers practice LCT to identify the most relevant ecological impacts and to inform their decisions for or against ecodesign interventions?*

The empirical investigation showed that LCT is applied in collaborations between IDCs and their clients to direct design decisions. LCT was applied in particular in Project#2, Project#3 and Project#4A.

Even though the data confirmed the expanded notion of ecodesign, it also showed that it is not necessarily always reflected by an incorporation of ecological considerations into industrial design practice. The influence of industrial design practice on the meaning dimension to convert ecological considerations into product designs was utilised only to a limited degree in the design of Product#1, Product#3 and Product#4B. It also appeared to be very limited in the general ecodesign practice the IDCs reported about. The same is true for the extent to which

LCT was applied to direct this ecodesign practice. LCT did not guide the ecodesign practice in Project#1 and Project #4B, and it also appeared to be absent in most of the general ecodesign practice the IDCs reported about. This is surprising, as all of the interviewed IDCs had the capacity to acquire information about the ecological impact along the entire life cycle of the products they designed. They either had this capacity in-house or were in close contact with LCT experts, with whom they can collaborate.

The collected data does not deliver straightforward answers to why the expanded notion of ecodesign was reflected only sometimes in the observed ecodesign practice and why LCT often remained limited. Thus, a discussion of the observed scenarios preventing/allowing LCT and ecodesign practice that reflects the suggested expansions is necessary to answer the research questions 2a and 2b.

> *Research question 2a: What limits the ecodesign practice of industrial designers?*
> *Research question 2b: How can industrial designers progress their ecodesign practice?*

7.5.3. Overview of the discussion chapters

Addressing the research questions 2a and 2b by analysing the causal relationships within the investigated ecodesign practice is the subject of discussion in Chapter 8. Chapter 8 develops an ecodesign-specific version of the client readiness factors after Williamson, Kalmar & Tischler (1996) that were introduced in Chapter 5. Chapter 8 concludes by presenting a refined version of the preliminary theoretical framework from Chapter 5. This also highlights a possible pathway for industrial designers to progress their ecodesign practice.

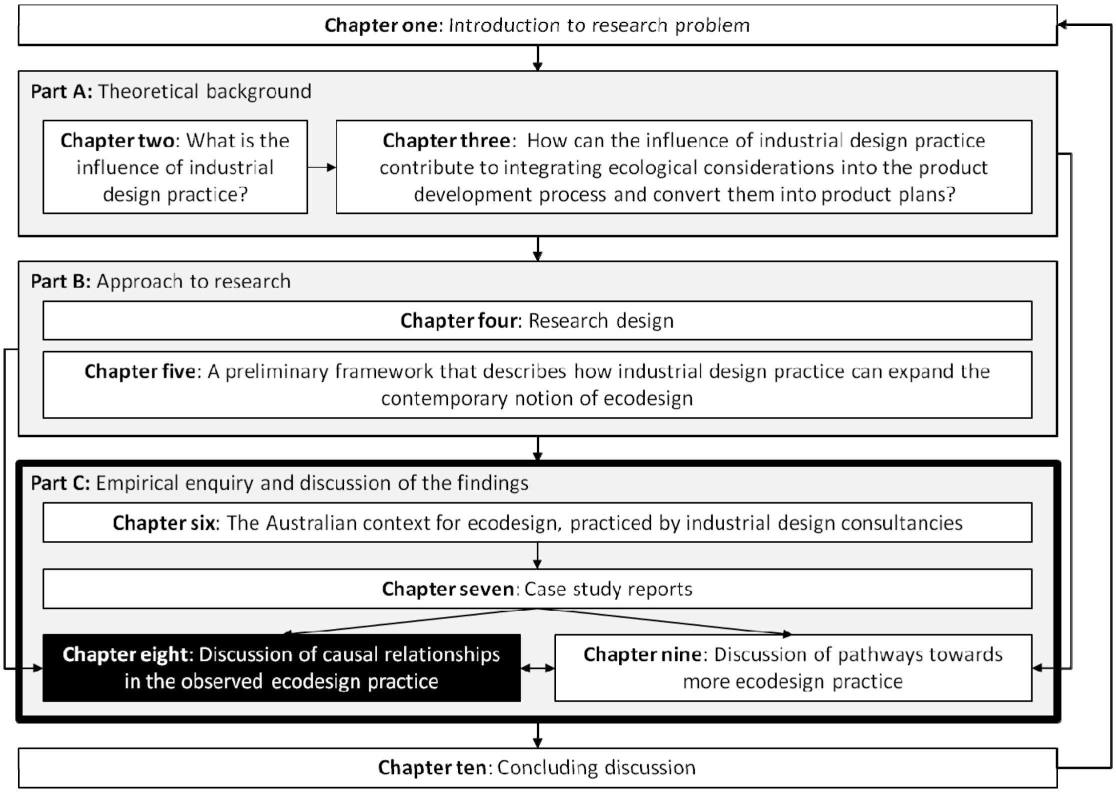
Chapter 9 links this pathway back to suggestions from the interview partners and suggestions found in the literature for how real-world ecodesign practice can be progressed. It also discusses potential barriers for industrial designers to fully embrace this suggested pathway, and engages with the question if the expanded notion of ecodesign can be seen as a promising way to progress towards sustainable design.

Finally, Chapter 10 draws conclusions from the two preceding discussion chapters and brings forward three recommendations for industrial designers that respond to the overarching research question of this thesis:

> *Where should industrial direct their efforts to improve the integration of ecological considerations in the product development process and to strengthen their capacity to translate them into product concepts?*

Chapter 10 also highlights the wider implications of the findings of this thesis and provides directions for further research.

CHAPTER 8. DISCUSSION OF CAUSAL RELATIONSHIPS IN THE OBSERVED ECODESIGN PRACTICE



This chapter analyses the causal relationships in the observed ecodesign practice in regard to interrelationships within this practice that facilitated or hampered the application of LCT. It also specifically accounts for the extent to which this practice reflected the expanded notion of ecodesign. The collected data revealed two scenarios for ecodesign practice, termed *activist approach* and *collaborative approach* in this thesis. In the activist approach the IDCs practiced ecodesign without the knowledge and support of their clients. This was the case for Project#4B and for most of the general ecodesign practice of the investigated IDCs. No LCT or ecodesign practice that reflected the expanded notion of ecodesign was observed in an activist approach. This gives rise to question i:

i. Why does ecodesign in an activist approach remain limited?

In a collaborative approach, ecodesign happens in mutual agreement between the IDC and the client. Project#1, Project #2, Project #3 and Project #4A were conducted in a collaborative approach. In a collaborative approach, the ecodesign design practice—which this research initially assumed to be specific to industrial designers—can be distributed amongst the stakeholders of the product development process. In particular, this was observed in Project#2 and to a lesser extent in Project#4A. LCT, a conscious manipulation of the meaning dimension and the application of solution-focused thinking were only applied in the context of a collaborative approach. The observation that the collaborative approach seems to provide a more fertile environment for ecodesign leads to question ii:

ii. Which factors allow progressing from an activist approach to a collaborative approach?

The nature of the ecodesign practice in the observed collaborative approaches was not homogenous. Project#1 demonstrated that a collaborative approach does not guarantee the application of LCT. There is also variation in the extent to which the expanded notion of ecodesign was reflected in the exemplary projects that followed a collaborative approach. These differences (in the extent to which the observed ecodesign practice reflects these expansions) do not necessarily imply variations in the success of integrating ecological considerations into the design of commercial consumer products. However an absence of LCT reduces the potential of ecodesign practice to contribute to the development of lower impact solutions. This observation gives rise to question iii:

iii. What prevented LCT in Project#1?

This chapter is divided into four sections.

- **Sections 8.1 to 8.3** each use one of the questions i - iii as a guideline for a discussion that addresses the research question 2a in the context of the empirical enquiry of this research.
  Research question 2a: What limits the ecodesign practice of industrial designers?
- **Section 8.4** builds on these insights and develops a proposal to answer the research question 2b).
  Research question 2b: How can industrial designers progress their ecodesign practice?

8.1. What limits ecodesign practice in an activist approach?

Empirical investigations into commercial product development processes in which designers practice ecodesign without the knowledge and support of their clients have not received much attention in the academic literature thus far. Product development (and consequently, product development that considers ecological issues) requires the collaboration of multiple stakeholders (Berchicci & Bodewes 2005). This may have led to an implicit agreement, shared amongst most ecodesign scholars that a scenario in which individual stakeholders engage with ecodesign without the knowledge and involvement of the other stakeholders of a product development process is inherently limited. Thus this scenario may have not received much attention.

Despite the neglect of the scientific community to investigate cases in which individual stakeholders engage with ecodesign without the knowledge and involvement of the other stakeholders of a product development process, this is a possible scenario for the ecodesign practice of IDCs. An activist approach is not unique to the investigated Australian IDCs. Mawle, Bhamra & Lofthouse (2010), who research into the ecodesign practice of UK-based IDCs, observed that in most cases of ecodesign practice IDCs either pursue an activist approach or seek to identify designs that combine eco-benefits with financial savings. In these cases the financial savings allow them to justify their ecodesign practice. Fuad-Luke (2009) and Thorpe (2008) both write about design activism; however, they do not engage deeply with the commercial context for industrial design practice. Fuad-Luke (2009) merely points out that the scope of design activism in this environment is likely to be restrained. However, neither Fuad-Luke (2009) nor Thorpe (2008) go into much detail in describing this restrained practice. Also Mawle, Bhamra & Lofthouse (2010) do not analyse the phenomenon they observed. Even though they identified that an activist approach is frequently encountered, they do not provide detailed insights into the associated ecodesign practice. In particular they leave it open to whether the IDCs can follow a LCT approach when practicing ecodesign without the involvement of their clients. To address this research gap and to provide a more detailed answer to the question why ecodesign remains limited in an activist approach, it is useful to first describe the observed activist approach in detail. The next sub-section starts with the underlying reasons that triggered the investigated IDCs to embark on an activist approach to ecodesign. This section then proceeds to discuss the implications of an activist approach for the ecodesign practice conducted.

8.1.1. The underlying reasons for an activist approach

Convincing their clients to invest into ecodesign can be difficult for IDCs. Most clients of the interviewed IDCs either did not consider ecological issues at all or allocated a low priority to them. Thus, persuading their clients to engage them for practicing ecodesign was associated with considerable effort to the IDCs. Also during the design process, this indifferent attitude of the clients risked that they decide against eco-friendly solutions if presented with such a choice. The activist approach was a response of the IDCs to these difficulties.

The observed activist approach was solely driven by the personal ecological consciousness of the industrial designers. All interviewed industrial designers had an inherent motivation to minimise the negative ecological consequences of the mass-produced consumer products they designed. Practicing ecodesign without informing their clients reduced the barrier for the IDCs to follow this motivation. They did not need to overcome the resistance of their clients against including ecological considerations into the product development process. Not presenting ecodesign interventions as a choice but conducting them on their own authority furthermore reduced the risk of the clients' rejecting them.

8.1.2. Implications of an activist approach for the nature of the ecodesign practice

An activist approach brings along three implications.

1. It conflicts, at least in the short run, with the financial objectives of an IDC to obtain a monetary reimbursement for its services.
2. It restricts the availability of ecological information for practicing LCT.
3. It limits the ecodesign interventions that can be conducted. It particularly minimises the opportunity to manipulate the meaning dimension of the product properties.

These implications are discussed in detail below. Subsequently, the ecodesign practice that can be expected in an activist approach is described.

A conflict with the financial objectives of the IDC

Practicing ecodesign in an activist approach conflicts with the financial objectives of the IDCs. They are service providers who rely on financial reimbursement of their efforts by their clients.

Ecodesign increases the complexity of a product development process (Åkermark 2003). It requires investment of time and resources. As an activist approach to ecodesign happens without the consent of the client, the IDCs cannot expect to be reimbursed for this effort. On the contrary, the IDCs even need to bring up the necessary resources and time for their ecodesign activities themselves. In other words, an activist approach not only fails to contribute to help the IDCs to meet their financial interests, it is even, at least in the short run, counterproductive in this respect. In the long run an activist approach to ecodesign may be justifiable from a financial perspective if it allows an IDC to build up and/or maintain skills and knowledge in ecodesign it then monetizes on in a collaborative approach.

To mediate the conflict between meeting their own financial interests and practicing ecodesign, the IDCs need to keep the effort they invest in an activist approach to a minimum. This effort minimisation is also necessary to avoid compatibility issues with the time-driven context of the product development process. Clients expect the work of the IDCs to be finished at a certain deadline, which further restricts the effort IDCs can invest into ecodesign practice in an activist approach.

Restrictions on the available information for LCT

The necessity to minimise the effort of their ecodesign practice in an activist approach limits the capacity of the IDCs to acquire context specific ecological information and to practice LCT. In an activist approach, the observed IDCs commonly used information they had acquired independently from the particular projects they were working on to direct their ecodesign interventions. This information either focused on isolated product qualities (typically on materials), or consisted of general rules of thumb. Examples include the minimisation of material quantity and variety, or designing for recyclability by minimising fasteners. This can be problematic as it can lead to the application of inappropriate general information for a particular project context. For example, lists that provide information about the ecological performance of materials may not contain those that are used in the project. In the observed ecodesign practice, the limited effort that can be invested into ecodesign practice in an activist approach also restricted the use of analytical LCT tools such as streamlined LCAs or life cycle mapping. Thus, the capacity to analyse benchmark products and to account for the implications of ecodesign interventions along the entire life cycle of a product was limited.

Accounting for the implications of ecodesign interventions along the entire life cycle of a product does not always necessarily require a level of detail where a full or even a streamlined LCA is conducted or rigorous life cycle mapping is applied. If the complexity of the consequences of ecodesign is already low, less in-depth approaches may be sufficient. Even thinking through the life cycle of a product, step-by-step, may already reveal the expected consequences of the ecodesign interventions. For instance, in Product#4B the material quantity and variety of the redesigned product had been reduced compared to its predecessor. These ecodesign interventions did not compromise any other aspect along the product's life cycle. Consequently, as argued in Sub-section 7.4.3, this thesis sees it in this case as justified to claim that the redesign was preferable to the predecessor from an ecological perspective. Thus, it can be said that the lack of resources to conduct more in-depth assessments of entire product life cycle in an activist approach does not completely prevent purposefully selecting ecodesign interventions. It merely limits this capacity to the extent where common-sense reflections already allow for foreseeing that no further consequences along the product's life cycle can be expected from an ecodesign intervention.

General and directional information together with common sense reflections can, in some cases, sufficiently guide decisions for or against individual ecodesign interventions. However, in the absence of the possibility to conduct more comprehensive assessments, this brings along two further limitations for LCT. Firstly, it prevents looking for benchmark products that can be used to formulate goals for the ecological improvements. As explained in Sub-section 7.5.3, this is also the reason why it remains unclear if Product#4B represents a preferable solution from an ecological perspective when also considering competitor products. Secondly, the importance of the conducted ecodesign interventions remains unclear. Without thinking through the life cycle of the product that is designed in a structured way, it remains ambiguous where its most profound impacts come from and if they are addressed by the ecodesign interventions.

An activist approach limits the ecodesign interventions that can be conducted

Besides the restrained resources and time and funding issues in an activist approach, there is another factor that prevents the application of LCT. Investigating potential benchmark products, identifying the most relevant ecological impact of a product and tracing the consequences of ecodesign interventions only make sense if the possibility is given to actually apply this information. This capacity is limited in an activist approach. As the IDCs do not communicate their ecodesign practice to their client, it is not possible for them to openly negotiate ecodesign interventions with other project requirements. Thus, only ecodesign interventions can be conducted that do not require the agreement of their client. The reports from the IDCs illustrated only two circumstances that allow them to practice ecodesign in disguise.

Firstly, for aspects like specifying finishes or materials, IDCs are sometimes allowed room to manoeuvre without having to explicitly justify their activities to their clients. These are usually decisions where no notable consequence for the cost and/or product performance can be expected. In other words, the IDCs used those opportunities where they were able to influence the product properties without major implications for any stakeholders in the product development process. Industrial designers may also manage to avoid having to justify some very minor changes to the product interface to their clients. So even in an activist approach they may have some room to manoeuvre to try to influence the meaning dimension to achieve ecological benefits. However this room to manoeuvre can be expected to be very minimal and the activist approach furthermore limits the capacity of IDCs to navigate it purposefully. Even simple changes such as positioning the hard-off switch of an appliance in an area that is visible for consumers and thus encourages them to save energy when they do not use the device are most likely not possible in an activist approach. The position of buttons on an appliance usually has implications for the product architecture – PCBs and wiring need to be engineered accordingly. Also the product´s sculptural qualities are affected – the reason why most hard-off switches today are on the side or back of the appliances is a clear intention to achieve an uncluttered look of a product. Altering the position of a hard-off switch certainly cannot be decided and achieved by the industrial designer alone but needs to happen in dialogue with other stakeholders including the client. Even though industrial designers may be able to conduct some minor, ecologically motivated changes to the product interface they will not have the opportunity to engage in a reflective dialogue to evaluate if these have their intended effect on the meaning dimension. This is also exemplified by Project#4B where it remains unclear if consumers actually reuse the part of the product that was designed for being reused. In other words focusing only on ecodesign interventions that do not have noticeable consequences for any stakeholders in the product development process limits the scope of ecodesign practice. Thus, an activist approach allows those ecodesign interventions that were added in the expanded notion of ecodesign only to a very limited degree. In other words, this scenario mainly facilitates product-technology-focused ecodesign interventions and behaviour-focused ecodesign interventions, to the extent they can be conducted by influencing only the technological dimension of the product properties.

