The exploration of a sustainable design method targeting the conceptual and creative design stage

Karl Martin Kjærheim

Faculty of Industrial Engineering
University of Iceland
2013

The exploration of a sustainable design method targeting the conceptual and creative design stage

Karl Martin Kjærheim

60 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Environment and Natural Resources

Advisors
Rúnar Unnþórsson
Brynhildur Davíðsdóttir

Faculty of Industrial Engineering
School of Engineering and Natural Sciences
University of Iceland
Reykjavik, February 2013

The exploration of a sustainable design method targeting the conceptual and creative design stage.
60 ECTS thesis submitted in partial fulfillment of a *Magister Scientiarum* degree in Environment and Natural Resources

Faculty of Industrial Engineering
School of Engineering and Natural Sciences
University of Iceland
Hjarðarhagi 6
107, Reykjavik
Iceland

Telephone: 525 4000

Bibliographic information:
Karl Martin Kjærheim, 2013, *The exploration of a sustainable design method targeting the conceptual and creative design stage*, Master's thesis, Faculty of Industrial Engineering, University of Iceland, pp. 92.

Printing: Háskólaprent
Reykjavik, Iceland, February 2013

Abstract

The purpose of this thesis is driven by the notion of giving designers a tool to be creative with sustainable design practices. After conducting a thorough literature review it was evident that the conceptual design phase holds the most influence on decisions defining the final product, and that no tool currently exists targeting this phase, a sustainable design model was created and the content of a conceptual design tool targeting sustainable intervention proposed. Environmental problems related to the apparel industry, design processes and creativity were explored, in order to provide suitable answers to the inherent problems. A questionnaire was utilized to understand the designer's perception (visual analogue scale), needs and wanted features (open text) within a future tool targeting their conceptual design process. Further, a sustainable design model was created to be able to fully understand where in the conceptual design process sustainable strategies would be best implemented. Results from the questionnaire showed that most of the designers were positive towards the inclusion of further sustainable practices, but felt the need for more incentives and recognition, more educated help and further guidance from management. The results from the sustainable design model indicated when and where designers should include sustainable practices within their conceptual process, and therefore acted as a blueprint towards the future implementation and success. The results from both the questionnaire and the sustainable design model aided the birth of a proposed solution to the inherent problems that exist within developing a computer-based platform in which collaboration, creativity and sustainable practices may thrive.

Útdráttur

Markmið þessa verkefnis er að skapa verkfæri fyrir hönnuði til að vinna skapandi vinnu með sjálfbærni að leiðarljósi. Þar sem fyrri rannsóknir hafa sýnt að ákvarðanir sem snúa að lokaútgáfu vöru koma fram strax í upphafi þróunar hennar, og að ekkert verkfæri er til taks sem beinist sérstaklega að þessum hluta þróunarferilsins, var líkan til að beina vöruþróun á sjálfbæra braut þróað. Umhverfisvandamál af völdum fataiðnaðar og hönnunarferlar voru skoðaðir til að veita viðeigandi lausnir við þessum vandamálum. Spurningalisti var notaður til að öðlast skilning á upplifun og þörfum hönnuða á slíku verkfæri sem notast gæti á upphafsstigum hönnunarferilsins. Ennfremur var sjálfbært hönnunarlíkan þróað til að skilja fyllilega hvar í upphafsstigum þróunarferils slíkar áherslur væru auðveldast innleiddar. Niðurstöður frá spurningalistum sýna að meirihluti hönnuða var jákvæður þegar kom að innleiðingu sjálfbærni í hönnunarferli þeirra, en fannst þó að frekari hvata, viðurkenningu og menntun vantaði ásamt frumkvæði frá stjórnunarstigum. Niðurstöður frá sjálfbæra hönnunarlíkaninu benda á hvenær og hvar hönnuðir ættu að innleiða sjálfbærni í þróunarferlinu. Líkanið gagnast því sem leiðarvísir að innleiðingu slíkra aðferða. Afsprengi niðurstaða frá spurningarlistanum annarsvegar og líkaninu hinsvegar er lausn á því vandamáli sem er til staðar þegar hönnunarforrit eru þróuð þar sem samvinna, sköpun og sjálfbær þróun starfa saman.

This thesis is dedicated to my beautiful fiancée

Preface

Being a seven year old boy, suddenly not being able to join the typical soccer match during recess because of the fear of dirtying up my newly bought shoes, I understood from an early age that I had a passion for shoes and its design aspects. After an initial disappointment from my mom, believing I wanted to become a shoe salesman, she saw me travel to Australia to commence an undergraduate in product design. It was there, with the help of a truly engaged teacher, the sustainable design bug bit me. From Australia, the road took me to Iceland to pursue studies in the natural sciences, as I saw the two separate fields as highly interlinked and important for our mutual sustainable future. Having finished my compulsory units, my inner child told me to follow my childhood dreams, and to apply for an internship within the apparel design sector. Unexpectedly I found myself moving across Europe and being part of an interdisciplinary resource team at a sports apparel company. Being truly inspired by the designer's creativity, I wanted to let designers explore their creative side with sustainability, believing that from this, the end product would be bound to be more environmentally friendly. It was from this notion; the following thesis idea came to life; to create a tool designers can utilize within their conceptual design phase, which prosper sustainable design practices.

Table of Contents

List of Figures

List of Tables

Glossary

BU	-	Business Unit
C2C	-	Cradle-to-Cradle
CAD	-	Computer Aided Design
DfE	-	Design for Environment
FOB	-	Freight On Board
LCA	-	Life Cycle Analysis
PDPs	-	Product Development Processes

Acknowledgements

It gives me great pleasure in acknowledging the support and help of my advisors Dr. Rúnar Unnþórsson and Dr. Brynhildur Davíðsdóttir, for their steady contribution, pointers and valuable feedback. I would further express my deepest gratitude to my faculty supervisor, Dr. Brynhildur Davíðsdóttir, for her motivation and encouragement in applying for an internship within an apparel company, which allowed this thesis to come about. I would also like to express my deepest thanks to my managers at the apparel company I had a chance to intern for, Simone Cesano and Rebecca Silver, who both contributed with valuable insight into design processes and practices. To my colleague Nils Brosch for his impeccable desire to discuss the following topic, give me further insight and raise questions. To Rúna Vigdís Guðmarsdóttir, for helping me out with the Erasmus grant, thank you for all your friendly and consistent support. To my family who has supported me throughout everything the last couple of years, both financially and emotionally, know that I would not have been able to do this without you. Further special thanks must be direct to my mom, Kristina Kjærheim, for her critique, support and help with the final product. Finally, I must give my greatest thanks to my better half, my fiancée, for her support, patience and love.