The other circumstance that allows IDCs to conduct ecodesign interventions in an activist approach is when they not only reduce the ecological impact but also bring along effort reductions for realising the product. This allows the IDCs to camouflage the ecodesign interventions as cost savings. Such an overlap happens when the efficiency of a product is increased through interventions like reducing material quantity or decreasing the number of parts (Horbach, Rammer & Rennings 2012). This again represents only a share of the possible ecodesign interventions. Furthermore, it is questionable how far the ecodesign interventions that are facilitated this way can be claimed as genuine. Ecodesign seeks to integrate ecological considerations in an economic context (Karlsson & Luttropp 2006). This understanding implies an economic and an ecologic agenda. As explained in Section 2.1, the problem situation IDCs seek to address already demands them to minimise the cost associated to realise the product they design. Thus, a drive towards seeking cost-efficient solutions is inherent to the industrial design profession and does not require any ecological agenda. In other words, it can be expected that all industrial designers seek to minimise material and part quantity to some extent. Thus, classifying design interventions that are geared towards minimising cost as ecodesign interventions may be a case of just labelling an activity that would have happened anyway as ecodesign.

On the other hand, it can be claimed that many opportunities exist for reducing the cost of realising a product. Some of them bring along inherent ecological benefits while others don't. Thus, it can be argued that intentionally identifying and conducting design interventions where ecological benefits and cost savings overlap still requires an ecological agenda.

While it is to some extent open to interpretation to classify design interventions that combine eco-benefits with financial savings as ecodesign interventions, it can be concluded that an activist approach limits the variety of possible ecodesign interventions. Because this situation leaves the IDCs little possibilities to select between ecodesign interventions in an activist approach, it can be expected to be directed by opportunity rather than LCT.

8.1.3. The ecodesign practice that can be expected in an activist approach

In conclusion, the ecodesign practice that can be expected to happen in an activist approach is limited in regard to the application of LCT. An activist approach furthermore limits the possibility to influence the meaning dimension when converting ecological considerations into product designs. This restrains the expansions to traditional ecodesign regarding ecodesign interventions that are proposed in this thesis in Section 5.2. Consequently, also the outcomes of an activist approach can be expected to mainly represent technological improvements. It can be expected that neither problem- nor solution-focused thinking is applied to identify goals and drivers for including ecological considerations into the product development process. This is because the activist approach is only driven by the personal motivation of the IDCs; as they seek opportunities where they can practice ecodesign in disguise, they do not need to justify their practice to their client.

It can be concluded that due to its limitations, an activist approach does not allow designers to draw on the influence of industrial design practice to expand the traditional notion of ecodesign. Furthermore, as the application of LCT is limited, it may remain unclear whether ecological benefits were achieved. The individual factors determining the ecodesign practice and the potential outcomes in an activist approach are also visualised in the mind-map, shown in Figure 47.

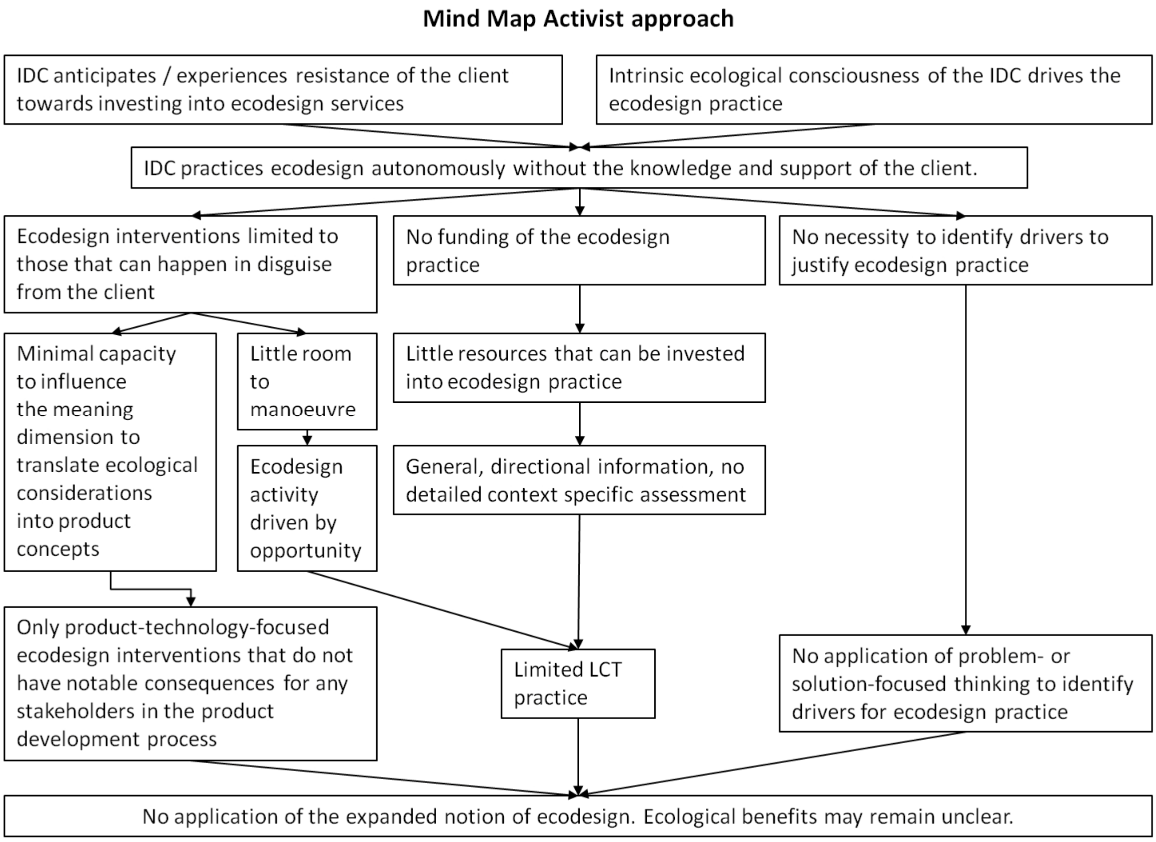


Figure 47: Mind-map of the activist approach, highlighting the individual factors determining the ecodesign practice and the expected outcomes
(Source: created for this research)

8.2. Progressing from an activist approach to a collaborative approach

Section 8.1 established that an activist approach prevents influencing the meaning dimension and thereby constrains practice that reflects the expanded notion of ecodesign when converting ecological considerations into product designs. Furthermore, the lack of budget and time that can be allocated to ecodesign practice and limited room to manoeuvre minimise the capacity to practice LCT. These characteristics of an activist approach are one explanation for why the associated ecodesign practice of the observed IDCs remains limited, delivering one answer to research question 2a:

Research question 2a: What limits the ecodesign practice of industrial designers?

While the ecodesign practice that is possible within an activist approach is limited, it reflected the most commonly followed approach to ecodesign in the general practice of the investigated IDCs.

Ecodesign practice that reflected the expanded notion of ecodesign and the application of LCT were only observed in the context of a collaborative approach. Despite the general rarity of this scenario in the general practice of the investigated IDCs, four of the five exemplary projects followed a collaborative approach. As the representatives of the IDCs were given a say in selecting the exemplary projects, this preference can be seen as indication for a general awareness that a collaborative approach allows for more genuine ecodesign practice than an activist approach.

8.2.1. The potential benefits of a collaborative approach

A collaborative approach can allow for addressing the implications associated to an activist approach that restrict ecodesign practice. If ecodesign is practiced in mutual agreement between the IDC and the client, it is possible to negotiate allocating time and resources to this activity. As a result, a collaborative approach can facilitate a reimbursement of the IDC for its ecodesign services. The possibility to allocate time and resources to ecodesign practice also facilitates investing into acquiring more context-specific ecological information and possibly also the application of analytical LCT tools. Openly practicing ecodesign expands the possible scope of ecodesign interventions beyond those that can be conducted without the knowledge of the client. This facilitates in particular the possibility to influence the meaning dimension for converting ecological considerations into product concepts. It also allows for the open mediation of the consequences of ecodesign interventions, relative to other goals for the design process. This is important because ecodesign interventions can have consequences that conflict with these goals. For example, in Project#4A, the reduction of the number of parts and complexity required a compromise in regard to the product aesthetics. This was accepted in favour of achieving a low ecological impact for the product. Similarly in Project#3, the utilitarian functionality of the product was slightly diminished in favour of avoiding materials with a high ecological impact and minimising material variety. These compromises would not have been possible without discussing ecodesign openly. The issues associated with an activist approach and how the collaborative allows addressing them are collated in Table 11.

Table 11: Issues associated with an activist approach and the capacity of a collaborative approach to address them (Source: created for this research)

Issues associated with an activist approach	The capacity of a collaborative approach to address these issues
conflicts with the financial objectives of an IDC to obtain a monetary reimbursement for its services	possibility to negotiate allocating time and resources to ecodesign can facilitate negotiating a monetary reimbursement of the IDCs for their ecodesign services
restricts the availability of ecological information for practicing LCT	possibility to negotiate allocating time and resources to ecodesign and to collect the required information allows acquiring more context specific ecological information and the use of analytical LCT tools
limits the ecodesign interventions that can be conducted. It particularly prevents manipulating the meaning dimension of the product properties.	allows ecodesign practice to be recognisable for the client facilitates influencing the meaning dimension for converting ecological considerations into product concepts allows mediating the consequences of ecodesign interventions openly

A collaborative approach allows for the addressing of issues that limit ecodesign practice in an activist approach, but does not guarantee this. For example, IDC#3 was only partially reimbursed for its ecodesign services, even though they happened in mutual agreement with the client. This arguably was due to an exceptional situation. The extra investment of IDC#3 of its own resources IDC#3 in Project#3 was driven by the intention of IDC#3 to expand its ecodesign expertise and to have a representative case study for their portfolio.

Also, the ecodesign practice in a collaborative approach is not always based on LCT nor does it necessarily reflect the expansions that have been suggested in this thesis. This is particularly visible in Project#1. Even though ecodesign was practiced in mutual agreement with the client and was fully funded, no LCT was applied to inform the decisions for or against ecodesign interventions. Due to the absence of LCT, Project#1 is the only exemplary project that was conducted in a collaborative approach where it remains uncertain if the final product is preferable from an ecological perspective. Also, no influence on the meaning dimension was exerted in Project#1 to convert ecological considerations into the final product.

To analyse the underlying reasons for these phenomena, the next sub-section 8.2.2 first discusses how an activist approach can be overcome. Thereafter, Section 8.3 addresses the question: ‘what limited the ecodesign practice in Project#1?’

8.2.2. Progressing from an activist approach to a collaborative approach

The key difference between an activist approach and a collaborative approach is the explicit agreement of the client company to practice ecodesign. As observed in particular Project#2, this can even involve the client actively engaging with ecodesign practice. The reports from the interviewed IDCs show that three factors need to align to grant the buy-in from the clients. First and foremost, it is important that the client exhibits a general openness towards discussing the integration of ecological considerations into product development processes with the IDC. Otherwise, it is impossible to start the conversation about the topic. Secondly, the representatives of the IDCs saw it as necessary that the client has some idea of ecodesign, as they are unlikely to invest into a service they do not understand. Thirdly, the client needs to be incentivised through drivers that justify ecodesign practice from a business perspective. In particular, this latter factor aligns with findings from scholars like Mathieux et al. (2001), Van Hemel & Cramer (2002) and Boks & McAloone (2009). They claim that in a commercial environment ecodesign needs to be incentivised by other drivers than the ecological benefit alone.

The necessity of these three factors for a collaborative approach is supported by the observed exemplary projects. As shown in Table 12, they are ecodesign-specific forms of three of the client readiness factors after Williamson, Kalmar & Tischler (1996), that were introduced in Chapter 5. While the empirical evidence proposes that these three factors take an ecodesign-specific form, it does not suggest that this applies also for the other three client readiness factors. Thus, it is assumed in this thesis that they also occur in their general form in ecodesign projects.

Table 12: General client readiness factors and specific client readiness factors for ecodesign (Source: created for this research)

General client readiness factors after Williamson, Kalmar et al. (1996) as introduced in Chapter 5	**Ecodesign-specific forms of client readiness factors**
Client recognises a problem or an opportunity	Drivers for practicing ecodesign can be identified
Client is aware that the IDC can address that need or help to create an opportunity	Client-awareness of the possibility to practice ecodesign
Client is willing to address a need or create an opportunity	Client-openness for ecodesign
Client has the necessary resources for engaging the IDC and for realising and commercialising the outcome of the work[31]	Not applicable (No evidence found of ecodesign-specific form)
Client has the ability to communicate with the IDC	Not applicable (No evidence found of ecodesign-specific form)
Client has trust in the capability of the IDC	Not applicable (No evidence found of ecodesign-specific form)

[31] Note that this factor only describes the general availability of resources on the side of the client, not the willingness of the client to allocate them.

The drivers for an ecodesign project

The literature lists numerous drivers for including ecological considerations into the product development process (see for example: Crul, Diehl & Ryan 2009; Tischner et al. 2000; White, Belletire & St Pierre 2009). In the framework introduced in Chapter 5, they were allocated to three categories:

1. **Drivers that allow a reduction in the involved effort and risk associated with manufacturing, distributing and commercialising a product**—for example, achieving both ecological and economic benefits though efficiency improvements, or avoiding extra costs or penalties by complying with ecological legislation.
2. **Drivers that increase the personal value consumers see in a product**—meeting a consumer demand for a specific product that has either explicit or implicit ecological benefits.
3. **Drivers that ensure compliance with client preferences**—responding to a self-driven motivation of a client to reduce the ecological impact of its products.

The collected data confirms only the first two of these categories as drivers that can support an entire ecodesign process. The term *entire ecodesign process* describes the capacity to take a product concept all the way through until it is fit for mass production. This was not observed for the third category of drivers. An intrinsic motivation of a client to develop products with a low ecological impact can be an important factor for creating openness within the client company to be receptive for a conversation about ecodesign. However, in none of the observed exemplary projects this motivation alone allowed to carry the development of the product far enough through to make it production-ready. In Project#2, Project#3 and Project#4A, the second category of drivers—the personal value consumers see in a product—played the leading role for justifying the ecodesign practice. In Project#1, this was facilitated by the first category of drivers. The associated cost savings were the main argument that allowed IDC#1 to conduct the ecodesign interventions in this project. These observations challenge the notion of ecological ambitions of decision-makers as a driver for ecodesign in a product development process, and suggest that it would be more appropriate to see them as a potential facilitator which then still needs to be supported by other drivers. This seems to be particularly true when the ecodesign practice or the result of the ecodesign interventions requires a substantial investment. This investment can only be justified by drivers that promise to bring along tangible benefits from a business perspective in compensation. In the exemplary projects, these benefits represented either a revenue potential or cost savings.

That ecological ambitions of decision makers in a product development process alone may not be sufficient for successfully bringing a product to market is also supported by Berchicci (2009). He observes that ecological ambitions can play an important role for initiating the integrating of ecological considerations. However, if a product development process is exclusively driven by the ecological ambition of the decision makers, it can jeopardise the capacity to develop a product that is financially viable. As Berchicci (2009) describes the personal ecological motivation as 'non rational', he points out that it can cause decision-makers to misinterpret the benefits of an idea from a business perspective.

Client awareness of the possibility of ecodesign

The clients need to be aware of the capacity of the IDCs to practice ecodesign. For example Client#4A only started utilising ecodesign services after it was suggested to them by IDC#4. By contrast, Client#2 and Client#3 approached the IDCs already assuming that they were capable of designing products with a low ecological impact. However, they relied on the IDCs to inform them about the associated design practice and to advise them how to best use it. Also, Client#1 relied on the expertise and knowledge of IDC#1 to guide them through the application of ecodesign practice in the product development process.

The observations from the exemplary projects show that the depth of this understanding can vary. Client#2, for example, exhibited a strong drive to build up their own understanding for ecodesign, also contributing to acquiring the necessary ecological information for LCT. In comparison, Client#3 exhibited a less detailed awareness of and involvement in ecodesign—particularly in regard to LCT. They relied much more strongly on the expertise of IDC#3 to guide them in the right direction. This situation did not hinder the ecodesign practice of IDC#3. As a conclusion from these observations, this research suggests that the client needs to be sufficiently aware of the consequences of ecodesign practice to not hinder or jeopardise it. However it is not necessary that the client has a fully detailed understanding of every aspect of this practice.

Client-openness for ecodesign

Openness on the side of the client company towards a conversation about ecodesign is a prerequisite for a collaborative approach. Without it, it is impossible to facilitate the other two factors. The exemplary projects display two scenarios that created the opportunity for IDCs to have an open discussion about ecodesign.

Firstly, it can be rooted in the personal ecological awareness of the responsible persons in the client company. This was the case in Project#2, Project#3 and Project#4A. In Project#3 and Project#4A, this allowed the IDCs to initiate a conversation about ecodesign. In Project#2, the motivation from the client side was even so prominent that they already approached the IDC demanding ecodesign and even partially practiced it themselves. However, as discussed under the Sub-section 'The drivers for an ecodesign project' the personal ecological awareness alone did not carry the ecodesign practice all the way through the product development process if not supported by other drivers.

Secondly, a strong personal ecological awareness of the responsible persons in the client company is not the only scenario that can facilitate the opportunity for opening the discussion about ecodesign. Also, Client#1 was open to engage in a dialogue about ecodesign with IDC#1. Neither ClientContact#1 nor any other stakeholder in Client#1 exhibited an exceptionally strong personal ecological awareness. Client#1's openness towards discussing ecodesign can be attributed to two factors. The first factor was a general sense within the company that considering ecological issues in commercial activities is becoming increasingly important. This attitude was informed by various sources. Examples were activities at Client#1 to minimise the ecological impact of other business processes, a sensitivity of the retailer through whom they sold most of their products towards ecological issues, and legislative requirements and standards that affect the company's supply chain. Also, the long-term relationship with IDC#1, during which the IDC frequently lobbied for considering ecological issues, played a role. The second factor was the company policy of Client#1 to actively seek new business opportunities through innovative products. This willingness to change, together with the general sensitivity towards an increasing importance of ecological issues, created the opportunity for IDC#1 to discuss ecodesign with Client#1.