1 Introduction

"In an age of mass production when everything must be planned and designed, design has become the most powerful tool with which man shapes his tools and environments".

Victor Papanek (Papanek, 1984).

1.1.1 Motivation

Since the beginning of humanity, man has created tools to conquer his surroundings in order to survive. The industrial revolution in the 1750s, and the mass production in the 18^{th} hundreds, truly intensified our production, and with it, the strain on our environment. The classic economic thought on development, brought forth by Adam Smith, David Ricardo and others, was to increase productivity by specialization and less labor intense work, which basically meant maximizing output per unit input (Smith, 1976). Today, the human population has reached over seven billion (UNFPA, 2011) and environmental strains such as degradation of land due to heavy extraction of raw materials continue to pose environmental risks, as contaminated water, air and soil, wastes and deforestation are all side effects to our development model (Bodkin & Keller, 2010). Our very own economic market system is dependent on our continued and increased consumption. We desire more, buy more, pollute more and waste more (Meadows et al., 1992; EPA, 2009). With this reality in mind, Brundtland et al., (1987) coined the term sustainable development, which aims for human wellbeing and health throughout the triple bottom line, both now and for future generations (Crofton, 2000). This means that all three pillars (economical, environmental and social) (Lumsden, 2003, p. 3) should be considered, and not only economic gain based on heavy extraction and increased production.

1.1.2 Background

Within the last decades, production companies have undergone large attitude changes towards environmental issues, much as a response to global competition, the fulfillment of government regulations, international standardizations, good publicity and increasing demand from consumers (Melnyk et al., 2001; Unger & Eppinger, 2011). With the change of attitudes, comes also a change in the methodology, production models, product development processes (PDPs), design processes and tools which manufacturing corporations utilize. Within the design industry, by taking Papanek´s quote above into consideration; it is evident that designers sit on huge possibilities to both better themselves, and their industry towards environmental improvements. However, little research has been conducted in regards to designers and their environmental initiatives, incentives or opportunities (Melnyk et al., 2001). Take the definition of sustainable development as an example. Gladwin, Kennelly and Krause (1995, p. 878), define sustainable development as "a process of achieving human development in an inclusive, connected, equitable, prudent, and secure manner" and the study conducted by Starik and Rands (1995), states that sustainable development is defined as the "ability of one or more entities, either individually or collectively, to exist and flourish”. As general guidelines and definitions of sustainable development, both of these definitions would be sufficient, however, to apply them in a practical manner, to a design activity would prove to be more difficult. The difficulty to link environmental theory to actual design activity has to be viewed from both angles, as the designer’s beliefs and understanding of environmental issues also have proven to be difficult to map (Melnyk et al., 2001, p. 2-3). Further supporting Papanek´s quote (in the beginning of this chapter) is a study by Hakkio and Laaksonen (1998) as they studied the relationship among designers, manufacturers and retailers, and concluded that designers actually have more responsibility towards material selection and the creation of products than manufacturers and retailers. Other research studies point out that more than 80% of the environmental impact of products is decided upon within the product design phase (Subic et al., 2009, p. 68). This is further emphasized below in Figure 1.1 by Rebitzer et al., (2004), which state that the early phase (concept creation) of the design/development stage proves crucial to deal with damaging environmental factors later in the products life cycle of the products.

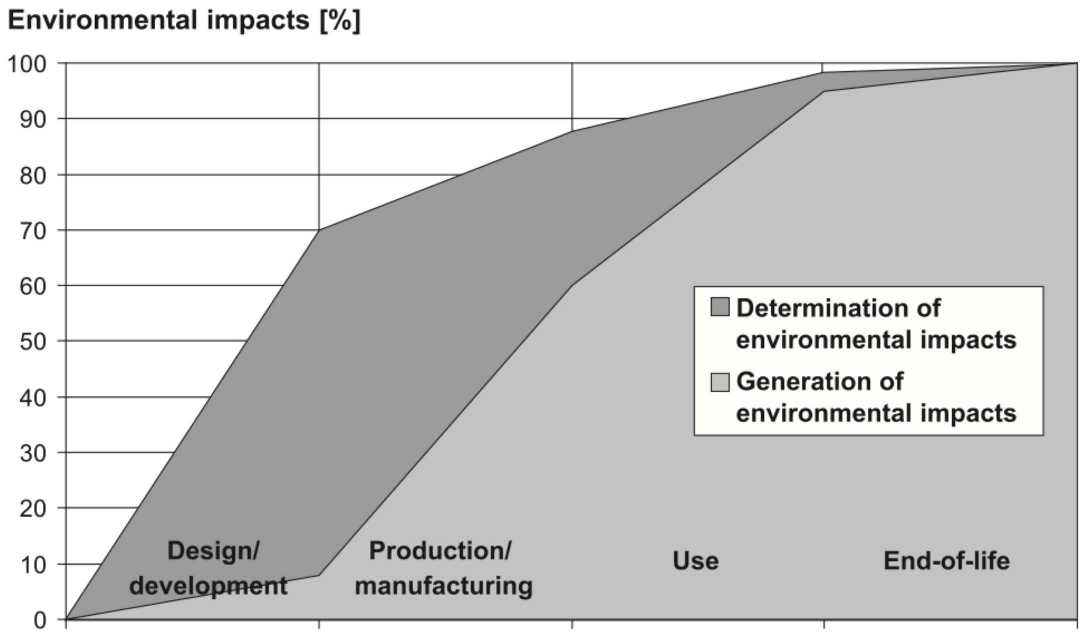

Figure 1.1 Generalized representation of the (pre)determination and the generation of environmental impacts in a product's life cycle (Rebitzer et al., 2004, p. 702).

1.1.3 Obstacles

Most private corporations do not account for their social and ecological impact. This leads designers to “assume” that their area of responsibility is limited to function and appearance (Mackenzie, 1997). Nathan Shedorff states that; “designers and developers, who are in a position to make evaluated choices based on a deeper understanding need to employ their help at every possible step of the design process” (Shedroff, 2011). However, this lack of understanding towards environmental models or processes is also evident in the apparel design field. Gam et al., (2009) found that “existing apparel design and production models help designers focus on aesthetics, function, and economics, but not environmental impacts” and conclude that “no apparel design and production model puts the designer’s role in environmental sustainability into consideration”. This shows that little or no attention has been paid to apparel designers who hold an important key in reducing the environmental impacts of their respective companies. Two main problems arise when one includes the environment within known practical design and production processes.

First, the two terms *sustainable* and *environmental* is fairly vague or general, and are therefore hard to comprehend for designers without any prior knowledge of the field (Hacco & Shu, 2002, p. 2). Thus, the words sustainable and environmental most likely mean different things to different people, and as design teams are often highly interdisciplinary in design background, nationality and practices, it is hard to find common ground of the two concepts (Melnyk et al., 2001, p. 24-25). Sustainable development within design is referred to as sustainable design, which basically refers to lower social costs towards pollution control and higher levels of environmental protection through the use of more efficient consumption of resources, emissions and waste. With the following sentence, Subic et al., (2009), comprise the famous quote in the Brundtland report, with what they define as sustainable design, "Sustainable design addresses not only the functional and aesthetic requirements of products, but more importantly, aims to meet the needs of the present, without compromising the ability for future generations to meet their needs" (Subic et al., 2009, p. 68). These concepts regarding sustainable design are hard to understand and act upon without any prior education.

Secondly, by dealing with the initial design stage, namely the conceptual design phase, specifications and environmental criteria, one enters the creative field, the designers mind (Warr & O'Neill, 2005; Austin et al., 2001). Wang et al., (2002) identifies the design concept as ´soft´ in nature and it "is often difficult to capture, visualize or communicate" and then continue by acknowledging that "great opportunity exists at the preliminary design stage". Bowman (1996) and Fiskel (1993; 1996), bluntly state that the most appropriate place for considering environmental issues are in the design phase, as the generated concept affects the whole life cycle of the product concerned. In the following stages it becomes extremely difficult, almost impossible to correct any shortcomings of a poorly executed design concept (Hsu & Liu, 2000; Pahl & Beitz, 1996). Having stated the importance the conceptual stage could have on environmental concerns, one must not forget the difficulty it would be to alter this process to something generalized and practical, as *creativity* is highly individual and not something that is either general or easy to assess. Dorst and Cross (2001) states that "creativity in the design process is often characterized by the occurrence of a significant event - the so-called *creative leap*", referring to the 'ah-ha' moment when suddenly all falls into place. Taylor et al., (1958) argues, "that the larger the number of ideas produced, the greater the probability of achieving an effective solution", and therefore, the more creative we are when designing, the probability of good design increases. If one considers these notions of creativity, one can see that through education and repetitive encouragement in the creative phase, environmental practices can and should be incorporated within the conceptual design process. Previous literature within the textile and apparel industry offers a wide array of apparel and manufacturing models (LaBat & Sokolowski, 1999; May-Plumlee & Little, 1998; Regan et al., 1998; Workman et al., 1999). However, as LaBat & Sokolowski (1999) and Gam et al., (2009) highlights, these models focus on functionality, aesthetics and economic gain, leaving out models related to the designers' role towards sustainability. Goan (1996) summarizes it by stating that "product designers should take responsibility in developing and producing products with more environmentally friendly functions and production methods in order to reduce harmful environmental impacts and to improve environmental compatibility". The problem then, is that designers (often) do not have prior environmental education, as their previous education existed of design studies. It is therefore often the managers responsibility to deal and hand out environmental specifications related to the designs, to often confused and frustrated designers who see environmental specifications as further strain on their own time and freedom (Melnyk et al., 2001). What all these studies illustrate is the lack of, and therefore the need for an understanding of how to successfully employ a sustainable mindset in regards to environmental practices within a design process/activity, targeting the initial creative concept phase.

1.2 Research question

As stated above, there are two main problems within the design community when one introduces environmental aspects. First, the vague definition of sustainable design, and thereof confusion when both tried implemented and understood. Secondly, the need to utilize the conceptual design phase to its fullest potential, which is the core of this thesis.

Within the following background chapters, numerous environmental issues in apparel design, various design processes and the possible impact of creativity on environmental problems are identified and discussed. Whilst briefly summarizing what has been identified as the main issues, the lack of existence of environmental consideration is highly noticeable and thus pertains to the need and motivation to deal with the identified problems. First, it was identified that the vast amount of direct environmental hazards present is directly correlated to the designer's choices within the initial design stage, namely the concept phase. This is further evident as research revealed that more than 80% of the environmental impacts of products are decided upon within the early product design phase (Subic et al., 2009, p. 68). Studies also point out that the process of revisiting and amending incorrect decisions within the conceptual phase proves difficult as funds already has been spent, the pressure to innovate within the design field is high and deadlines are to be upheld to satisfy both stakeholders and consumers alike. A methodology to encounter environmental hazards within the initial concept phase proves absolutely crucial as it will hinder unwanted environmental threats, and in turn, reduce the inherent damaging environmental impacts from the product production or the product life cycle. Second, most design driven tools focus on the latter stages of the design process, and not on the conceptual design stage. This is mainly due to the "soft" nature and highly individual creative process that occurs within all people, and to try and tame it has proved difficult. It must be taken into account that a design tool that focuses on the environment within the creative stage will have strong influences on the future impacts of the product-to-be-created, and these early decisions must be taken with a strong understanding of how it will affect its surroundings and context. Thirdly, research state that no conceptual design tools incorporate environmental concerns (Gam et al., 2009). However, it has been identified that creative concepts are brought forth through a list of requirements, including sustainability within these requirements would force designers to rethink and include the environment as a factor in their design process. Other research also demonstrates that Internet based CAD (computer aided design) software proves to facilitate the necessary requirements to solve many of the problems a designer encounter within the conceptual design phase in terms of sustainability and collaborative creativity (Hsu & Liu, 2000; Wang et al., 2002). Connecting the conceptual design phase with environmental requirements and educational guiding and providing a portal where collaborative creativity may prosper has therefore been identified as the most suitable option. This thesis sets out to answer the following six research questions, and to suggest a proposed a solution to the problems identified:

Questionnaire

1. How do apparel designers perceive sustainability?
2. How do designers usually conduct research and how would they rate the importance of their research methods?
3. What is the most restricting factor for sustainable design in their daily design practice and how is new technologies (such as new tools) get integrated with the design process?
4. How would designers embrace an environmental design tool targeting their conceptual design phase?
5. What kind of existing design features would designers have integrated into (Internet) CAD software to further their understanding and improve their skill towards better sustainable practices?