8.3. What prevented life cycle thinking (LCT) in Project#1?

The collaborative approach provides a significantly more fertile environment for practicing LCT than the activist approach and can facilitate the expansions to the concept of ecodesign that are suggested in this thesis. This is supported by the circumstance that LCT was practiced in Project#2, Project#3 and Project#4A and that the ecodesign practice within these projects reflected to varying degrees the expanded notion of ecodesign. However, Project#1 demonstrates that a collaborative approach does not guarantee that these two potentials unfold. This is surprising because like the other investigated IDCs, IDC#1 had the capacity to acquire relevant ecological information to practice LCT via an expert it collaborated with. Furthermore, IDC#1 showed high awareness of the possibility to influence the meaning dimension to convert ecological considerations into product designs and to draw on the solution-focused element of Design Thinking to inform the strategy of a product development process.

Project#1 differs from these other exemplary projects that were conducted in a collaborative approach in three regards. Firstly, it is the only project that was conducted for a well-established, large company. Project#2, Project#3 and Project#4A were all conducted in collaboration with start-ups. Secondly, the openness on the side of Client#1 towards discussing ecological issues was not rooted in a strong personal awareness of the responsible persons in the client company. Rather, it was due to a combination of a general sensitivity of the company towards ecological issues and a willingness to seize new opportunities. Thirdly, the driver that justified the ecodesign practice in Project#1 were cost savings, as opposed to the revenue potential due to the personal value consumers were expected to see in an eco-friendly product. These three specifics of Project#1 and their potential impact on the nature of the ecodesign practice are discussed below. The guiding questions for these reflections are:

1. Do start-ups offer more potential to practice ecodesign?
2. How important are the underlying reasons for the client-openness to discuss ecodesign?
3. Are the drivers for ecodesign and the resulting ecodesign practice interrelated?

Table 13 again contrasts Project#1 with the other three exemplary projects that were conducted in a collaborative approach.

Table 13: Contrasting the Project#1 with the other exemplary projects that were conducted in a collaborative approach
(Source: created for this research)

	Client type	Main factor, facilitating client openness	Driver	LCT	Exp. notion of ecodesign
Project#1	**Well-established company**	**Company sensitivity towards ecological issues and willingness to seize new opportunities**	**Cost savings**	**No**	**No**
Project#2	Start-up	Personal motivation	Revenue potential	Yes	Yes
Project#3	Start-up	Personal motivation	Revenue potential	Yes	Yes
Project#4A	Start-up	Personal motivation	Revenue potential	Yes	Yes

8.3.1. Do start-ups offer more potential to practice ecodesign?

LCT and ecodesign practice that reflected the expanded notion of ecodesign were only observed in exemplary projects that were conducted in collaboration with start-ups. This can be interpreted as an indicator that this scenario is more favourable for ecodesign.

Project#4B demonstrates that collaborating with established companies can create a hostile climate towards innovation in a product development process. Factors contributing to this were:

- the necessity to secure their current market share;
- public ownership which exerts constant pressure to generate short term gains; and
- an established infrastructure and distribution system they use for their products.

Dougherty & Heller (1994) explain that these factors can hamper innovation in established firms in general. The capacity to innovate is important to practice ecodesign, as lowering the ecological impact associated to products requires innovation in a specific direction. Start-ups are much more likely to try to enter the market with a product with a high degree of novelty than trying to compete via incrementally improving existing products (Ashkenas 2013). However, they also can face difficulties to innovate. For example, they often lack capital, which jeopardises their capacity to carry an innovation through until it is ready for the market (March-Chorda 2004).

A general comparison of start-ups and established companies is not the focus of this thesis. Both scenarios can pose barriers for innovation that hamper ecodesign. The data this thesis collected does not provide sufficient insight to draw general conclusions about which scenario can be generally expected to be more fertile for ecodesign. However, as discussed below, this thesis argues that the circumstance of Client#1 being an established company was not the key factor limiting the ecodesign practice in Project#1.

The preference of Client#1 to use its existing suppliers to manufacture Product#1 restrained the material choice. This prevented selecting materials that could potentially have lowered the ecological impact. It also locked in the necessity to manufacture the product in China and ship it to Australia. It can be argued that these limitations caused a lack of alternatives that constrained or even foreclosed LCT.

Start-ups may have more flexibility in choosing their suppliers. For example, Client#2 and Client#4A accommodated for enough flexibility to choose suppliers and technology according to their ecological performance. On the other hand Client#3, also a start-up, exhibited a certain lock-in that restrained the possible scope for ecodesign. Because their funds to invest into research and development were limited, they had to draw on already-established infrastructure and technology. However, this did not prevent the application of LCT for Project#3. It merely required negotiating the consequences of the limited resources with the directions for the ecodesign practice that were identified through LCT. Consequently, it is argued in this thesis that the bias of established companies to utilise their existing structures, resources, assets and skills does not inherently prevent LCT.

Also, the pressure on established companies to maintain their market position and to achieve short-term gains did not apply in Project#1. Project#4B illustrates that that these factors can result in a preference for known and established products. This inherently made influencing the meaning dimension difficult, as it changed the consumer perception of a product. It thus also restricted manipulating the meaning dimension to translate ecological considerations into product concepts. However, with Product#1, Client#1 tried to enter a market that was new to them. Their strategy to enter this market was to develop a product with a high degree of novelty. This facilitated an environment that has a similar openness to innovation, like start-ups.

8.3.2. How important are the underlying reasons for the client-openness to ecodesign?

The second aspect—which is specific to Project#1 compared to the other exemplary projects that followed a collaborative approach—is the underlying reason for the client-openness that allowed initiating the conversation about ecodesign. In Project#2, Project#3 and Project#4A, this openness was facilitated by a strong personal ecological awareness of the responsible persons in the client company. This was not observed for Project#1.

It was argued under Sub-section 8.2.1 that client-openness represents a prerequisite for initiating the conversation about ecodesign but cannot support an *entire ecodesign process*. Still, it is possible that this point of departure has an impact of the nature of the ecodesign practice. Berchicci (2009, p. 170) observed that the personal ecological ambition of decision makers 'is likely to have an impact when objectives are established, resources mobilised and performance criteria evaluated.' Thus, it may be that a strong personal ecological awareness of the responsible persons in the client company puts the IDCs in a strong position to justify allocating resources to consider and mediate the ecological consequences of design decisions along a product's entire life cycle.

Even though this research only observed the application of LCT in the context of exemplary projects where the client of the IDC had a strong personal ambition to develop low-impact solutions, the data does not explicitly support a direct causal relationship between these two aspects. Not all ecologically aware clients explicitly agreed to the endeavours of the IDC to practice LCT. Client#4A for example was not aware of IDC#4 applying LCT. Client#4A was so convinced of the ecological benefits of Product#4A that ClientContact#4A did not consider a potential necessity to account for consequences of design decisions along the entire life cycle of Product#4A. In contrast, Client#2 was explicitly informed about the application of LCT in Project#2 and also actively contributed to it. They were aware that every design decision had potential trade-offs and thus were convinced about the necessity to practice LCT. While their ambition to practice LCT was stimulated by the personal motivation of the decision makers within Client#2, it was also driven by the intention to communicate Product#2 as an eco-friendly solution to consumers. This situation was similar for Project#3.

While the data that was collected for this research does not allow exploration of the causal relationship between the personal ecological ambitions of the decision makers and of the possibility to justify LCT in detail, it is argued that the underlying drivers for ecodesign play a more important role. This is discussed in more detail in the next section, particularly with regard to how a focus on cost-savings constrained LCT in Project#1.

8.3.3. Are the drivers for ecodesign and the resulting ecodesign practice interrelated?

Horbach, Rammer & Rennings (2012) find that the driving force for a company to integrate ecological considerations into their business activities also determines how the company reacts. However specifically for ecodesign this relationship between drivers and the nature of the resulting ecodesign practice is poorly covered in the literature. Most studies into real-world ecodesign practice only investigate which drivers trigger ecodesign practice but do not describe the characteristics of this practice in detail (see for example: Mathieux et al. 2001; Ritzén & Beskow 2001). An exception in this regard is the PhD dissertation from Van Hemel (1998) *Ecodesign empirically explored: design for environment in Dutch small and medium-sized enterprises*. She finds that the presence of certain barriers and stimuli are likely to trigger specific types of ecodesign interventions. However, she does not go to the level of detail where she explores whether these decisions for or against these ecodesign interventions are informed by LCT.

Justifying ecodesign practice via cost savings can limit LCT

It is argued in this thesis that the main factor that prevented LCT in Project#1 was that the ecodesign practice was justified via cost savings only. Whilst an anticipation of potential consumer preferences for eco-friendly products played a role for initiating ecodesign in Project#1 the subsequent ecodesign practice was exclusively justified via cost saving potentials. This prevented establishing a low ecological impact as a goal in its own right. Instead cost-savings were used as a proxy indicator for ecological benefits. This brought along two implications.

1. The ecodesign interventions were not targeted towards aspects that had been identified as most relevant from an ecological perspective but towards those that were most relevant from a cost perspective.
2. The consequences of ecodesign interventions were only assessed in regard to their cost impact. Their ecological consequences remained unclear. This is problematic because not all ecological impacts of economic activities are reflected in their costs (Hanley & Barbier 2009).

The absence of an explicit consideration of ecological consequences of design decisions is particularly problematic when trade-offs need to be made. In Project#1, the cost for distributing Product#1 within Australia was higher than the cost for shipping it from China. The prioritisation of cost reductions forced the decision to focus on increasing the efficiency of distributing the shipping within Australia. As this decision decreased the efficiency of shipping the product from China, it remains unclear if it was beneficial from an ecological perspective.

It can be concluded that justifying ecodesign via cost savings can prevent LCT. Additionally to the scenario of an activist approach this delivers a second explanation for why the ecodesign practice within an IDC-client collaboration can remain limited, addressing the research question 2a.

Research question 2a: What limits the ecodesign practice of industrial designers?

Justifying ecodesign via increasing the personal value consumers see in a product can facilitate LCT

Analogously, it is argued in this thesis that the justification of the ecodesign practice (through the expectation that the ecological performance of the product would play a role in the consumer’s purchasing decision) allowed LCT in the other exemplary projects. This was observed in particular in Project#2 and Project#3, but also to some extent in Project#4A. While the ecodesign interventions still needed to be mediated with other product requirements, the anticipation that the ecological performance of the product would play a role for the consumer allowed for establishing the achievement of a low ecological impact as a goal in its own right. As observed in particular in Project#2 and Project#3, this context also allowed specifically for monitoring of this goal.

It needs to be highlighted that the ecological performance of the products was never expected to be the only or even the primary concern to the consumer. In particular, the capacity of the products to provide the desired utilitarian functionality was seen as pivotal to their success. It was also necessary to mediate the consequences of the ecodesign interventions with regard to the cost for manufacturing and distributing the products. The extent to which other project requirements could be compromised varied between the exemplary projects. For example, Client#4A accepted ecodesign interventions that increased the cost. By contrast, Client#3 was very focused on not increasing the cost for the product, but agreed with a slight compromise in regard to the utilitarian functionality their product provides.

8.4. Progressing ecodesign through industrial design practice

Sections 8.1 and 8.3 delivered two explanations that address research question 2a.

Research question 2a: What limits the ecodesign practice of industrial designers?

Firstly an activist approach to ecodesign and secondly, the use of cost to justify the inclusion of ecological considerations in a collaborative approach can limit ecodesign practice. In the cases that were investigated for this thesis both scenarios limited or foreclosed LCT. This is problematic because without LCT it remains uncertain as to whether ecodesign interventions successfully target the most relevant ecological impact of a product and if the ecodesign interventions actually reduce the negative ecological impact, associated to a product. This section now develops an answer to research question 2b:

Research question 2b: How can industrial designers progress their ecodesign practice?

It was argued in Section 8.2 that a collaborative approach offers the potential to address the factors that hamper ecodesign in an activist approach. In Section 8.3 it was concluded that in the observed ecodesign practice this was only possible when this practice was justified by the expectation that the ecological performance of a product plays a role in the personal value consumers saw in a product. Thereby the ecological performance of a product cannot be expected to be the only or most important element of this value. However a perception of the eco-benefits was nevertheless part of it. In other words the clients of the IDCs expected their consumers to attach eco-friendly meanings they perceived as valuable to the products. Such meanings align ecological objectives with the agenda of industrial design practice that was introduced in Chapter 2: Industrial designers need to design products their clients can sell for a price that allows them to generate income that exceeds their expenses for developing, manufacturing, distributing and commercialising the products. This is only possible when consumers see sufficient value in a product to pay an adequate price. Consequently, if the ecological performance of a product is part of the value consumers see in a product it offers the potential to justify LCT / the allocation of resources to assure that the product really has quantifiable ecological benefits. These causal relationships are visualised in Figure 48, which illustrates the problem situation for industrial design practice as introduced in Sub-section

2.1.2. To draw out the interplay of the factors that were discussed here, the relevant arrows are emphasized.

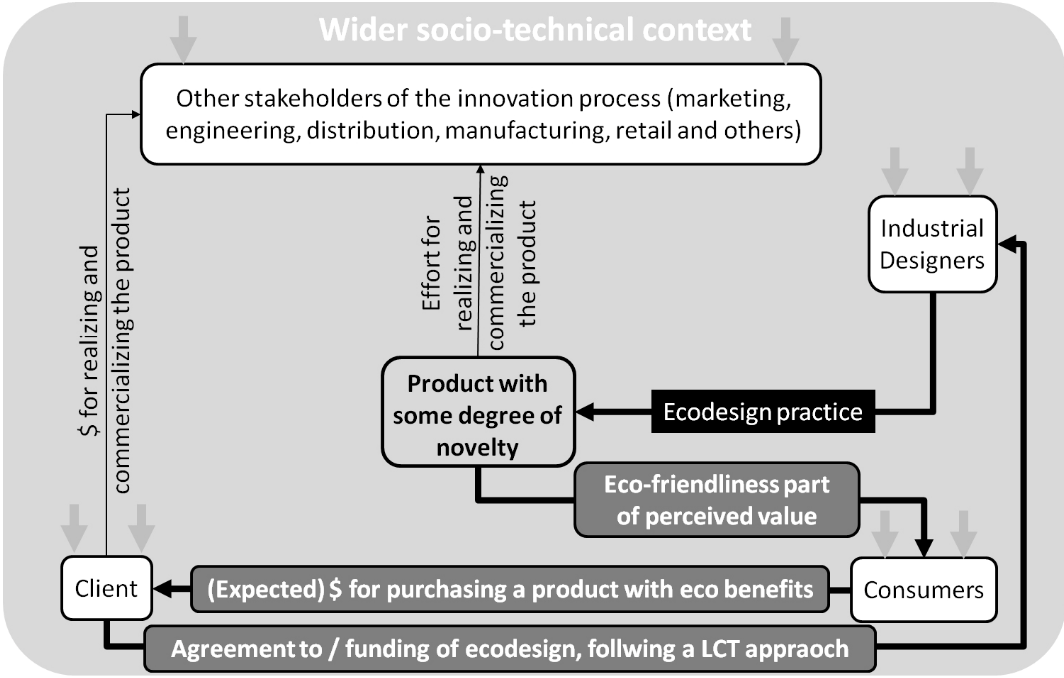


Figure 48: Alignment of justifying ecodesign practice via eco-friendly meanings, consumers perceive as valuable with the agenda of industrial design
(Source: created for this research)

The argument of this thesis proposes that the identification of eco-friendly product meanings that are perceived as valuable can justify LCT. It is important to stress that it *can* justify LCT but does not *have to* do so. Companies could also just wrongly communicate products that do not have eco-benefits as ecologically superior products. However this is associated with a high risk. It can lead to boycotts of the product if the unjustified eco-friendly product meaning becomes public (see for example: Purkayastha & Fernando 2007). As the empirical data of this thesis shows, misleading communication of unjustified eco-benefits of a product can also have legal consequences for a company making those claims. As the report from Designer#4 and the reluctance from ClientContact#1 illustrate there also is awareness about these risks amongst Australian IDCs and their clients.

In the investigated exemplary projects only the scenario, shown in Figure 48 allowed practicing LCT and explicitly considering the ecological implications of the design decisions. Thus, it is important to identify business opportunities for products that allow consumers to attach eco-friendly meanings they perceive as valuable.

8.4.1. Identifying business opportunities for products with eco-friendly meanings

Demand-focused ecodesign interventions that were applied in Project#2, Project#3 and Project#4A allow consumers to attach eco-friendly product meanings to products. However, the timing of their application varied, as did the underlying logic applied to identify business opportunities within the exemplary projects for products that allow consumers to attach eco-friendly meanings. In Project#2 and Project#4A, the underlying logic was mainly solution-focused. In both cases, representations of solution suggestions were proposed to the problem situation that was designed for, which uncovered/stimulated a demand for Product#2 and Product#4A (for more detail on these processes, see sub-sections 7.3.1 and 7.5.2). The extent to which this uncovered/stimulated demand was directly supported by the eco-friendly meanings that may have varied between individual consumers. However, in both exemplary projects, demand-focused ecodesign interventions were embodied in the representations of the solution-suggestions. In other words, the solution-suggestions communicated ecological benefits of the products to the consumers. Thus, it is argued in this thesis that these eco-friendly meanings can be seen as an integral element of the value consumers saw in the representations of these products.

In direct contrast to Project#2 and Project#4A, problem-focused thinking was applied in Project#3 to identify business opportunities for products that allow consumers to attach eco-friendly meanings to them. Demand-focused ecodesign interventions were applied after Client#3 was convinced of this business opportunity. Even though this shows that business opportunities for products with eco-friendly meanings can sometimes be identified through problem-focused thinking, the argument of this thesis proposes that solution-focused thinking in tandem with demand-focused ecodesign interventions is the more promising pathway.

The importance of the solution-focused element of Design Thinking

Problem-focused logic seeks to establish the requirements for a product development process by researching into the status quo. In some cases, this approach can successfully identify business opportunities for products with eco-friendly meanings, if the market for which they are developed expresses an explicit sensitivity towards the ecological performance of products. This was the case for Project#3. However, such circumstances are rare. Most consumers do not show a high motivation to change their consumption behaviour to favour the currently available eco-friendly products (Boks & McAloone 2009). Besides consumer motivation, a lack of uptake of eco-friendly products may also be rooted in the lack of such products that are perceived positively by the consumer (Polonsky 2008). Thus, it is argued in this thesis that developing new solutions that propose new meanings to consumers is a more promising pathway to identify opportunities for eco-friendly product meanings that consumers perceive as valuable, rather than problem-focused thinking. This is demonstrated in particular by Project#2. At the time Project#2 was conducted, products were available that had a comparable utilitarian functionality to Product#2. However, the meanings consumers attached to them were only perceived as positive by a very small share of the market. Thus, they were not adopted widely and only had the potential to create little economic value. Consequently, problem-focused logic would have indicated a very limited market potential for Product#2. It was only possible to uncover the market potential for Product#2 through solution-focused thinking. This required interpreting, representing and testing new product-consumer interfaces.

The importance of drawing on the solution-focused element of Design Thinking is further underscored by the circumstance that Product#3 was developed as a competitor of Product#2. The new meanings Product#2 offered to consumers had transformed the market. Now, sensitivity towards the ecological performance within this market was explicit. Without this pioneering work, it would not have been possible in Project#3 to identify opportunities for products with eco-friendly meanings that were perceived as valuable by consumers, by using problem-focused logic.

Drawing on the solution-focused element of Design Thinking is always an explorative process. Thus, it cannot be determined upfront as to whether it is possible to uncover business opportunities for products with eco-friendly product meanings. Despite this uncertainty, the argument of thesis proposes that that using industrial design practice to interpret, represent and test product designs that offer eco-friendly meanings to consumers is important to embrace. Consumers are becoming increasingly ecologically aware (García Gallego & Georgantzis 2011). The study of Hassi & Kumpula (2009) highlights that eco-friendly and eco-unfriendly product meanings are constructed around consumer products. This applies even if these meanings are not intended by the companies providing the products, and it shows that consumers incorporate ecological considerations into their sense-making process when attaching meanings to products. Consequently, as a sense-creating practice, industrial design needs to react to this phenomenon. This is crucial not only to explore and identify potential new business opportunities for products that offer consumers eco-friendly meanings. It also can help to avoid pitfalls that may occur through product-consumer interfaces that stimulate unintended eco-unfriendly product meanings.

The importance of demand-focused ecodesign interventions and the necessity to explore new product interfaces

The application of solution-focused thinking to explore opportunities for products which offer consumers to attach eco-friendly product meanings to them requires developing accordant representations of solution suggestions. In other words, demand-focused ecodesign interventions need to be applied that communicate ecological benefits to consumers. As explained in Sub-section 5.2.4, industrial designers can use their influence on the product-consumer interface for this purpose.

Thereby, it is important to not only rely on product-consumer interfaces that currently communicate ecological benefits to consumers, but also to explore new ways of conveying this message. Most product-consumer interfaces that are currently used to trigger eco-friendly product meanings (such as the visible application of bamboo or recycled material) are observed to trigger other product meanings also. These interfaces often can stimulate consumers to attach additional product meanings such as a compromised utilitarian or emotional functionality (Huang & Henry 2009). As these additional meanings are usually perceived as negative, it often is not advisable to use them as they may diminish the value consumers see in a product.

That industrial design practice also allows for developing new product-consumer interfaces that allow consumers to attach eco-friendly product meanings is in particular demonstrated in Product#4A. IDC#4 did not use any established product language to communicate ecological benefits of Product#4A. Instead IDC#4 developed a new interpretation of how the ‘form’ and ‘mode of use’ levers could be applied in tandem with accordant market communication to propose an eco-friendly meaning to consumers. (For more detail see Sub-section 7.5.2.)

8.4.2. Refining the preliminary theoretical framework

It can be concluded that industrial design practice can help to identify and stimulate eco-friendly product meanings that are perceived as valuable by consumers through demand-focused ecodesign interventions and the application of solution-focused thinking. If this endeavour is successful it in turn justifies investing into LCT when practicing ecodesign. This represents a pathway specific to industrial design practice and addresses research question 2b:

Research question 2b: How can industrial designers progress their ecodesign practice?

These findings show the importance to acknowledge the link between the influence of industrial design practice on the individual socio-cultural context of products, and its potential to convert ecological considerations into product designs with a quantifiable low ecological impact. Based on these insights, Figure 49 refines the preliminary framework introduced in Chapter 5.

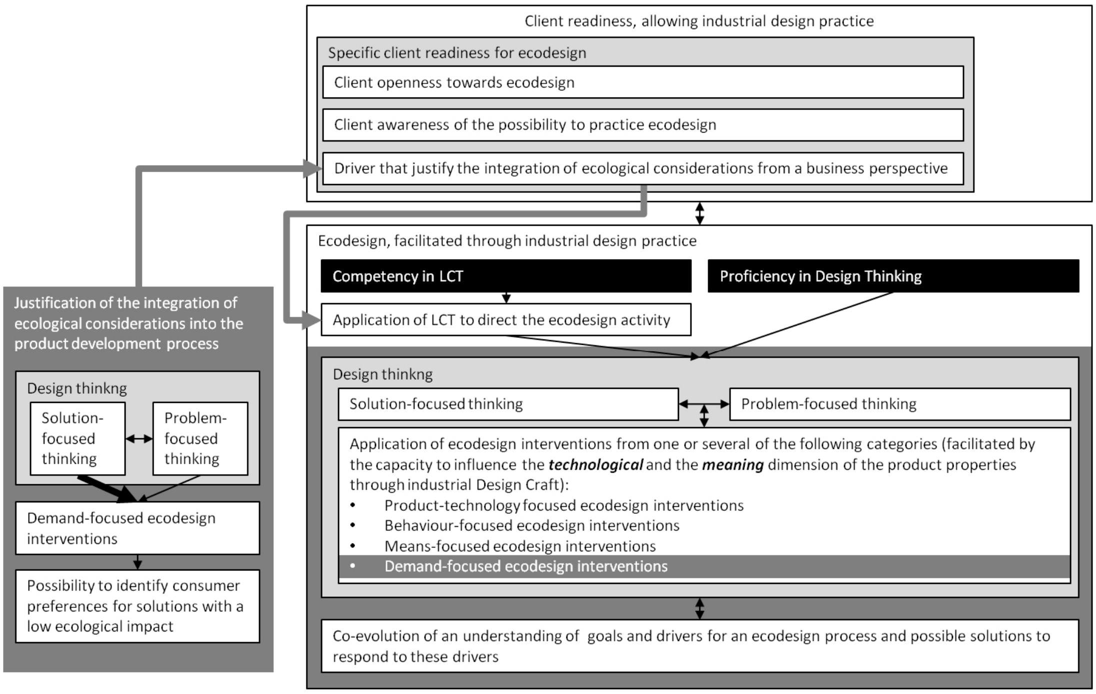
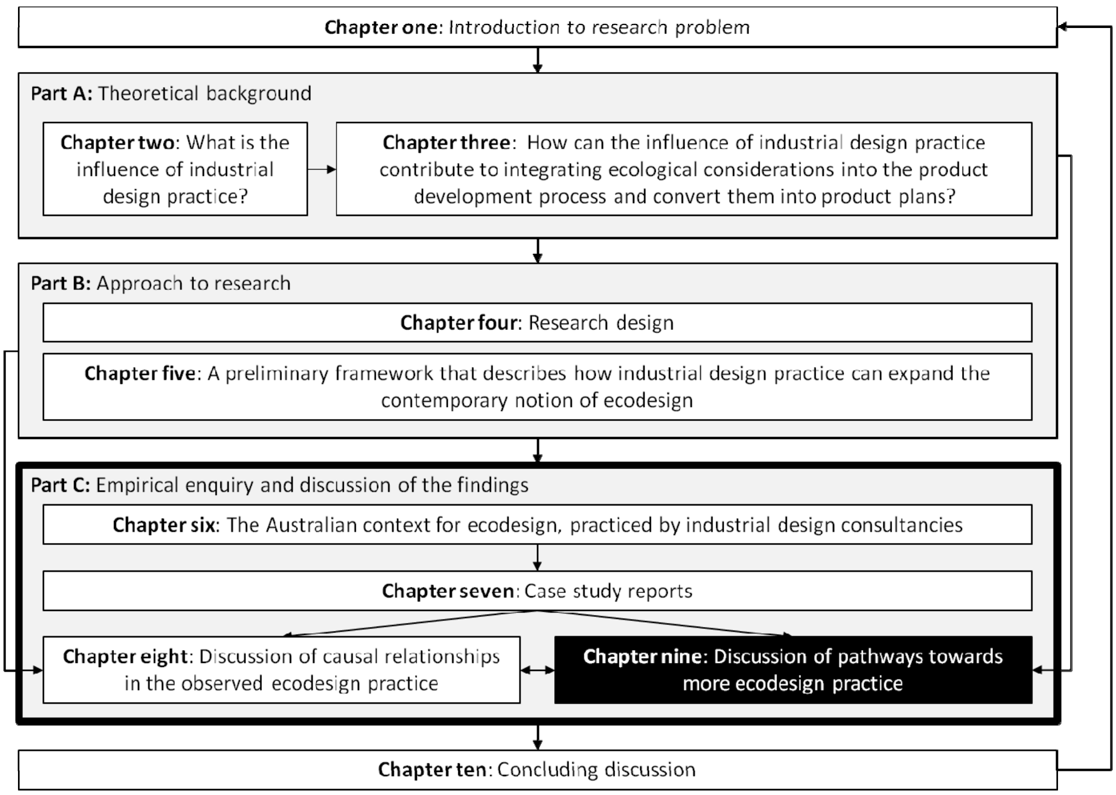


Figure 49: The role of industrial design practice for developing products with a low ecological impact, emphasising the importance of justifying the integration ecological considerations into the product development process via identifying consumer preferences for eco-friendly solutions
(Source: created for this research)

Figure 49 emphasises the importance of justifying the integration ecological considerations into the product development process via identifying opportunities for solutions that allow for eco-friendly product meanings that consumers perceive as valuable. This is shown in the dark-grey box on the left-hand side of the diagram, which isolates and magnifies the capacity of the industrial design practice to uncover and/or stimulate an accordant consumer demand. The aspects that are magnified and isolated are highlighted in the main diagram also in dark-grey. The emphasised arrow, which connects the solution-focused element of Design Thinking to the demand-focused ecodesign interventions, highlights the relative importance of solution-focused thinking compared to problem-focused thinking.

The argument of this thesis does not suggest that the pathway to justify ecodesign, visualised in Figure 49 is a panacea. It should not be misunderstood as proposition that it is always possible to justify LCT and the integration of ecological considerations into a product development process via exploring product interfaces that offer eco-friendly product meanings that consumers perceive as valuable. In some cases, consumers may not be sensitive to ecological issues in a way that motivates them to make sense of the products with which they engage so that an eco-friendly or unfriendly meaning is constructed. It also cannot be expected that eco-friendly product meanings are always perceived as positive. However, because utilising the solution-focused element of Design Thinking is an explorative process, it cannot be stated upfront with certainty whether the proposed pathway is successful or not.

CHAPTER 9. PATHWAYS TOWARDS MORE ECODESIGN PRACTICE



Chapter 8 concluded that industrial design practice can help to identify and stimulate eco-friendly product meanings that are perceived as valuable by consumers through demand-focused ecodesign interventions and the application of solution-focused thinking. If this endeavour is successful, it in turn can justify investing into LCT when practicing ecodesign. However, demand-focused ecodesign interventions were not frequently conducted by the interviewed industrial designers. They were either perceived as difficult or not so important. Instead, the industrial designers relied on or hoped for other potential drivers for ecodesign, in particular legislation and standards or cost savings. In other words, the industrial designers were reluctant to use or were unaware of the influence of their practice to drive the integration of ecological considerations into the product development process. These findings are discussed in this chapter. This chapter also links the insights this thesis delivered to the discussion about the necessity of ecological information in the form of analytical LCT tools to further real-world ecodesign practice. It also relates back to the proposition this thesis made in Chapter 3: that incorporating ecological considerations into industrial practice can form a bridge between ecodesign and sustainable design. This chapter is divided into four sections.

- **Section 9.1** discusses the role of cost-savings, legislative requirements and standards as drivers for ecodesign from the perspective of the IDCs.
- **Section 9.2** links the insights of this thesis to the discussion about the necessity of ecological information in the form of analytical LCT tools to further real-world ecodesign practice.
- **Section 9.3** discusses potential difficulties IDCs can face with demand-focused ecodesign interventions. This is necessary because the collected data reveals that industrial designers seem to rarely make use of the potential to conduct these kinds of ecodesign interventions. The barriers that seem to be responsible for this phenomenon are difficulties related specifically to proposing eco-friendly product meanings, and more generally to influencing the meaning dimension and applying solution-focused thinking. This poses upfront barriers to follow the suggestion that these two capacities of industrial design practice can help to facilitate ecodesign and LCT.
- **Section 9.4** finally engages with the question of whether the expanded notion of ecodesign can be seen as a promising way to progress towards sustainable design.

9.1. The role of cost-savings, legislative requirements and standards as drivers

The capacity to identify eco-friendly product meanings through solution focussed thinking that are perceived as valuable by consumers as a pathway to justify LCT and ecodesign is specific to industrial design practice. However, it is not the only possible driver that can stimulate ecodesign and, as pointed out in Chapter 8 it also cannot be expected to be always successful. This underlines the importance to also understand the potential of other drivers that can stimulate ecodesign. The representatives of the IDCs saw cost savings and legislation and standards demanding the considerations of ecological issues as particularly promising.

9.1.1. The hope for legislation and standards, demanding eco-friendly products

Neither legislation nor standards relating to eco-friendly products were reported by any representatives of the IDCs as having helped them to justify practicing ecodesign when working on consumer products. However, most IDCs had high hopes that this would change in the future and that legislation and standards would become a driving force for ecodesign. This aspiration was also shared by the interviewed ecodesign experts. It is also supported by empirical research into the driving forces for eco-innovation, where legislation in particular is found to be ‘the most important stimulus’ (Triebswetter & Wackerbauer 2008, p. 1484).

The collected data provides only a very limited foundation for a discussion about the potential of legislation and standards to justify the ecodesign practice of IDCs when working on consumer products. The absence of legislation and standards as drivers for ecodesign in the observed ecodesign practice in the context of consumer product development may be specific to the observed IDCs. It may also be that it applies specifically for the Australian context, as the experts saw these legislations and standards demanding eco-friendly products being more prominent in other parts of the world, such as Europe. On the other hand, the interviewed IDCs also worked for international clients; thus it can be expected that the IDCs are exposed also to international legislations and standards.

While this ressearch cannot contribute to illuminating the interrelationship between the ecodesign practice of IDCs and current/potential future legislation and standards that demand eco-friendly products, it can be said that industrial design practice will always be reactive to these factors. Industrial design practice allows industrial designers to exert influence on the technological and the meaning dimension of the products they work on and on identifying goals and drivers of a product development process. However, it does not provide them with direct influence over legislation and standards[32]. Thus, any aspiration for legislation or standards to drive their ecodesign practice puts them in a passive role in their day-to-day practice. This can have a negative effect. A hope for change from elsewhere may keep them from exploring and using their own influence. This is underlined in particular by one quote of an industrial designer who was interviewed for this thesis.

> *'If it was taken for granted* [that legislation demands products to be eco-friendly] *we would not talk about an ecodesign look. We would just talk about: Well look, it is this design or this design? It would be completely ingrained. You would not even see it. But now, because it is on top of things, you sort of label it and explicitly talk about it and give it a shape as well to communicate it. But let's say in 30 years there is going to be regulations over the world, there is going to be everything hopefully, there will be like you cannot design a product in a bad way because it is just a part of it' (Designer#3)*

This quotation illustrates that an excessive reliance on the hope that legislation and standards will drive ecodesign in the future may hamper demand-focused ecodesign interventions. If IDCs take a passive role, they are unlikely to invest efforts into exploring demand-focused ecodesign interventions to translate eco-friendly messages into representations of product interfaces and test their potential to generate value.

9.1.2. Is it possible to achieve eco-benefits if ecodesign is justified via cost-savings?

Project#1 showed that justifying ecodesign via cost savings could constrain LCT and jeopardise the achievement of an eco-friendly product. The coupling of cost reduction and ecodesign practice resulted in the use of cost as a proxy indicator for the ecological performance and prevented an explicit assessment of the ecological implications of the ecodesign practice. It is argued in this thesis that this observation can be expected to be non-specific to Project#1. It is highly likely that ecodesign practice that is justified by cost savings always bases decisions for or against design interventions on their cost reduction potential, rather than on an explicit consideration of their ecological consequences. Consequently, LCT—i.e. the accounting of ecological impact along a product's entire life cycle to inform the design decisions—is most likely to be limited.

However, it is not necessarily the case that the potential for ecological improvements is always compromised when ecodesign is justified by cost-savings. In some cases, using cost as a proxy indicator may successfully guide the design interventions towards achieving a reduction of the ecological impact. Such a scenario can be expected for every case when the efficiency is raised through resource reductions that do not require any trade-offs. For example, if the overall

[32]The only way industrial designers could directly influence legislation is through a lobbying role, potentially through industry associations such as the Design Institute of Australia. However, as the focus of this thesis was on the influence of industrial design practice, this pathway was not investigated.

energy consumption or overall quantity of material can be reduced without any further implications, it is safe to say that the interventions that achieve these results are not only positive from a financial perspective but also from an ecological one. In this research, this can, for example, be expected from the follow-up project of Project#1. In Project#1, a trade-off was made that increased the resource efficiency at one step of the life cycle and decreased it at another step. This left it uncertain as to whether design interventions achieved an ecological benefit. Nevertheless, in the follow-up project, IDC#1 and Client#1 intended to eliminate this trade-off and increase the resource efficiency along the entire life cycle, which also made it highly likely that an ecological benefit was achieved.