Sustainable design model

6. How can a conceptual environmental design process look like within the apparel industry?

To be able to answer these questions, a hands-on approach was utilized towards the creation and completion of a questionnaire. Twenty apparel designers were thoroughly questioned, to be able to understand their perceived needs towards environmental sustainability. From this, a sustainable design process model was created to be able to understand how a future tool would fit existing design processes. With the provided answers towards the questionnaire and the exploratory sustainable design process, the author was able to propose detailed information towards crucial content within a conceptual sustainable design tool. Even though the apparel industry has been selected as a focus within this thesis, it must be noticed that much of the contents of this thesis would apply to other areas of design. The apparel design industry were chosen as test subject due to the authors own inclusion within an apparel company for six months, and therefore the participants of the questionnaire were apparel designers. Second, the apparel design industry struggle with many environmental hazards (as is discussed within the background chapter), so it was further easy to explain the necessary implementation of the proposed solution.

Last, to not confuse the reader, the words sustainable and environmental are utilized interchangeably throughout this thesis even if they can be defined differently, as this practice is common within the design industry (which may be the root of the confusion for designers). As a result, whenever the word sustainability or sustainable design is used within this thesis, the focus is on environmental sustainability. Still, the author has tried to utilize the word sustainability, to keep a consistent thread throughout.

1.3 Contribution

Based on the need of creating a conceptual design process imbedded with sustainable practices, a PDP model which stresses the importance of sustainable issues and the incorporation of creativity within the conceptual phase was created. From this model, a solution to a practical design activity incorporating an Internet based CAD software was proposed. The explored model and the proposed design tool will both fill a gap in the academic literature and in practice as no conceptual design tool currently embraces the notion of collaborative creativity with the inclusion of a sustainable mindset. Furthermore, the designers' attitudes towards such a tool will be highlighted through the results of a questionnaire study of a sample group of 20 designers; this will also go in conjunction with other research, which attempts to map the needs of designers towards the utilization of CAD tools and their perception of sustainable design. In effect, the desired outcome would see the blueprint of such a tool being developed; a tool that fully engages itself with the processes within the conceptual design phase, aiding to the fundamentally important notion of improving the environment by resulting in sustainable aware designs.

1.4 Thesis structure

This thesis has been divided up utilizing the IMRAD method, which is the abbreviation of Introduction, Methods, Results and Discussion, which is a common structural method for scientific papers (Sollaci & Pereira, 2004). However, the author has here taken the liberty to slightly modify it, as a background section has been included between the introduction and the methods section. This is done to give the reader a better understanding of why the present work has been conducted and to highlight further decisions taken within the methods section, in particular towards the final proposition. A reader knowledgeable about design processes, environmental hazards towards the apparel industry and creativity in general, can however skip the background section, and still make sense of the entire thesis as the major discoveries have been identified and discussed briefly within the 1.1 Research Question section above. The methods section has been further divided up into three segments according to the research questions and the proposed solution. These segments consist of a *questionnaire*, a *sustainable design model* and the *proposed solution*. These sections have been divided to keep the reader informed of the authors thought process, and to follow a linear timeline in which they occurred. Meaning that without a questionnaire, the creation of a sustainable design model would be difficult, and without both a questionnaire and a sustainable design model, it would not have been possible to propose a solution to the inherent problems within the results section and within the final proposed solution. The results are then presented and discussed. Suggestions for further work are compiled within the discussion chapter, as well as a brief summary within the conclusion chapter.

2 Background

To fully understand the subject at hand, three main background topics will be highlighted further to let the reader understand the underlying importance on the following subject. The first topic covers the apparel industry and its effect on nature. This is highlighted to identify the vast environmental problems that occur from product creation, and the thereof proposed necessity for designers to redefine their conceptual design stage. Second, design processes are covered to get a glimpse into the various design processes that exist, in order to understand how one would fit environmental concerns within the processes. Here, also a brief summary of design tools/guidelines that are often utilized incorporating environmental issues will be assessed as a step to understand the pitfalls and the previous successes of various integration methods, and how satisfactory they are for the individual designers. Last, the creative process is discussed, as creativity within the conceptual design phase is crucial to understand for the purpose of implementing an environmental strategy to this stage. Creative support tools are further discussed to understand what would be needed in a future tool, embodying notions of creative surplus. It must be mentioned that much of the research on creativity that exist range back some decades, but as most new research all refer to older books or journals, it is evident that the field has not dramatically changed (Shneiderman, 2007, p. 25). These three chapters have been selected, as they are all crucial to one another, and for the entirety of this thesis.

2.1 Environmental issues related to the apparel industry

There is no denying it, as with any production industry, the apparel industry is a major contributor to various environmental problems ranging from textile material manufacture to apparel production to the saturation of landfills with synthetic hazardous fabrics (Gam et al., 2009). This contribution to environmental issues is mainly due to the utilization of output from other industries such as the agricultural, tanning and dyeing industry. A report from the Blacksmith Institute (2011) place the agricultural sector as number three on their list of most toxic polluting industries, the tanning industry as number five and the dying industry at number thirteen. They further estimate that 2,245,000 people are at risk from pesticide pollution through the agricultural sector and that 1,848,000 people within the tanning industry face risks due to chromium pollution. Within the apparel industry, falls the sub-category called; sporting goods, which comprise of sports apparel, sports footwear and sports equipment (Subic et al., 2009, p. 67). As sports products require rapid innovation and are brought to the market swiftly to satisfy hungry consumers, it has resulted “in a shorter life cycle of sports products and increased disposal rates and waste” (Subic et al., 2009, p.67).