While justifying ecodesign via cost savings may achieve ecological benefits for a scenario where no trade-offs are necessary to increase the resource efficiency of a product, one limitation still remains. As it limits the opportunity to argue for an explicit consideration of the ecological impact, it is not possible to make sure that the most relevant ecological impact of a product is addressed.

9.2. Expectations for further development of analytical LCT tools

For years, researchers have focused on making relevant ecological information accessible to designers to support LCT. As discussed in Section 3.3 in detail, these endeavours have established an essential foundation for ecodesign by providing analytical LCT tools. As real-world uptake of LCT in commercial product development processes remains limited (Baumann, Boons & Bragd 2002; Boks 2008; Knight & Jenkins 2009; Tukker, Haag & Eder 2000), the question arises if the available LCT support is adequate. Empirical investigations into ecodesign practice repeatedly find that the access to ecological information and the accuracy and relevance of this information is often perceived as insufficient and offers room for improvement (Mawle, Bhamra & Lofthouse 2010; Stevenson et al. 2011; White et al. 2004). These observations propose that further development of analytical LCT tools is needed to progress the real-world application of LCT.

The empirical data collected by this thesis allows only to a limited degree to contribute to this discussion. As a lack of access to relevant ecological information had already been identified as a potential barrier, it was decided for this research to only investigate into the ecodesign practice of IDCs where this potential barrier was minimal. If the investigated IDCs did not have the capacity to acquire and interpret ecological information that allowed them to practice LCT in-house, they commonly had experts in their network they could contract to support if needed. Consequently, a lack of LCT could not be expected from a deficiency in the ability to make relevant ecological information available that could be compensated by an analytical LCT tool that is easier to use and understand. This should not be misunderstood as dismissing efforts to improve the available analytical LCT tools.

Further development of analytical LCT tools is important. It can in particular help IDCs who do not have access to experts that can support them in acquiring and interpreting ecological information to practice LCT. However, tool development should not be approached with false expectations. More and better tools alone are unlikely to facilitate more ecodesign practice. The same is true for up-skilling industrial designers in following a LCT approach. Industrial designers will only practice LCT and apply analytical LCT tools if two criteria are fulfilled. Firstly, they need sufficient room to manoeuvre in their design decisions to apply the knowledge that they gain from LCT. Secondly, the application of analytical LCT tools needs to be funded by the clients of the IDCs. While some industrial designers may have sufficient intrinsic ecological ambition to bring up the necessary resources for ecodesign and LCT on their own expense, such an altruistic attitude cannot be expected from all industrial designers. Industrial designers are generally reliant on receiving an adequate financial reimbursement for their design services from their clients. This also includes the effort they invest into applying analytical LCT tools in order to acquire relevant ecological information. In conclusion, the IDCs need to be able to gain a financial reward from the application of the analytical LCT tools and they need to be able to openly mediate the consequences of the insights from the analytical LCT tools with other requirements for the industrial design process. Both of these criteria demand an explicit agreement on the client side to the industrial designers practicing ecodesign and applying LCT. Thus, this thesis proposes that further tool development can only improve real-world ecodesign practice in cases where not only the designer but also the client sees a clear justification for practicing LCT when incorporating ecological considerations into the product development process. As concluded in Chapter 8, a possible pathway to justify LCT through industrial design practice can be stimulating and / or uncovering a demand for eco-friendly products.

In this context, it needs to be highlighted that the application of the information that can be derived from analytical LCT tools is not necessarily limited to informing LCT in a product development process. When companies make explicit claims about quantifiable eco-benefits (such as their carbon dioxide emissions to consumers through marketing materials), these need to be verified (Baumann & Tillman 2004). In the current situation, this is a job for an expert, as the analytical LCT tools that have been developed specifically for industrial designers do not provide sufficiently accurate data that allow for making these claims legally. If the analytical LCT tools that are available to industrial designers would be able to produce sufficiently accurate data, this data may then be used to explicitly communicate eco-benefits to consumers. This can support demand-focused ecodesign interventions or help to address an already explicit consumer preference for an eco-friendly product. In other words, analytical LCT tools that produce more accurate data may make it easier to justify the integration of ecodesign in a commercial product development process. However, it remains questionable if it is possible to develop analytical LCT tools that balance applicability by industrial designers with the necessary accuracy. Thus, engaging with the question how far new or improved analytical LCT tools may allow industrial designers to generate detailed information about the ecological impact of a product is an important area of further research.

9.3. Difficulties with demand-focused ecodesign interventions

Chapter 8 has highlighted that products expected to be positively perceived by consumers as eco-friendly solutions can offer the possibility to justify the application of LCT for directing the design decisions. Despite the importance of understanding the consumer's response towards proposed eco-friendly meanings, the collected data shows that this matter was often not investigated in detail in the projects the IDCs worked on. Sometimes, like in Project#1, no explicit enquiry into the consumer perception of the ecological performance of the product was conducted at all. Instead, it was assumed that ecological issues currently do not influence consumption behaviour. In other cases such as in Project#4B, the reaction of consumers towards eco-friendly solutions was based solely on research following a problem-focused logic, enquiring only into currently explicit consumer preferences. As discussed in Section 8.4, relying only on problem-focused thinking has limited potential to identify opportunities that allow for products with eco-friendly meanings that are perceived by consumers as valuable.

Chapter 8 concluded that industrial design practice can help to identify and stimulate eco-friendly product meanings that are perceived as valuable by consumers through demand-focused ecodesign interventions and the application of solution-focused thinking. Even though this represents a pathway to trigger ecodesign that is specific to industrial design practice, the collected data shows two categories of barriers that kept industrial designers from utilising it. Firstly, some of the interviewed industrial designers showed a certain reluctance to develop representations of solution suggestions that offer eco-friendly product meanings. Secondly, the interviewed industrial designers faced difficulties with conducting demand-focused ecodesign interventions and with applying solution-focused thinking. This posed upfront barriers for the suggestion that these two capacities of industrial design practice can help to facilitate ecodesign and LCT.

The extent to which the individual representatives of the IDCs reported about each barrier varied (for more detail, see the case study reports in Chapter 7). Table 14 provides an overview of the individual barriers and links them to the individual research participants who mentioned them. Table 14 not only shows barriers that were explicitly mentioned but also those that were apparent in the exemplary projects the research participants reported about.

Table14: Overview of the individual barriers and the individual research participants who mentioned them (Source: created for this research)

		Designers				
		Designer#1	Designer#2a	Designer#3a	Designer#3b	Designer#4
Barriers, causing a reluctance to develop suggestions for eco-friendly product meanings	Eco-friendly meanings are linked to an established formal language that has negative connotations	X		X		X
	The ecological impact of a product is difficult to translate to the consumer			X		X
	Meanings may be too subjective to purposefully influence	X		X		
	Communicating the ecological performance of the product through its design is not a key area of ecodesign		X	X		X
General difficulties with influencing the meaning dimension and applying solution-focused thinking	Difficulties to influence product meanings	X	X	X	X	X
	Not valued/understood by the client	X	X			X
	Consumer research dominated by client	X		X	X	
	Difficulties to apply solution-focused thinking	X	X	X	X	X
	Prototyping too late	X			X	
	Prototyping mainly to assure the utilitarian functionality		X	X		
	Consumer research dominated by client	X		X	X	X
	Explicit client preference for organising the product development process linear	X	X	X	X	X

9.3.1. A reluctance to develop propositions for eco-friendly product meanings

The reluctance to develop representations of solution suggestions that offer eco-friendly product meanings varied in prominence. Also, the extent to which the barriers appeared to affect this attitude differed between the individual interview participants. For example, Designer#4 and Designer#3a both reported that they experienced that eco-friendly product meanings are linked to an established formal product language that often also triggers additional, negative product meanings. Even so, Designer#3a still seemed to see this product language as the only way to trigger ecodesign. In contrast, Designer#4 demonstrated in Project#4A that it is also possible to communicate the ecological performance of a product by proposing a new formal language.

IDC#1 showed the least reluctance to develop suggestions for eco-friendly product meanings. Designer#1 reported to frequently direct effort in the general practice of IDC#1 towards exploring how such meanings can be suggested to consumers through the 'form' lever. However, these explorations were usually hindered by IDC#1's clients. They commonly preferred to minimise the engagement of IDC#1 in the consumer research—particularly in regard to developing the market strategy for the product—and pushed for a linear product development process that adhered to a problem-focused logic. These factors are discussed in more detail in Sub-section 9.3.2.

The variances in the extent to which the individual representatives engaged with the possibility to try to translate a low ecological impact into proposals for product meanings show that there was no shared understanding amongst the industrial designers of how their profession can develop its own take on ecodesign. The most obvious approach to ecodesign for the majority of the interviewed industrial designers still seemed to be closely linked to the traditional notion of ecodesign, focusing mainly on the technological dimension of product properties. The potential of also utilising the influence of their practice on the meaning dimension for ecodesign seemed to be less obvious to them. The underlying reasons for this phenomenon can be varied, and fully exploring and elaborating them is beyond this thesis. However, some things can be said based on the insights this research provides.

As the background chapters of this thesis elaborated, the influence of industrial designers has not been fully acknowledged by contemporary concepts, describing the incorporation of ecological considerations into design practice. This may impact the university and ongoing professional education that industrial designers receive and ultimately inform their practice. For example, the practice notes published by the DIA discuss the traditional notion of ecodesign (Design Institute of Australia 2004). The focus of the traditional notion of ecodesign—which prescribes a focus on the technological dimension of the product properties when converting ecological considerations into product designs—may have been readily adopted by the interviewed industrial design professionals. Thus, the underlying technical perspective of most ecodesign theory that the industrial designers confronted may represent one barrier for them to develop their own interpretation of the ecodesign idea.

Another explanation for a hesitance in exploring potentials of eco-friendly meanings may be rooted more in the general nature and self-understanding of industrial design. Eco-friendly meanings that are perceived as valuable by consumers represent a very specific kind of value. While Chapter 2 has explained that industrial designers are skilled in creating different kinds of value for various different stakeholders, they are neither trained to develop a specific value, nor do they need to acquire explicit and detailed understanding of the value they create for consumers. Their work is usually seen as finished and successful once they have found a solution that can be expected to have sufficient personal value for consumers so they are willing to pay a price that allows meeting the economic agenda of the client of the industrial designer. Intentionally seeking to create value through eco-friendly meanings may require from industrial designers to reflect about their practice in a much more critical and explicit way than they are used to do. It would also require an explicit understanding of industrial designers of the influence their practice can have. Such an explicit self-understanding may be lacking for many industrial designers in general. As design is not a process that always happens at a fully conscious level (Cross 2011) such an explicit self-understanding is not a pre requisite for being a good designer.

9.3.2. Barriers for influencing the meaning dimension and solution-focused thinking

The other factor that handicapped the interviewed industrial designers in utilising their capacity to explore the potential for eco-friendly product meanings that are valued by consumers lay in a more general challenge the profession faces. Numerous authors have long advocated the benefits of using design practice strategically and drawing on the solution-focused element of Design Thinking (Blaich & Blaich 1993; De Mozota 2003; Jevnaker 2000; Kotler & Rath 1984). However, in reality industrial designers struggle to gain this influence (Von Stamm 2010). Mainly the resistance from clients makes it difficult for them to draw on the solution-focused element of Design Thinking and to explore the implications of interventions at the product interface for the consumer perceptions. This is problematic as these are prerequisites to use design practice to explore the potential for eco-friendly product meanings that are valued by consumers.

Client preference for structuring the product development process in a problem-focused logic

One underlying cause for this phenomenon is a reluctance of the clients of the IDCs to allow for the structuring of the product development process that follows a more solution-focused logic. In particular, the insights collected from IDC#4 show that clients perceive the explorative nature in a solution-focused approach as negative. Foote (2003) confirms that clients of design services generally hold this perception. Because solution-focused thinking relies on the capacity to creatively generate solutions, it is not possible to predict the outcome in the beginning of the design process. This opposes risk minimisation strategies commonly used by companies to inform their investment decisions and makes it difficult for IDCs to negotiate an adequate reimbursement for drawing on the solution-focused element of Design Thinking (Foote 2003). Product development processes that follow a problem-focused logic allow for predicting the expected outcome with more certainty right from the start, and are therefore commonly perceived by clients as less risky.

To some extent, this was also reflected in the approach of most IDCs interviewed for this thesis when they communicated the structure of their work to their clients. Even though the representatives of the IDCs highlighted that this structure was to some extent iterative and explorative, they pointed out that communicating it as if it would be a linear process made it easier to convince the client that they worked efficiently and made progress. The IDCs commonly tried to limit the iterations and explorations to contained stages in the product development process. However, this minimised or even foreclosed the possibility of feeding the learning from more refined solution suggestions back to the formulation of the strategy for the product development process. Furthermore, this reduced the capacity of IDCs to engage in a dialogue with the context that was designed for through these solution suggestions.

A design process always has elements of solution-focused thinking and elements of problem-focused thinking. A successful product development process has a beginning and an end. Thus communicating and structuring a design process as a linear process with an underlying problem-focused logic is one representation of this process. However it is not a comprehensive representation as it misses the solution-focused element of Design Thinking which is, as explained in Chapter 2 particularly important for achieving novelty and/or exerting influence on the meaning dimension of a product. IDCs can only expect to be in a position to also allocate time and budget to the solution-focused element of Design Thinking if they make this quality of their practice explicit in their negotiations with their clients.

If IDCs communicate their design process as a linear stage-gate process they will face time and budget constraints that keep them from drawing on the solution-focused element of Design Thinking. In a linear stage-gate process that exclusively follows a problem-focused logic the generation of representations of solution suggestions happens after the formulation of the strategy for the product development process. The representations of solution suggestions are a means to evaluate how well they meet previously set requirements. If taken to the extreme, this structure forecloses allocating time and budget to altering the strategy based on insights gained through the synthesis of the solution-suggestions. If the solution suggestions do not sufficiently match the previously set requirements efforts are rather directed towards looking for other, more appropriate solution suggestions. This approach is particularly problematic for influencing the meaning dimension. In a product development process that applies only problem-focused thinking holistic representations of solution suggestions are only generated towards the end. This limits the capacity of industrial design practice to utilize holistic representations of solution suggestions as a means to engage in a reflective conversation that seeks to understand how consumers make sense of new products.

Barriers for IDCs to develop insights into the consumer perspective

Another factor that hampered the application of solution-focused thinking—particularly in regard to the exploration of product meanings—was the circumstance that clients often preferred to minimise the engagement of IDCs with consumers. The insights that the representatives from the client companies and the IDCs provided revealed four underlying reasons within the client companies that can lead to this attitude.

1. Clients saw it as a cost factor to commission the IDCs with this task. To minimise that cost they either conducted research into consumer preferences themselves or relied on their intuition.
2. Clients regarded the information they had about consumer preferences and their strategy to respond to them as confidential, and thus shared these insights as little as possible with the IDCs they commissioned.
3. In particular, the entrepreneurial clients showed a strong urge to take ownership of the product development process. They thus tried to play the leading role in the product development process wherever this was possible.
4. Perhaps most importantly, most clients often did not see the practice of the IDCs they commissioned as a potential means to explore the consumer perspective. Rather, they perceived its role as responding to consumer preferences that were previously established via market research. In this role, they saw the capacity of industrial design predominantly as realising the product so that it could provide the intended utilitarian functionality they envisioned and meet manufacturing requirements. Thereby, the understanding of the clients regarding the influence of industrial design practice on the meaning of the product appeared to be often limited to making it look beautiful. Such a rather undifferentiated understanding of the capacity of industrial design practice to influence the meanings consumers attach to products can prevent clients from seeing the interface of a product as a more sophisticated means of

communication. This can also constrain allocating resources towards utilising this influence in a product development process.

The role of the self-representation of the IDCs

The perception of the clients of the IDCs is to some extend informed by the self-representation of the IDCs. How IDCs describe and advertise their services in their personal communication with their clients and their communication with the broader public (for example, through their website) has an influence on this perception. Thus, one factor causing a limited appreciation on the client side of the abilities of industrial design can be rooted in the self-representation of the IDCs.

Explaining their capacity to influence the meanings consumers attach to products is difficult for industrial designers (Best 2010; Ingols 1996). This is partially because meanings cannot be verified or tested in any quantitative way (Verganti 2009). This is different from the results IDCs can achieve when influencing the technological dimension of the product properties. This can cause a focus on communicating the capacity of industrial design practice to influence the technological dimension to illustrate the value of the practice of an IDC. That this represents a challenge for communicating the benefits of exerting influence on the meaning dimension is also reflected in the collected data. (See in particularly the report from IDC#2 in Sub-section 7.3.3.)

Also, communicating the possibility to structure the product development process more in a solution-focused logic can be expected to be difficult for industrial designers. While all investigated IDCs highlighted in their self-representation that their services can provide valuable strategic input into a product development process, none of them elaborated the application of Design Thinking in detail on their website. As no conceptualisation exists that fully captures the nature of Design Thinking in a flow chart or diagram (Visser 2006), it can be expected that explicitly communicating an accordantly structured design process is a challenge for industrial designers.

That the communication between industrial designers and their clients can cause difficulties that hamper their professional practice is not a new insight (see for example: Foote 2003; Hakatie & Ryynänen 2007). Arguably, the self-representation within this communication is not the only factor that can cause difficulties for IDCs to apply solution-focused thinking and to exert influence the meaning dimension. As Project#4B illustrates, the favour of client companies for prioritising following a problem-focused logic in structuring a product development process is also strengthened by market structures, company cultures and other factors. Also, the public perception of design in society plays a role in informing the expectations of clients. However, the focus of this thesis is specifically on understanding how industrial designers can improve their influence to develop products with a low ecological impact. In this regard, the self-representation of the IDCs is the only factor that determines the willingness of their clients to invest into solution-focused thinking and influencing the meaning dimension over which IDCs have direct influence.

9.4. The expanded notion of ecodesign: a pathway towards sustainable design?

The empirical investigation of this research has confirmed the expansions to the concept of ecodesign that have been suggested in the background chapters of this thesis. This supports the suggestion that industrial design practice can facilitate progress towards sustainable design as shown in Figure 50 by arrow number one. Applying industrial design practice to incorporate ecological considerations into the current commercial context allows realising aspects of sustainable design within this context. In particular it allows influencing the interrelationship between the product and the individual consumer to convert ecological considerations into products. It also allows drawing on the solution-focused element of Design Thinking, which facilitates a higher degree of novelty. Higher degrees of novelty are also associated to more fundamental change and improvement potential from an ecological perspective. While the appropriateness of arrow number 1 has been confirmed it remains unclear if this pathway really represents progress towards sustainable design.

1. Chapter 8 argued that that industrial design practice could contribute to uncover and/or stimulate a consumer demand for eco-friendly solutions and thereby justify the integration of ecological considerations and LCT from a commercial perspective. As this can be expected to be accompanied by an increased consumption of the eco-designed solution, it conflicts with the maxim of sustainable design to reduce consumption in order to avoid a potential rebound effect.
2. While the expanded notion of ecodesign allows incorporating some aspects of sustainable design into the current context, it remains unclear how far it prepares this context for the step indicated by arrow number two.

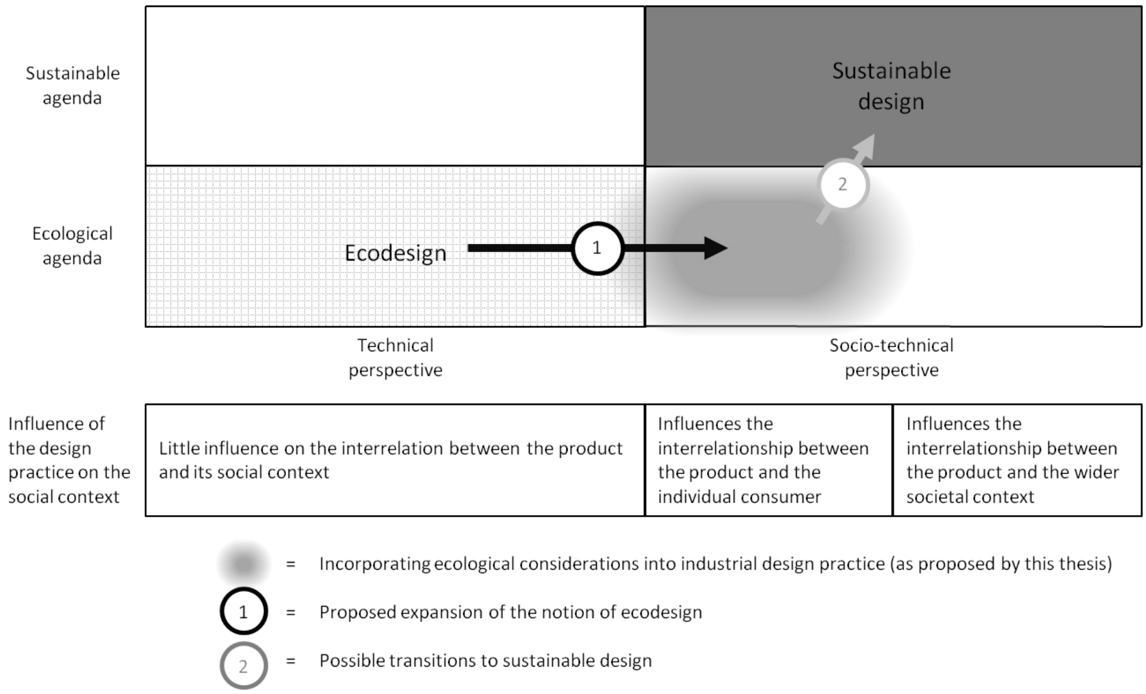


Figure 50: Incorporating the ecodesign idea into industrial design practice—an expanded notion of ecodesign as a possible transition towards sustainable design
(Source: created for this research)

9.4.1. How problematic is justifying ecodesign through increasing the consumption of an eco-friendly solution?

Justifying ecodesign through increasing the consumption of an eco-friendly solution by uncovering and/or stimulating a demand for it conflicts with the maxim of the sustainable design literature to reduce consumption. This body of knowledge sees uncovering or stimulating consumer demands as a concern because it bears the risk of a rebound effect (Vezzoli & Manzini 2008).

Whilst this concern is not unjustified a general rejection of options to increase the consumption of an eco-friendly solution is problematic. It prevents a potential pathway for amplifying the development of eco-friendly solutions in a commercially driven context (McDonough & Braungart 2002). If an explicit consumer demand for eco-friendly solutions can be uncovered or stimulated, it is likely that companies are more open to invest in addressing them. This can theoretically create an ongoing incentive for innovation that in the long run outweighs any initial rebound effect. That eco-friendly product meanings consumers perceive as valuable can become such an ongoing driver for an explicit consideration of ecological issues was also observed in the ecodesign practice that was investigated for this thesis. Product#2 changed the market. The ecological benefits of Product#2 are part of the value consumers see in it. Product#3 is a competitor product of Product#2. As Client#3 sought to enter the market that had been uncovered / created through Product#2, they had an incentive to practice ecodesign in the development of Product#3. The benchmark for the ecological impact was set to be lower than Product#2.

Past studies of the rebound effect have commonly explored an increase in consumption that was not directly linked to the eco-friendly meanings of a solution consumers perceive as positive (see for example: Giddings & Park 2012). The long-term dynamics of consumption patterns, market development and innovation trends associated with eco-friendly product meanings have not received much attention. Thus, it remains unclear how likely it is that an increase in consumption cancels out the ecological benefits of ecodesign practice if the consumption dynamics are linked to eco-friendly product meanings. Understanding this issue is a promising area of further research. It would require longitudinal studies of consumption behaviour in markets with products with eco-friendly product meanings, the associated product development processes, and the development of the ecological impact associated with the overall consumption.

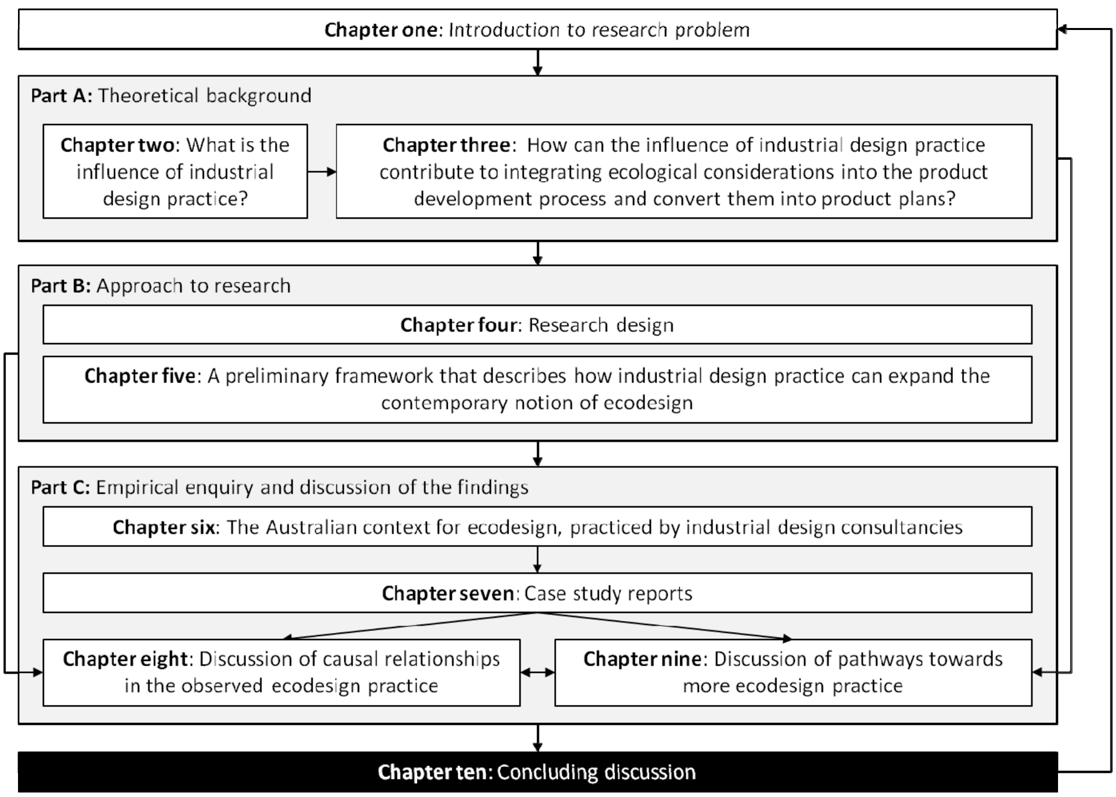
9.4.2. How far can the expanded notion of ecodesign prepare the current context for a transition towards sustainable design?

Fuad-Luke (2009) suggests that a new context for design activity is necessary to progress towards sustainable design—one where designers are no longer bound to only serve the interests of a bounded group of stakeholders. Only accounting for the interests of a bounded group of stakeholders constrains considering social and ecological issues that are beyond these interests. The expanded notion of ecodesign does not directly address this issue. It does not change the context for industrial design practice by directly expanding the considerations of this practice beyond accounting for the interests of the bounded group of stakeholders.

While the expanded notion of ecodesign does not directly challenge the current context for industrial design practice, the argument of this thesis proposes that it may support transitioning this context towards one that facilitates sustainable design. Through applying demand-focused ecodesign interventions and solution-focused thinking, industrial designers can potentially uncover and/or stimulate a demand for products where the ecological performance is part of the purchasing decision. If this is successful, it allows an expansion of the considerations of the design process to also include ecological issues along the product's life cycle. In other words, it allows the *environment* to be included as a stakeholder and thereby can bring the current context for industrial design closer to the one that is needed for sustainable design. The success of demand-focused ecodesign interventions partially depends on sensitivity within consumers towards ecological issues. It is argued in this thesis that demand-focused ecodesign interventions not only respond to this sensitivity but can also strengthen it. Through demand-focused ecodesign interventions, industrial design practice can contribute to the debate within society about the desirability of eco-friendly solutions and their compatibility with everyday life. Other than traditional debates about ecological issues like the ones in the media, this debate is not verbal—even though parts of it can be expressed verbally. However, like the other debates that deal with ecological issues, it can change the values and views present in society and contribute to a generally more ecologically aware society.

Even though this thesis investigated only the application of the influence of industrial design practice to ecological issues, it may be possible to apply it also to issues related to social and economic equity. The influence of industrial design practice on the meaning dimension of products and the application of solution-focused thinking can potentially also stimulate and/or uncover a demand for products that address issues related to social and economic equity.

CHAPTER 10. CONCLUDING DISCUSSION



This chapter draws final conclusions from this thesis by summarising the key findings and relating them back to the overarching research question. It is divided into three sections.

- **Section 10.1** summarises the key findings of this thesis.
- **Section 10.2** discusses these key findings with respect to addressing the overarching research question. This highlights how this research can inform industrial designers.
- **Section 10.3** covers how the findings can inform researchers, studying eco-innovation with a focus on industrial design and points to directions for further research.

10.1. Summary of key findings

The aim of this thesis was to identify pathways for ecologically motivated industrial designers to better utilise their influence to design consumer products with a low ecological impact. The focus of the investigations was on the influence of industrial design practice, rather than on the relationship-specific influence that the industrial designers as individuals can have within a product development team. Because the implications of incorporating ecological considerations into industrial design practice had not yet been fully formulated, this thesis started out by elaborating them at a theoretical level. This resulted in a proposition for an expanded notion of ecodesign that Chapter 5 described in a preliminary framework. The traditional notion of ecodesign comprises the integration of ecological considerations into a commercial product development process and their conversion into product designs by influencing their technological dimension. For ecodesign, the entire life cycle of the product needs to be considered, an approach that is termed *life cycle thinking,* or LCT. Ecodesign currently structures design practice according to a problem-focused logic. This creates a bias towards identifying goals and drivers for an ecodesign process solely through an enquiry into the status quo. The argument of this thesis proposed that industrial design practice could not only comply with the traditional notion of ecodesign, but also expand it in two ways:

1. By drawing on the solution-focused element of Design Thinking—through creatively generating representations of solution suggestions, industrial designers can uncover/stimulate opportunities for ecodesign within the context they design for which would not have become apparent through a problem-focused enquiry in the status quo.
2. By not only influencing the technological dimension of the product properties but also their meaning dimension when converting ecological considerations into product designs—this allows the influence of the individual social context within which a product is positioned, in order to aim for a low ecological impact.

This expanded notion of ecodesign was then used to guide and structure an empirical enquiry into case studies of ecodesign, practiced by Australian IDCs and their clients. The empirical data and its discussion revealed seven key insights.

1. The expansions that this thesis suggested to the traditional notion of ecodesign are appropriate. The observed ecodesign practice showed that problem-focused thinking as well as solution-focused thinking could both be applied to identify opportunities for ecodesign. To convert ecological considerations into product designs, both dimensions of the product properties—their meaning and their technological dimensions—were influenced. This allowed going beyond incrementally improving the ecological performance of pre-established product concepts through technical innovations only. It allowed the fulfilment of higher degrees of novelty and also influenced the individual social context of products to achieve ecological benefits.
2. The industrial design practice that was observed in this thesis (which reflected the proposed expansions) was not exclusively conducted by the industrial designers but to some extent also by entrepreneurial clients. This suggests that industrial design practice may, to some extent, be non-specific to industrial designers and can also be executed by other stakeholders in the product development process. Consequently, the expanded notion of ecodesign can also be relevant to the practice of other stakeholders as well as industrial designers.
3. The expanded notion of ecodesign was observed only in cases when IDCs and their clients collaborated on integrating ecological considerations into a product development process and converting these considerations into product designs. This scenario was termed *collaborative approach* in this thesis. It was observed that IDCs could also follow an *activist approach*: practicing ecodesign without informing their clients. This latter scenario appears to be rather common amongst IDCs. The work of other researchers had already identified an activist approach as a possible and frequently encountered phenomenon, but had not analysed its implications.
4. The ecodesign practice that can be expected from an activist approach is constrained. That IDCs hide their endeavours to develop low-impact solutions limits the possible room to manoeuvre when converting ecological considerations into product designs as well as the resources that can be allocated to acquire ecological information. This restrains the possibility to practice LCT. An activist approach also restricts ecodesign interventions that have noticeable consequences for any stakeholder in the product development process. Consequently, only very minimal efforts to influence the

meaning dimension can be expected when converting ecological considerations into product designs, as such changes are noticeable to consumers and also for other stakeholders. Thus, an activist approach does not accommodate the expanded notion of ecodesign. Furthermore, an activist approach conflicts, at least in the short run, with the interest of industrial designers to meet their own financial needs. As an activist approach implies not informing the clients about the ecodesign practice, it also eliminates the possibility of a reimbursement of the industrial designers for this practice.

5. Ecodesign practice in an activist approach remains limited and conflicts with the immediate financial interests of the IDC. If no dialogue with the client about ecodesign is possible an activist approach may be the only way for an IDC to practice ecodesign. In the light of the need to reduce the negative ecological impact of society and the opportunity for the IDC to maintain and/or build up its knowledge and skills in ecodesign an activist approach may in some cases be worthwhile pursuing. However, to overcome the limitations to ecodesign associated to practicing it without the knowledge and support of their clients and to monetise on their investment into building up ecodesign capacity, IDCs have to aim for a collaborative approach. This thesis has identified six factors which need to align for a collaborative approach:
   - Drivers for practicing ecodesign can be identified
   - Client-awareness of the possibility to practice ecodesign
   - Client-openness for ecodesign
   - Client has the necessary resources for engaging the IDC and for realising and commercialising the outcome of the work
   - Client has the ability to communicate with the IDC
   - Client has trust in the capability of the IDC.

   The findings of this thesis show that the drivers for ecodesign and the opportunity to apply LCT are interlinked. In the observed ecodesign practice, LCT was applied only when ecodesign was justified by an expectation that the perceived eco-benefits of the product would be part of the value consumers saw in them. No other driver in the ecodesign practice that was observed for this research successfully triggered LCT. This is important, as LCT is the most powerful way to assure that ecodesign interventions are successful and relevant in addressing the ecological impact associated with a product.

6. The interviewed industrial designers and ecodesign experts suggested that ecodesign could also be justified through cost savings, facilitated by efficiency improvements, laws and standards. While cost-savings may lead to ecological improvements, using them as a driver for ecodesign is unlikely to trigger LCT with a focus on the ecological performance of a product. Furthermore, it is debatable whether design practice that is justified via cost-savings can rightfully be claimed as ecodesign practice: Industrial design practice is *always* motivated to seize cost reduction potential by raising the efficiency. Thus, such design interventions can be expected to happen even without an ecological motivation behind them.
   The investigations for this thesis did not allow for developing a detailed understanding about the interrelation between laws and standards and ecodesign practice. In the observed ecodesign practice, laws and standards did not have a significant impact on triggering ecodesign in the development of consumer products. Nevertheless, while there may be the potential for legislation to trigger ecodesign guided by LCT, industrial design practitioners will be reactive to this. In other words, it transfers the responsibility from them to those drafting accordant legislation. A too-strong hope for changes in legislations and standards brings along a risk. It may lead to industrial designers ignoring and deferring the exploration of how they can utilise the influence of their own practice to justify ecodesign and LCT in a product development process.
7. The two expansions to the traditional notion of ecodesign can, when used in tandem, represent a pathway to uncover and/or stimulate opportunities for products where the perceived eco-benefits form a part of the value consumers see in them. Industrial design practice can creatively generate and test representations of solution suggestions that offer eco-friendly meanings to consumers. These activities were classified as demand-focused ecodesign interventions in this thesis. Drawing on the solution-focused element of Design Thinking allows using representations of product designs where demand-focused ecodesign interventions were applied as a means to explore the response of the problem situation to them. This can uncover opportunities where consumers perceive products with eco-friendly meanings as valuable, thereby providing a justification for LCT. This highlights a link between the influence of industrial design practice on the individual socio-cultural context of products and the potential of industrial design practice to convert ecological considerations into products with a quantifiable low ecological impact.