2.1.1 Cotton vs. polyester

Two fibers dominate the world market, cotton, which is natural and polyester, which is synthetic. Demand for polyester has doubled during the last 15 years, and taken the throne from cotton as the single most popular textile (Simpson, 2006). Synthetic fibers are usually deemed as the worse of the two, however the reality is not that evident. Take the production of cotton; due to the attack by various insects species, large quantities of pesticides, fertilizers, and defoliants are used on cotton fields, causing serious environmental damage and making it the single largest insecticide consumer worldwide (Marquardt, 2001; Matthews & Tunstall, 1994). Throughout cotton manufacturing, by utilizing (on average) 160 pounds of water per 1 pound of textile product, and a various arrays of chemical-intensive processes such as chemical baths in preparation, dyeing, finishing, slashing, to name a few (EPA, 1996, p.16), our cotton example is transformed into an apparel garment. Further, to improve the cotton properties, the apparel industry "commonly performs wet processing such as de-sizing, scouring, bleaching, and mercerizing" (Gam et al., 2009). Wet processing requires a significant amount of water, which then creates wastewater full of toxic chemicals (Ren, 2000, p. 474). Color, salt, acids, biocides, phenols, phosphates toxic anions, and heavy metals in various textile processes all cause environmental degradation (EPA, 2000; Hendrickx, 1995; Kadolph & Langford, 2002, p. 337). These industrial processes are not only applied to cotton, name almost any material, and one can be sure the garment has gone through a long and environmentally degenerating process. Looking at the environmental hazards cotton contribute to, one might add that, cotton, being a natural product, has a larger ecological water footprint than fabrics made of polyester (Chapagain et al., 2006; Mekonnen & Hoekstra, 2011; Cherrett, 2005). Polyester is defined as a "petroleum-based by-product" (Zeander, 2009), where the "manufacturing process involves high energy inputs which, unless sourced from renewable resources generate large amounts of particulates, CO2, nitrogen oxides, hydrocarbons, sulfur oxides and carbon monoxide subsequently released as atmospheric emission" (Cherrett, 2005, p.8). But again, one has to be careful to classify, as cotton, organic cotton and polyester all would differ related to their ecological footprint in terms of their location, energy usage, type of pesticide, or climate (Our Common Future, Chapter 7: Energy: Choices for Environment and Development, 2007). It is further difficult to measure, as one have to be concise with the stage in the life cycle of the product one measure. Do you measure the cultivation process, or the whole lifecycle, which amounts to the final garment?

What we then want to know is; which of the two are actually more environmentally friendly? What should we choose? By developing a set of questions, Baugh (2008), compared the production of cotton fiber (both conventionally and organically grown) to virgin polyester and recycled polyester fiber production. She was then able to determine that by utilizing recycled polyester fibers involved more sustainable practices than any cotton fiber production. Table 2.1 displays her main reasons why:

Table 2.1 Cotton vs. Recycled polyester

Cotton Summary	Recycled Polyester Fiber Summary
Water and energy use are high, and the useable fiber is one-third of the total harvest volume.	Low water use. Energy use is high, though one-third less than virgin fiber. Very little waste in fiber production.
Synthetic chemicals used continue to pose significant water, soil, and air pollution threats.	Chemicals used for recycled polyester fiber production are recycled back to produce more fiber.
Recycled cotton fiber is lower quality than the original fiber.	Recycled polyester fiber is the same quality as the original fiber.

2.1.2 Organic cotton

Organic cotton would still be a more environmentally friendly option than conventional cotton cultivation. Available research indicates that if one would shift from cotton to organic cotton, one would significantly reduce the life cycle toxicity of the cotton products (Allwood et al., 2006). For cotton to be considered organic, no synthetic commercial pesticides or fertilizers can be used, no antibiotics or hormones for livestock and no genetic modifications and organic feed at the farm for three years of production (Wilson & Mowbray, 2008). Other than only being able to certify their products for marketing and namesake, organic farmers actively make positive impact through their careful practices as it supports surrounding ecosystems, improves biodiversity and quality of soil, and leads to less water use during production (Walsh & Brown, 1995; Altieri, 1995, p. 181; Lampkin, 1998, p.4). Organic farming is further deemed economically viable, as it is a low input cultivation process, which means that less money is invested in expensive chemicals and fertilizers. And the decline in initial production is balanced against these reduced costs. Organic farming, due to the less likely result of land degradation, result in the reduction of long-term production costs. Finally, the public demand for organic produce has markedly increased over recent years (Shiva, 2005).

2.1.3 Viable options to cotton and polyester

Designers should perhaps draw from the environmental success of the organic farmer, and be creative with other viable options such as for example by switching polyester with Poly lactic acid, which is a biopolymer derived from 100% renewable resource, presently corn (Gupta, 2007). Bamboo is also highlighted as a textile fiber that could become highly sought after by the sports industry, due to its softness, thermal and moisture properties (Xu et al., 2007). To take it to the extreme, scientists have managed to produce soya protein fibers, which can be extracted from milk or beans. Being biodegradable, with flame resistant moisture management and non-electrostatic properties, soy protein fibers deliver unique and appealing features for use in the sports apparel industry (Lodha & Netravali, 2005). Developments in materials for sportswear have led to new specialized performance properties, such as “good thermal properties for cold-weather sport, aerodynamic properties for hi-speed sports, breathable waterproofing for outdoor sports, strength and durability” (Subic et al., 2009, p.75). Innovation seems to focus more on functionality, (aesthetics and economic gain), as was stated by LaBat & Sokolowski (1999) and Gam et al., (2009) in the introduction, rather than environmental efforts.

2.1.4 Existing problems

One environmental problem within the apparel industry remains to be briefly discussed. The continued utilization of plastic inks made from PVC (polyvinyl chloride), pose environmental threats to the environment. It is recognized by Greenpeace as one of the most environmentally hazardous substances ever produced (2003), but due to the low cost and versatility (Kamila, 2003), it is still utilized. Besides the clear water pollution (counting how products are produced), air pollution also threatens the environment, mainly through combustion flues and dust, fibers, and vapors from the production processes (Müzzinoğlu, 1998). Besides the obvious ecological damage, Müzzinoğlu (1998, p.342) also state “the presence of suspended particulates in the air in cotton textile production workplaces puts forward a serious challenge for the health of the workers”.

2.2 Design processes, methodology and the integration of environmental issues

People often think about design as purely aesthetics, but behind each design lies a well defined thought process. This *thought process* is refereed to as the design process, which will now be explained in detail. The design process is an activity that begins with specific requirements and ends with the product description (final design), as is shown below in Figure 2.1. In the design process, the first step is to determine the requirements to then be able to formulate the design specifications (Otto, 1996). The design requirements is categorized into two groups; structural and performance constraints. Structural requirements refer to restrictions to the basic shapes, dimensions and materials, where performance requirements are issues related to safety, functionality and manufacture. It is the design specifications that define the product description, which allow the designers to generate design concepts from the pre-set design specifications (Zeng & Gu, 1999).