The set of activities, described in insight 7, is specific to industrial design practice as defined in this thesis. Insight 7 addresses the initial aim of this thesis, which was to identify a possible pathway for how the influence of industrial design practice can be used to integrate ecological considerations into commercial product development processes. However, this does not yet fully answer the overarching research question:

> *Where should industrial designers direct their efforts to improve the integration of ecological considerations in the product development process and to strengthen their capacity to convert them into product designs?*

This is considered in the next section.

10.2. Answering the overarching research question—implications for industrial designers

Insight 7 highlights drawing on the solution-focused element of Design Thinking and applying demand-focused ecodesign interventions as a possible pathway to justify ecodesign and LCT that is specific to industrial design practice. To contribute to reduce the negative ecological impact of society, it is important that industrial designers are aware of this possibility and are able to utilise it. This requires applying the influence of industrial design practice on the meaning dimension for converting ecological considerations into product designs, an area that has not yet been discussed constructively in the context of commercial product development. This is likely to have contributed to an assumption that the most important contribution of industrial design practice in this context is its capacity to influence the technological dimension of the product properties instead of their meaning dimension. This assumption also appeared to be strong amongst the interviewed IDCs and is potentially also present within the wider industrial design community. However, the capacity to influence the meaning dimension is important for ecodesign. This is true not only for demand-focused ecodesign interventions, but also for all other ecodesign interventions that seek to convert ecological considerations into product designs. It is important to consider and potentially influence the meaning dimension as soon as an ecodesign intervention is perceptible for consumers. Thus, the first conclusion of this thesis for industrial designers to strengthen their contribution to ecodesign is:

> *Conclusion 1: Industrial designers need to consciously realise and utilise the potential of their practice to influence the meaning dimension of the product properties for ecodesign. This can allow them to contribute to the emergence and identification of drivers for ecodesign through demand-focused ecodesign interventions. It also allows them to draw on the capacity to influence the meaning dimension of the product properties when converting ecological considerations into product designs with a quantifiably low ecological impact.*

The discussion in Chapter 9 highlighted that the application of demand-focused ecodesign interventions is associated with difficulties for industrial designers. For one, they have to face the challenge of developing proposals for how product interfaces could offer consumers the opportunity to attach eco-friendly product meanings that they perceive as positive. This is not an easy task. Eco-benefits are often abstract for consumers and thus difficult to communicate through the product interface. Furthermore, merely trying for a ‘green look’ is not a promising way forward. Much existing product language that creates a ‘green look’ (like recycled cardboard, bamboo or similar) is also associated with other, negative meanings such as a compromised utilitarian or emotional functionality. None of the investigated exemplary projects communicated their eco-benefits by explicitly quoting existing product language that creates a ‘green look’. The opportunities for consumers to attach an eco-friendly meaning were rather holistically engrained in the user experience. If and how eco-friendly product meanings can be proposed to consumers so they perceive them positively can only be explored case by case. This leads to the second conclusion this thesis draws about how industrial designers can strengthen their contribution to the development of products with a lower ecological impact.

> *Conclusion 2: Industrial designers need to direct explicit effort towards understanding how ecological benefits of a product can be translated into the product interface. Because contemporary product languages that communicate ecological benefits often also trigger other, negative product meanings industrial designers should prioritise developing new product languages that trigger eco-friendly product meanings. For this purpose they need to draw on the solution-focused element of Design Thinking. They have to develop their own interpretations of product languages that offer consumers the opportunity to attach eco-friendly meanings to a product. They then need to create representations of these interpretations, suggest them to the problem situation they design for and listen to the ‘back-talk’. Only then can they understand a.) which product languages successfully trigger eco-friendly product meanings and b.) if these are seen as valuable in the context they design for.*

Besides the challenge of interpreting how eco-benefits can be communicated through the product interface, the application of solution-focused thinking and demand-focused ecodesign interventions is also associated with uncertainty. Because it is an explorative process, its outcome is not fully foreseeable. Nevertheless, industrial designers need to convince their clients to support them in these endeavours. In this regard, professional industrial design—particularly in Australia— already starts on a weak footing. It is generally problematic for the profession to communicate the value of its capacity to draw on the solution-focused element of Design Thinking and to deliver strategic input for product development processes. Thus, they tend to fall back on structuring the design process in a problem-focused way. This limits the possibility of drawing on the learning from the representations of the solution suggestions to inform the product requirements. Furthermore, the empirical data collected for this research showed that it was easier for industrial designers to convince their clients of a potential return from investing in influencing the technological dimension of the product properties than doing the same for influencing the meaning dimension. This was mainly because the consequences of influencing the technological dimension are quantifiable and measurable. However, the capacity to develop and explore opportunities for new meanings is an important prerequisite for demand-focused ecodesign interventions. These findings lead to the third conclusion.

> *Conclusion 3: Industrial designers should strengthen their capacity in convincing their clients to engage them for their capacity to draw on the solution-focused element of Design Thinking and for their ability to develop and explore new product meanings. They also should highlight that this capacity can specifically be used for demand-focused ecodesign interventions.*

This thesis proposes that industrial designers can only play an active role in expanding their contribution to the reduction of the negative ecological impact of society if these three recommendations are followed in tandem.

10.2.1. Clarification of the limitations and potentials of the conclusions

Even though the recommendations that are expressed in the conclusions above can allow industrial designers to play a more active role in expanding their contribution to the reduction of the negative ecological impact of society they should not be understood as a panacea and be followed blindly. Thus, their potential and limitations are clarified below.

The conclusions were not drawn in an idealist belief that industrial designers can, once they follow the recommendations they express, make big improvements on their own. They still depend on the agreement of their clients to practice demand-focused ecodesign interventions. Also, whether the demand-focused ecodesign interventions of industrial designers are successful depends on the ecological sensitivity within society and how the industrial designers interpret it. Still, it is the industrial designer's responsibility to communicate and utilise their capacity to exert positive influence on consumer demand for eco-friendly products. If they fail to meet this responsibility clients—in particular those with a limited understanding of the potential influence of industrial design—have little opportunity to commission industrial designers to take a strategic role for ecodesign. Similarly, if industrial designers fail to represent solutions that offer eco-friendly product meanings, no response to them—positive or negative—can be expected.

The argument in thesis does not propose that the recommendations expressed in the conclusions are easy to incorporate by industrial designers, nor does it assert that it necessarily makes sense to follow the recommendations regardless of the consequences. For example, industrial designers may very well have clients that cannot be convinced to invest in drawing on the solution-focused element of Design Thinking to identify goals and drivers for the product development process. These clients may have such a strong preference for using other sources of information that efforts to change their mind would jeopardise the relationship between the industrial designer and the client. As the operational tasks that these clients commission industrial designers to perform still generate income for the latter, it would not be wise to pursue the recommendations expressed in this thesis at all cost, risking the loss of these clients. Nevertheless, any novel suggestions are first likely to be met with resistance. Thus, some careful testing of the recommendations expressed in the conclusions of this thesis may still be advisable.

The conclusions of this thesis should not be misunderstood in a way that demand-focused ecodesign interventions are the only or best pathway towards integrating ecological considerations and LCT into product development processes. Other drivers such as laws and standards may also be successful in that regards. However the application of demand-focused ecodesign interventions is a way to stimulate ecodesign over which industrial designers have direct influence.

The opportunities for value generation that can potentially be uncovered and/or stimulated through the application of solution-focused thinking and demand-focused ecodesign interventions should not be over-estimated. Awareness within society about ecological issues has increased over the past. This is positively related to the possibility to uncover and/or stimulate opportunities for products which allow consumers to attach eco-friendly meanings to them that they perceive as valuable. However, the perceived ecological performance of a product can only be one element of the value consumers see in products. Thus, uncovering and/or stimulating opportunities for eco-friendly product meanings consumers perceive as valuable will always happen in tandem with and compete with uncovering and/or stimulating opportunities for *other* new product meanings consumers also perceive as valuable.

Finally, demand-focused ecodesign interventions represent a pathway that can only justify the integration of ecological considerations in a product development process and the application of LCT when converting these considerations into product designs. They alone do not result in ecologically improved products. For one, the industrial designers, together with other professionals such as engineering designers and marketing, still need to develop the product. Furthermore, the product needs to be manufactured, distributed and commercialised. In other words, all the relevant stakeholders along this value chain need to collaborate in achieving an ecologically superior product.

10.3. Implications for further research

The argument in this thesis has demonstrated that the traditional notion of ecodesign does not appropriately reflect the current or potential incorporation of ecological considerations into industrial design practice. To provide a more accurate description of the influence of industrial design practice to integrate ecological considerations into commercial product development processes, this thesis has developed and tested a framework, showing an expanded notion of ecodesign. This framework more accurately describes the application of the ecodesign idea in industrial design practice than other concepts that are currently available. Thus, it can provide a useful guidance for future researchers who study eco-innovation and need to account for the role of industrial design practice.

The framework developed in this thesis to describe the expanded notion of ecodesign also contributes to the debate about how high degrees of novelty can be achieved in commercial eco-innovation. Most past approaches had a strong focus on structuring the product development process following a problem-focused logic. This linear logic has difficulties with explaining how product development can overcome a lock-in on incremental, technological improvements of existing product designs. The framework developed in this thesis proposes that following a more solution-focused logic and using representations of product designs during their development as a means to explore the problem context can be a pathway to address this lock-in. This highlights the need of future research into eco-innovation to allocate more prominence to the role of representations of solution suggestions and the solution-focused element of Design Thinking.

10.3.1. Directions for further research

This research project has improved the understanding about how industrial design practice can contribute to the reduction of the negative ecological impact of society. It developed recommendations where professional industrial designers should direct their efforts to unlock this potential. Also, the insights reported in this thesis also point to areas of further research, in particular including the ones described below.

Pathways need to be developed to strengthen the capacity of industrial designers to (i) gain strategic influence on the product development process and to (ii) explicitly use their capacity to influence the meaning dimension of the product properties. While the role of the self-representation of the industrial designers in this regard has been discussed in this thesis, other aspects have not been investigated in detail. For example, how industrial designers can gain more self-confidence in advertising solution-focused thinking and selling the value of their capacity to influence meanings as non-quantifiable product qualities are important questions to address. Industry associations, university education, ongoing professional education and professional networks may play a role in this.

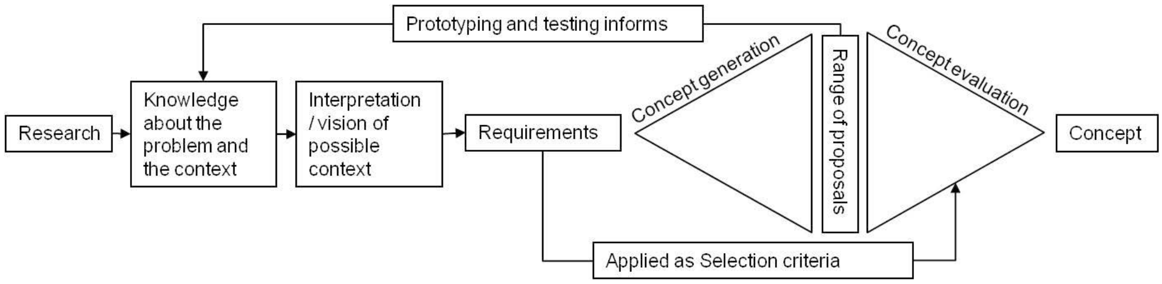
Industry associations, university education, ongoing professional education and professional networks can also play an important role for disseminating new ideas in the industrial design community. The conclusions, drawn in this thesis, call for a new consciousness amongst professional industrial designers about the influence of their practice. The conclusions also propose that industrial designers need to communicate this consciousness to their clients. It is unlikely that merely documenting these conclusions and recommendations in publications like this thesis will have significant impact. These ideas need to be integrated into the self-understanding of the industrial design community about the influence and role of their practice. Thus, it is important to investigate how the self-understanding of industrial designers develops and how it can be informed.

The argument in this has highlighted the importance of identifying products that are perceived positively as eco-friendly solutions by consumers—products to which consumers attach eco-friendly meanings. It also illustrated the role of industrial design practice in facilitating opportunities for consumers to construct accordant meanings. However, the actual emergence of meanings, the sense-making process by consumers has not been covered in the empirical investigation for this thesis. It did not capture the perspective of consumers. This is an important area of further research. Thereby, not only the sense-making process needs to be investigated, but also what impacts these new meanings again have on the social context from which they arise. This research area has already received attention from the social sciences, focusing on already existing products. However, as proposed in this thesis, a more promising approach would be to explore the emergence of eco-friendly meanings by research through design. In other words, the argument of this thesis proposes that representations of solutions that offer eco-friendly meanings to consumers should be developed and tested with consumers. A close observation and analysis of this process can then deliver valuable insights into how eco-friendly product meanings emerge. For example, this could happen in pilot projects at universities, companies or institutes.

Demand-focused ecodesign interventions bring along the risk of the rebound effect. An increased overall consumption may outweigh ecological impact improvements, achieved for the individual products. A limitation of the research, conducted for this thesis was that it focused only on individual products. It was not designed to capture the impact of the eco-friendly product meanings on larger production and consumption dynamics. However, it did indicate that eco-friendly product meanings, once present, may become an ongoing justification for companies within a market to invest into LCT when developing new products. Whether the ecological benefits that can be facilitated by such an ongoing innovation can outweigh a potential increase in impact through rising consumption, may vary between markets. Further research is needed to understand long-term dynamics of markets where products that trigger eco-friendly meanings are introduced.

Appendix 1: Diagram, conceptualising an iterative way of structuring design practice

This diagram was used to discuss with the industrial designers how far they saw their practice as exploring and determining the problem situation they work on.



Appendix 2: Full procedure of the website content analysis

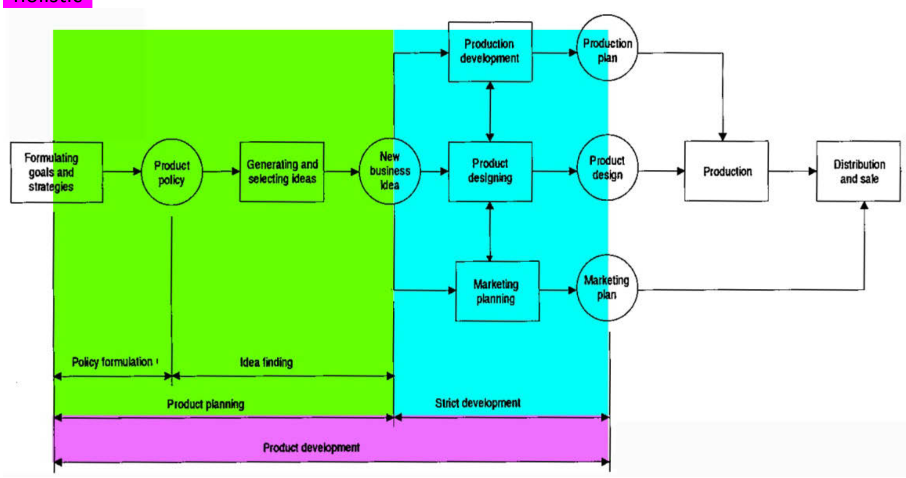
Note: the website content analysis was conducted at a very early stage of this research. This has two implications:

1. At this time the focus of the research had not been clearly formulated yet. Consequently more data was collected than ultimately used for this thesis. It was for example intended to focus on the impact of legislation that specifically seeks to improve the design of electronic and electric products such as the WEEE on the work of industrial design consultancies.
2. The theory that guided the content analysis was still strongly influenced by the traditional notion of ecodesign.

Procedure of the website content analysis

- Use the online databases Core77 (www.core77.com), ICSID (http://www.icsid.org/members/members.htm).
- Only use data **available through the online databases or the websites**.
- Only use websites of **companies that focus on design services**. No manufacturers, no shops, no Universities, no 100% Communication design agencies, no 100% interaction design consultancies etc. If a consultancy offers partially product design and partially either communication design or interaction design, include it in the review, but **exclude the communication design or interaction design** from the portfolio review.