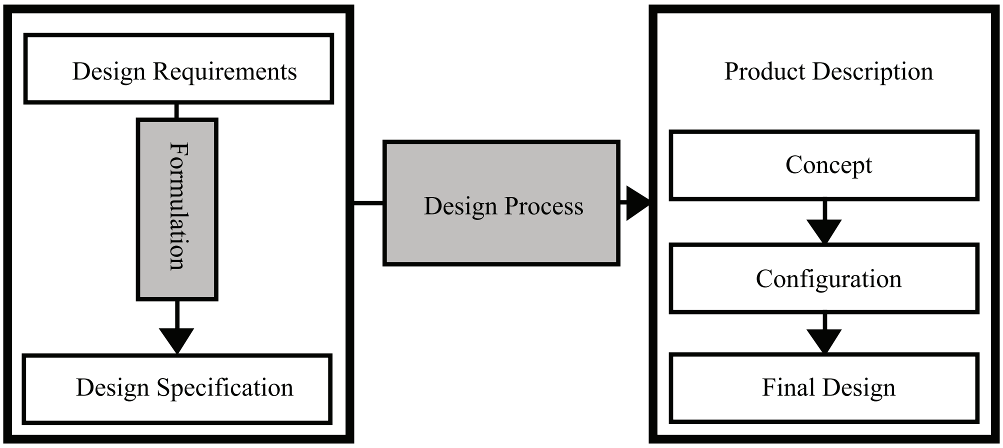

Figure 2.1 The design activity as explained by Zeng and Gu (1999).

2.2.1 The product design process

A product design process can be divided into three different stages, namely the conceptual stage, the configuration stage and the detailed design stage (Gu, 1998). The conceptual design stage is defined as a "series of orderly, organized and targeted design activities from analyzing needs of users to generate conceptual products, and expressing a continuously evolving process from crude to refined, from fuzzy to clear and from abstract to concrete" (Deng el al., 2002), all within the set parameters from the design specification. Configuration design refines the design concepts to concrete products as key parameters are defined (Zeng & Gu, 1999). The last stage, detailed (final) design, determines all the detailed restrictions and design specifications, often described by technical drawings or geometric models (Gu, 1998). What the different stages of the design activity, shown in Figure 2.2, have in common is that they all share some basic features of problem solving. Within the different stages, you would find two subclasses, linked to problem solving, namely the synthesis and evaluation (Figure 2.2). Basically, these two subclasses within each stage, is various sets of debates/discussions among designers, managers and/or marketing, determining in what direction the design task/project should go, which define the final outcome (the product description) (Zeng & Gu, 1999).

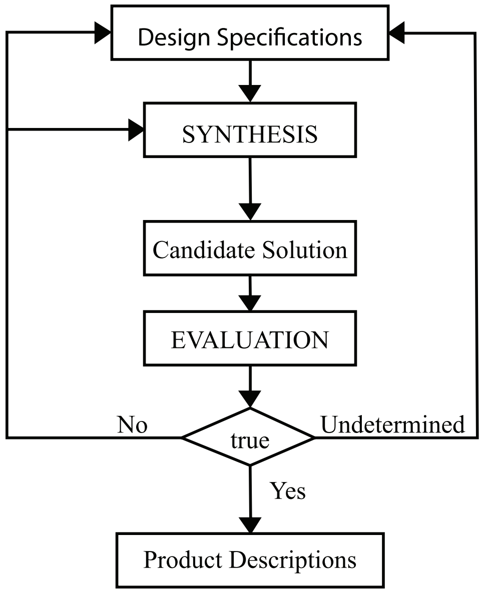

Figure 2.2 The basic design process by Jones (2002).

2.2.2 The engineering design process

The engineering design process can be viewed as similar to that of the product design process explained above, except the engineering design process weights more on the initial research phase, as is stated by Eide et al., (2002). This process is here divided up into a nine-step process, as is seen in Figure 2.3, which includes defining the problem, conducting research, narrowing the research, analyzing set criteria, finding alternative solutions, analyzing possible solutions, making a decision, presenting the product, and communicating and selling the product. Do note that not all engineering processes are similar to the one in Figure 2.3, however, they all display similar characteristics (Eide et al., 2002). Haik and Shahin (2010), also state that even though the engineering design processes are usually described dissimilar within research, they still resemble each other by the main steps, including requirements, product concept, solution concept, embodiment design and detailed design. What is further evident is that the engineering design process has evolved over time (Haik & Shahin, 2010), which is apparent in the three following engineering design processes shown in Figure 2.4 published by Johnson (1980), Figure 2.5 by Dym (1994) and in Figure 2.6 published by Pahl and Beitz (1996).

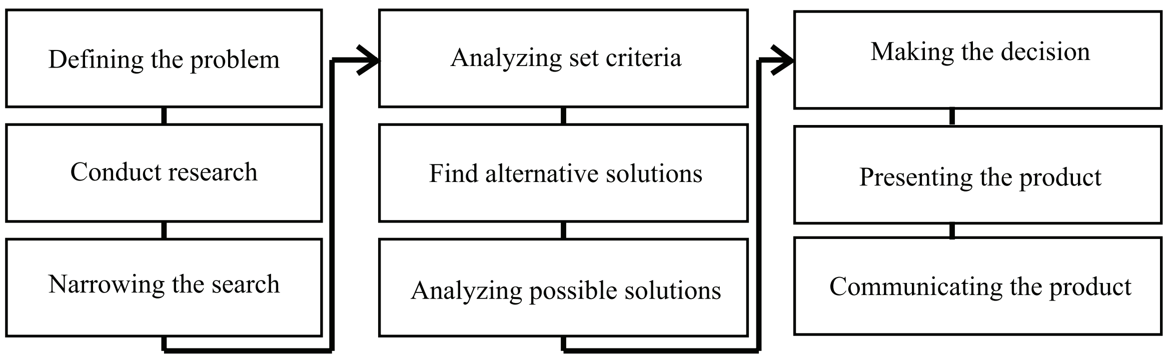

Figure 2.3 The engineering design process by Eide et al., (2002).

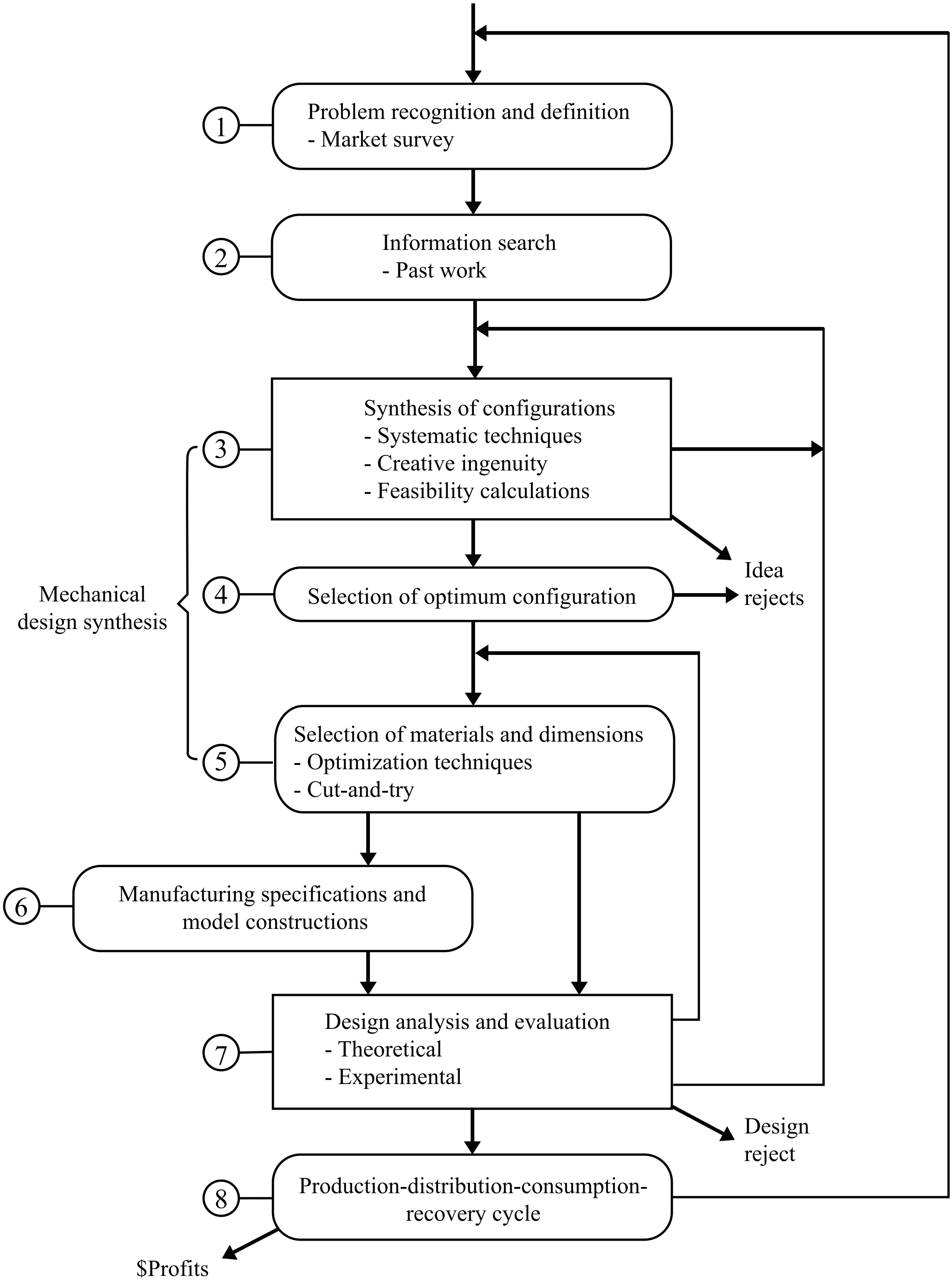

Figure 2.4 The design process map by Johnson (1980).