<table>
<tr><td>Name</td><td>Name of the consultancy</td></tr>
<tr><td>Membership</td><td>If the Industrial design consultancy is member in a environmental cautious organisation such as the Designers Accord, (http://www.designersaccord.org/) insert name of the organisation here.</td></tr>
<tr><td>Accreditation</td><td>If the Industrial design consultancy is iso 9000 or iso 14000 accredited (or complies to other environmental norms), insert information here.</td></tr>
<tr><td>Awards</td><td>Indicate if visible (e.g. red dot, IF, national awards etc.): Y
if not visible: not visible</td></tr>
<tr><td>Offered services</td><td>Copy list of services if available (just headlines). This helps to assure the role of the industrial design consultancy is allocated right.</td></tr>
<tr><td>Role</td><td>Allocate the services that are offered on the consultancy’s website along the model after Roozenburgh and Eekels (1995) below. Thereby title consultancies only offering services in the product planning phase as “strategic”, consultancies only offering services in the strict development phase as “operational”. If a consultancy offers services in both phases, title it as “holistic”



e.g. a consultancy offers: Project Specification; Invention Management & Research; Market and user research; Concept Development; Design & Documentation; Prototype Production; Prototype Validation; Final Design Documentation; Manufacturing Management
-> these services can be allocated as follows:
Project Specification; Invention Management & Research; Market and user research (if it aims at</td></tr>
</table>

	new markets) Concept Development (if it is a new product concept); = services used in the product planning phase Market and user research (if it aims at understanding the current market of the client) Concept Development (if it is just a "styling" concept); Design & Documentation; Prototype Production; Prototype Validation; Final Design Documentation; Manufacturing Management = services used in the strict development phase The consultancy offers services for both product development phases. It is titled as holistic.	
Team size	Enter team size if visible, if not visible: not visible	
Founded	Enter founding year, if visible, if not visible: not visible	
Environmentally aware	If any indication for environmental awareness is visible (including product examples), indicate Y	
Separate section on Website	Does the consultancy devote a separate section to environmental issues? Y / N	
Ecodesign support	If information is provided about the ecodesign support used, copy information from the website here (e.g. "we use the Greenfly tool to conduct our Life cycle assessments")	
General statements	Copy remarkable statements about environmental awareness from the website (e.g. "Our consultancy integrates environmental considerations in everything we do (…) We teach ecodesign at university XY"	
Supporting arguments	Copy supporting arguments for ecodesign from the website (e.g. "Our expertise in ecodesign **helps you to fully embrace the ongoing trend of sustainability**" or "ecodesign solutions **help to save material by optimising production techniques**")	
Announced Ecodesign strategies	Look for indications for the eight ecodesign strategies listed below. The substrategies (also listed below) help identifying them. Only list them if the intention of a reduced environmental impact is expressed (e.g. "to improve the recyclability of our products, we reduce the number of parts in our designs") not if just the result of a design appears to comply with a ecodesign strategy (e.g.: " to save costs we reduce the number of parts in our designs")	
	Ecodesign Strategy	Substrategy
	@* New concept development	Dematerialisation, shared use of product, integration of functions, functional optimisation of product components
	1 Selection of low-impact materials	Cleaner materials, renewable materials, lower energy content materials, recycled materials, recyclable materials
	2 Reduction of materials usage	Reduction in weight, reduction in transport volume
	3 Optimisation of production techniques	Alternative production techniques, fewer production steps, lower/cleaner energy consumption during production, less production waste, fewer/cleaner production consumables
	4 Optimisation of distribution system	Less/cleaner/reusable packaging, energy-efficient transport mode, energy-efficient logistics
	5 Reduction of impact during use	Lower energy consumption during use, cleaner energy source, fewer consumables needed, cleaner consumables, no waste of energy/consumables
	6 Optimisation of initial lifetime	Reliability and durability, easier maintenance and repair, modular product structure, classic design, strong product-user relation
	7 Optimisation of end-of-life system	Reuse of product, remanufacturing/refurbishing, recycling of materials, safer incineration
Other	In case there are any other ways to reduce the environmental impact, copy information from the website here	
Portfolio size	Count the number of products in the portfolio	
Electronic products	Count the number of electronic products in the portfolio; Electronic products as defined in the WEEE: Large household appliances Small household appliances Information and telecommunications Consumer equipment Lighting Tools Toys, Leisure, Sports Medical equipment Monitoring instruments	

	Dispensers
Ecodesign Products	Count the number of products that are advertised as having a reduced environmental impact
Specify examples	Copy environmental relevant product information from the website, Highlight the name of the product in Bold to separate examples. (e.g. **Product X:** is created from 100% post-consumer recycled content, derived almost entirely from recycled milk containers. **Product XX:** is made from 70% recycled content)
Applied ecodesign strategies	Look for indications for the eight ecodesign strategies listed above. The sub-strategies (also listed above) help identifying them. Only list them if the intention of a reduced environmental impact is expressed (e.g. "to improve the recyclability of our this product, we reduced the number of parts") not if just the result of a design appears to comply with a ecodesign strategy (e.g.: "to save costs we reduced the number of parts")
URL	Enter the URL of the website
Email	Contact email (preferably collected from the company website and not from the database such as Core77)
Phone	Enter Phone number
City	Enter the city where the consultancy is located
Address	Enter the postal Address
Access Date	Enter Access Date
Database	Enter Database

Appendix 3: Background information and interview questions, provided to the research participants

INFORMATION LETTER ECODESIGN EXPERTS

About this interview
Thank you for participating in this interview. It is part of the data collection for my PhD at the Institute for Sustainable Futures (UTS) which I intent to finish by the end of 2012.

Background to my research
With my PhD I hope to find answers to the overarching research question: "Where should industrial design (ID) consultancies direct their efforts to facilitate (more) ecodesign uptake in the development of consumer products they conduct in collaboration with their clients?" Of particular interest for this research is the extent to which ID consultancies can utilise their skills in creatively deriving solutions from a user perspective for developing ecodesign concepts. In my PhD, I seek to identify barriers for ecodesign, specific to the ID consulting process. In this process, not only the ecodesign proficiency of the ID consultancy is crucial, also the interplay of the ID consultancy and the client company plays a pivotal role. My research aims at developing a better understanding for the cause and effect of potential barriers and of the success of attempts to overcome them.

Purpose of this interview
This interview seeks to capture your perspective as expert in ecodesign on the potential of ID consultancies for ecodesign and the role of Australian ID consulting in that context. I furthermore would like to discuss which Australian ID consultancies have conducted projects, you can recommend as interesting ecodesign case studies.

INTERVIEW GUIDELINE ECODESIGN EXPERTS

The form of the interview will be semi-structured. Therefore, the questions below are to be seen as a guideline for the conversation rather than a check list.

Please describe your perspective on the role ID consulting can play for ecodesign

- What do you see as the main drivers for ecodesign uptake by ID consultancies?
- What would you state as the most important contribution of ID for ecodesign uptake?
- How does that differ from other disciplines, in particular engineering and marketing?
- To what extend and where can the work of ID consultancies have a transformative effect?
- How far can ID consultancies utilise their insights in the consumer perspective and their creative potential to become ecodesign innovators?

Please outline where you see the main bottlenecks for ecodesign, practiced by ID consultancies

- What knowledge and understanding do ID consultancies need to practice ecodesign well?
- Do they have (or are they capable to acquire) the necessary knowledge and understanding?
- Are industrial design consultancies aware of their ecodesign potential?
- What influence does the interaction between the client company and the ID consultancy have on the ecodesign activities?

- How can ID consultancies positively influence this interaction, facilitating more ecodesign uptake?
- What role do transformative effects of ecodesign projects in the client company play?

Please describe your perspective on the Australian situation

- How well informed are Australian ID consultancies about ecodesign?
- What do you see as main enablers of ecodesign projects in Australia?
- What are barriers for ecodesign uptake by Australian ID consultancies?
- How would you describe the development of ecodesign in Australia up to today and where do you see it heading in the future?

Selection criteria for ecodesign case studies

I am looking for projects, conducted by Australian ID consultancies you would classify as exemplary in ecodesign. I am in particular interested in cases where the ecodesign interventions were directed at the consumer's behaviour and did not only aim at increasing the eco efficiency of a conventional solution.

INFORMATION LETTER IDCS

About this research

My name is Johannes Behrisch. I am undertaking my PhD at the Institute for Sustainable Futures at the University of Technology, Sydney (UTS). I am supervised by Dr. Mariano Ramierez (UNSW) Dr. Damien Giurco (UTS) and Dr. Timothy Prior (UTS).

My PhD investigates the role which industrial design consultancies play for ecodesign uptake in the development of consumer products. The overarching research question, I seek to answer is: Where should industrial design consultancies direct their efforts to be in a position to enhance ecodesign uptake in the projects they conduct in collaboration with their clients? My research focuses not only on capturing the actual ecodesign activities of industrial design consultancies but also aims at developing a better understanding of the role of the dialogue between industrial design consultancies and their clients during the ecodesign process. The research will identify barriers for ecodesign, specific to the industrial design consulting process and investigate the success of attempts to overcome them. It will deepen the understanding of the interplay of the ecodesign activities of the industrial design consultancy and transformative processes in the client company. The outcome of this research will not only help industrial design consultancies and their clients to collaborate more successfully on ecodesign projects but also allow industrial design consultancies to extend their business towards more ecodesign services and to better understand the impact of ecodesign activities on their clients.

Incentive for participating in this research

As an incentive for participation I offer you to share the outcomes from this research with your company. This research will provide you deep insights in the perspective of the client company on the ecodesign projects. It will capture client internal consequences of ecodesign activities and their influence on the ecodesign process. The research will also provide insight about more long-term transformative effects for the client companies, arising from ecodesign projects. The theoretical part of this research has developed a detailed model of the implication of ecodesign in the collaboration between an industrial design consultancy and a client. Testing and refining this theoretical model with the help of investigating ecodesign projects, will allow identifying critical areas, where efforts can be directed to extend your ecodesign activities.

Participating in this research

For my research project, I will investigate a number of ecodesign projects in detail. Your company has been selected because of your experience in conducting ecodesign projects for your clients. The collaboration of your company in this research would require providing information about one to two ecodesign projects. Per project, this will involve:

1. An interview with the senior designer (about 60 min), who was managing in the ecodesign project
2. Possibly a follow up interview after the interview with a representative from a client company (about 20 min)
3. **Optional, only if compatible with confidentiality:** providing access to project documentation material
4. Providing a contact at the client company

PLEASE NOTE THAT: You are under no obligation to participate in this research. You can withdraw your participation from this research at any time without having to provide any reason.

Risks, involved in participating in this research

This research has been carefully designed to keep any potential risk for the participants to a minimum. Responses in the interviews will NOT be linked to the name of the interviewee (they will be labelled as Respondent 1, 2 etc). However, when responding to the interview questions, please ensure your answers do not cause a conflict of interest or breach any confidentiality with respect to your company, colleagues or clients. If providing project documentation material, please make sure that all confidential information such as detailed financial information (e.g. pricing of the design services of your consultancy) are removed or blacked out. No results of the research will be published without prior consent of the participants.

Concerns about this research

If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact us on

Johannes Behrisch I Level 11 I UTS Building 10 I 235 Jones Street I Ultimo NSW 2007 I t + 61 2 9514 4950 I Johannes.Behrisch@uts.edu.au.

Dr. Damien Giurco I Level 11 I UTS Building 10 I 235 Jones Street I Ultimo NSW 2007 I
t + 61 2 9514 4978 I Damien.Giurco@uts.edu.au

If you would like to talk to someone who is not connected with the research, you may contact the Research Ethics Officer on 02 9514 9772, and quote this number *(UTS HREC REF NO. 2010-253A)*

INTERVIEW GUIDELINE IDCS

Thank you for participating in this research. The interview will be structured in two sections. In the first section (about 15 minutes), I would like to learn about the general stance of your consultancy on ecodesign. In the second section, (about 45 minutes) I would like to talk more specifically about the development process of a consumer product where ecodesign was practiced by your consultancy. Please select a project that you would put forward as representative for your experience with ecodesign. The form of the interview will be semi-structured. Therefore, the questions below are to be seen as a guideline for the conversation rather than a check list.

Section 1: General questions (about 15 minutes)

- How does your company engage in ecodesign?

- What drives the ecodesign activities of your company?
- What are the main difficulties, your company faces with ecodesign?

Section 2: Project specific questions (about 45 minutes)
Please give me a chronological overview of the product development process. I am in particular interested in the following areas:

- Which were the drivers for this project on the side of the client and your consultancy?
- Please describe the design process and the implication of ecological considerations.
- Please describe the research, you conducted for this project.
- What was the influence of the consumer perspective on the ecodesign activities?
- Please describe the communication between your consultancy and your client.
- Please describe the outcome and consequences of this project for:
    - Your consultancy
    - Your client company
    - The consumer of the product

INFORMATION LETTER CLIENTS

About this research
My name is Johannes Behrisch. I am undertaking my PhD at the Institute for Sustainable Futures at the University of Technology, Sydney (UTS). I am supervised by Dr. Mariano Ramierez (UNSW) and Dr. Damien Giurco (UTS).

My PhD investigates the role which industrial design consultancies play for ecodesign uptake in the development of consumer products. The overarching research question, I seek to answer is: Where should industrial design consultancies direct their efforts to be in a position to enhance ecodesign uptake in the projects they conduct in collaboration with their clients? My research focuses not only on capturing the actual ecodesign activities of industrial design consultancies but also aims at developing a better understanding of the role of the dialogue between industrial design consultancies and their clients during the ecodesign process. The research will identify barriers for ecodesign, specific to the industrial design consulting process and investigate the success of attempts to overcome them. It will deepen the understanding of the interplay of the ecodesign activities of the industrial design consultancy and transformative processes in the client company. The outcome of this research will not only help industrial design consultancies and their clients to collaborate more successfully on ecodesign projects but also allow industrial design consultancies to extend their business towards more ecodesign services and to better understand the impact of ecodesign activities on their clients.

Participating in this research
You have been contacted because of your participation in the project product development process of the Product#X. For my research, I am investigating this project as a case study in detail. Designer#X from IDC#X has kindly provided me with your contact details. Your contribution to my research project would involve participating in a 45 minute interview, providing information about your perspective on the project.

PLEASE NOTE THAT: You are under no obligation to participate in this research. You can withdraw your participation from this research at any time without having to provide any reason.

Risks, involved in participating in this research
This research has been carefully designed to keep any potential risk for the participants to a minimum. Your responses in the interview will NOT be linked to your name (they will be labelled as Respondent 1, 2 etc). However, when responding to the interview questions, please

ensure your answers do not cause a conflict of interest or breach any confidentiality with respect to your company, colleagues or clients. No results of the research will be published without prior consent of the participants.

Concerns about this research
If you have concerns about the research that you think I or my supervisor can help you with, please feel free to contact us on

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If you would like to talk to someone who is not connected with the research, you may contact the Research Ethics Officer on 02 9514 9772, and quote this number *(UTS HREC REF NO. 2010-253A)*

INTERVIEW GUIDELINE CLIENTS

Thank you for participating in this research. The interview will be structured in two sections. In the first section (about 5 minutes), I would like to learn more about the general stance of your company on ecodesign. In the second section, (about 40 minutes) I would like to talk more specifically about your collaboration with the IDC and the dialogue between the IDC and your company during the product development process. The form of the interview will be semi-structured. Therefore, the questions below are to be seen as a guideline for the conversation rather than a check list.

Section 1, General questions
- How important is ecodesign to your company?
- What do you see as main stimuli for ecodesign for your company?

Section 2, Questions about the product development process
Please give me a chronological overview from your perspective of the development process of the exemplary product. I am in particular interested in the following areas:
- How did you identify and formulate the objectives for the product?
- How did you develop an understanding for the preferences of your customer group?
- Which environmental objectives did you focus on?
- How did you identify the IDC as the right partner for this project?
- Who was involved in formulating the product concept?
- Please describe the role, the IDC played in the product development process, in particular in regards to the implementation of ecodesign.
- How far did the product development process provide feedback to/alter the initial objectives?
- Please describe the communication between your company and the IDC.
- How were the generated concepts assessed?
- Please describe the main compromises that were necessary in regards to the ecological performance of the product.
- Will the environmental benefits be used as a selling argument / communicated to:
    - The consumer?
    - Retailers?

Appendix 4: Overview of the conducted interviews

Due to confidentiality reasons this table has been removed from the published thesis document.

Appendix 5: Presentation of the preliminary findings

This presentation was given to the representatives of the IDCs. These findings also covered data collected from consultancies that did not have a focus on industrial design and data about non-consumer products.

Due to confidentiality reasons this presentation has been removed from the published thesis document.

Appendix 6: Example of a mind map of the interview findings

The (at that stage), the preliminary codes with their descriptive topics were written into individual boxes that were connected with lines, illustrating causal relationships. Also, reflections by the researcher about the causal relationships were included in these maps. To distinguish these reflections from the codes and their descriptive topics, they were highlighted in grey.

Due to confidentiality reasons this map has been removed from the published thesis document.

Appendix 7: List of papers published in the course of this research

In the course of this research five papers were published. Three conference paper and one journal paper covered the results of the website content analysis:

> Behrisch, J., Ramirez, M. & Giurco, D. 2010a, 'Application of ecodesign strategies amongst Australian industrial design consultancies', *Sustainability in design: NOW! Challenges and Opportunities for Design Research, Education and Practice in the XXI Century*, Greenleaf Publishing, Sheffield, pp. 1377-87.
>
> Behrisch, J., Ramirez, M. & Giurco, D. 2010b, 'The use of ecodesign strategies and tools: state of the art in industrial design praxis', *Knowledge Collaboration & Learning for Sustainable Innovation: 14th European Roundtable on Sustainable Consumption and Production (ERSCP) Conference and the 6th Environmental Management for Sustainable Universities (EMSU)*, Delft University of Technology, Delft; The Hague University of Applied Sciences, The Hague; TNO, Delft, pp. 1-22.
>
> Behrisch, J., Ramirez, M. & Giurco, D. 2011a, 'Representation of ecodesign practice: international comparison of industrial design consultancies', *Sustainability*, vol. 3, no. 10, pp. 1778-91.
>
> Behrisch, J.C., Ramirez, M. & Giurco, D. 2011b, 'Ecodesign in industrial design consultancies–comparing Australia, China, Germany and the USA', *18th International Conference on Engineering Design (ICED11)*, The Design Society, Somerset, United Kingdom, pp. 1-11.

One conference paper discussed a preliminary version of the framework, describing the expanded notion of ecodesign:

> Behrisch, J.C., Ramirez, M. & Giurco, D. 2012, 'The role of industrial design consultancies in diffusing the concept of ecodesign', *DRS2012 Bangkok*, Department of Industrial Design, Faculty of Architecture, Chulalongkorn University, Bangkok, pp. 90-101.

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