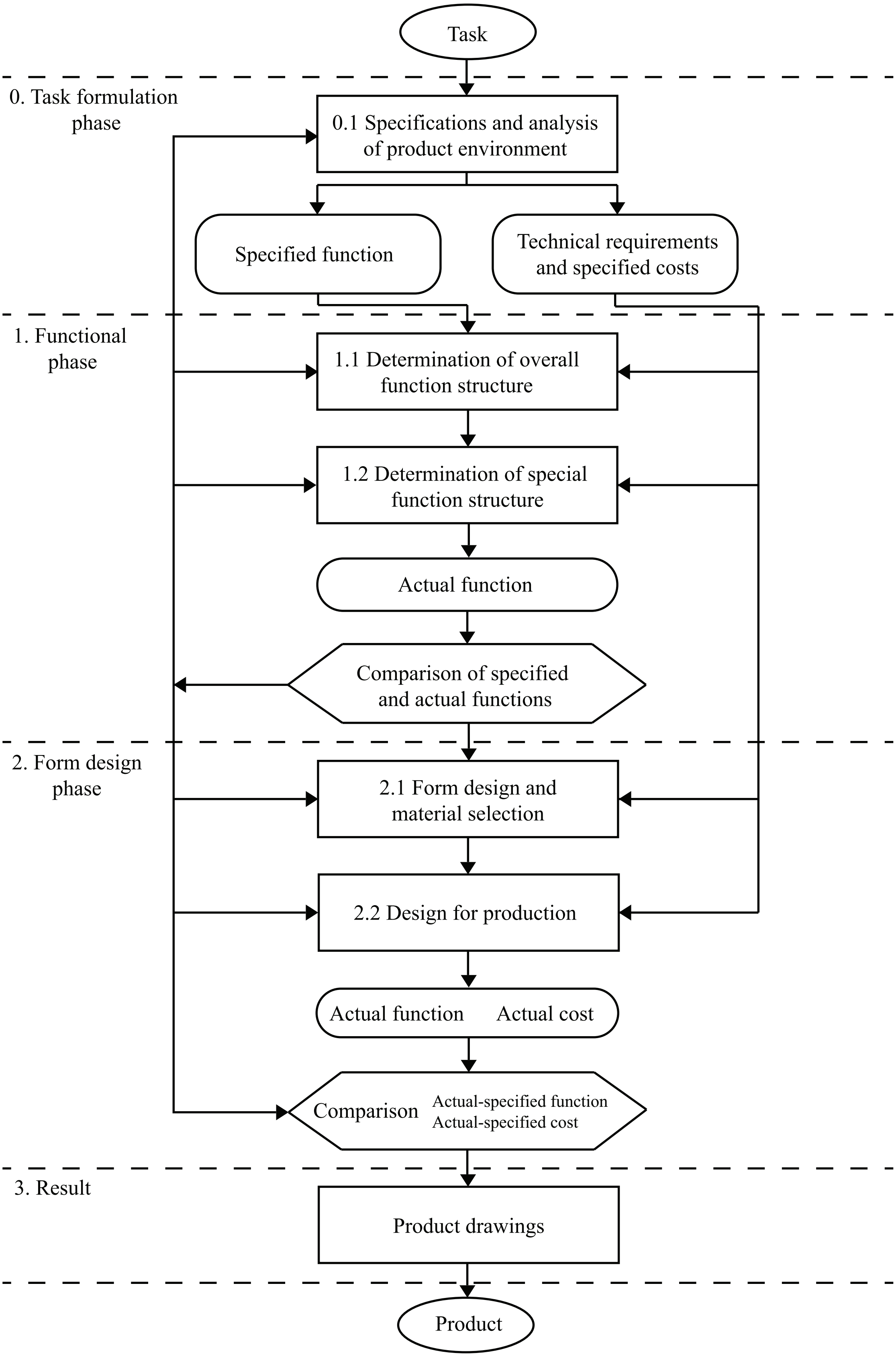

Figure 2.5 The design process map by Dym (1994).

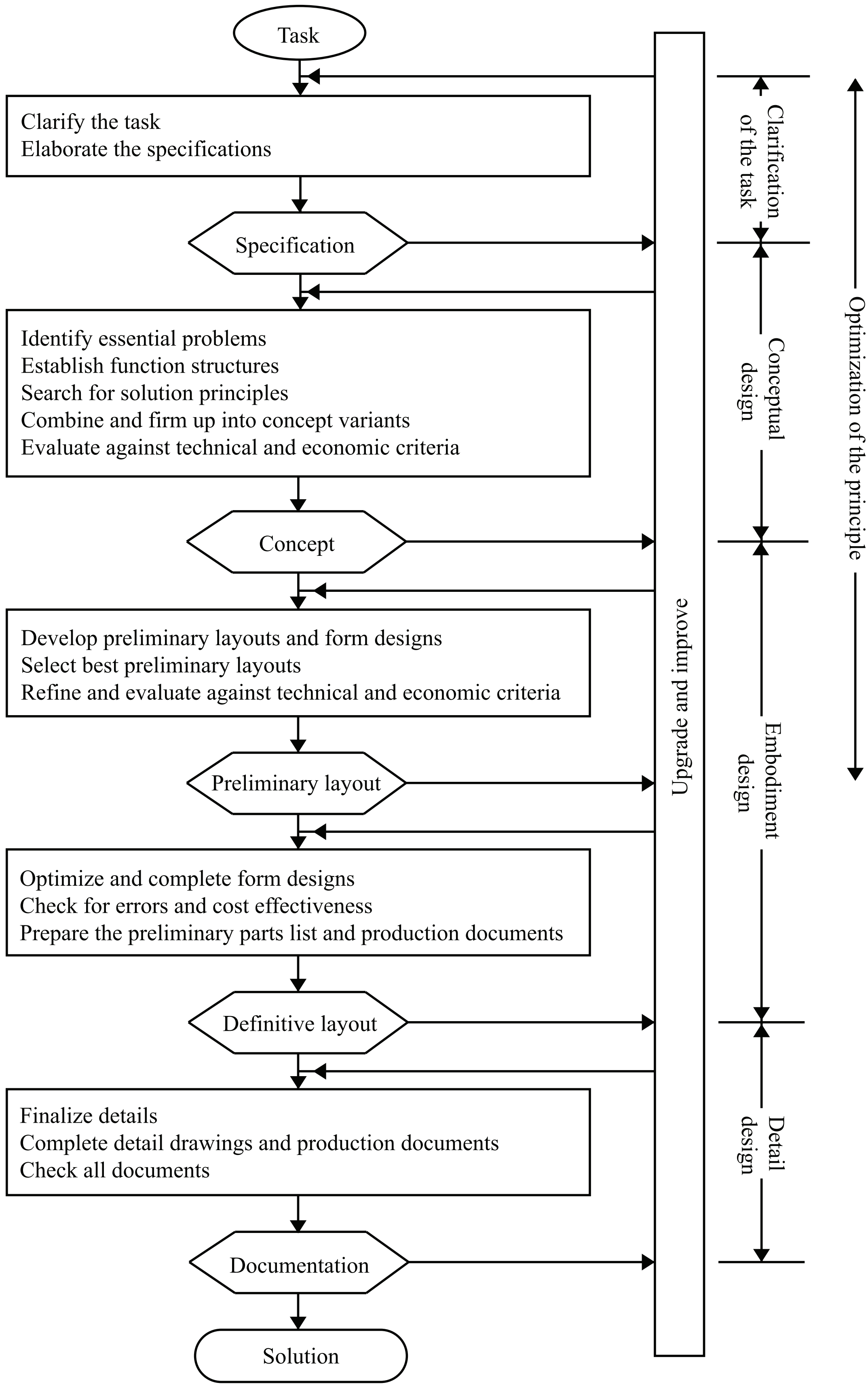

Figure 2.6 The design process by Pahl and Beitz (1996).

The most evident change is of course the structural hierarchy and sequence names, but they convey the same information as the stages are either just explained in more detail, or combined to explain less. However, as is stated by Haik and Shahin (2010), the "timeline of these charts hints towards a trend to further formalizing the design process and leaning more towards addressing the problem and postpone the solution to the latter stages rather than finding a solution early" in the design process. This, they state, is specifically evident between Figure 2.4 produced by Johnson (1980) and Figure 2.5 by Dym (1994). Figure 2.6 by Pahl and Beitz (1996) however, is defined as the "benchmark for the modern systematic design process, and new representations are invariably a modified version of this chart" (Haik & Shahin, 2010). What is interesting with the evolution of these models is that designers now spend longer time in the initial stages, namely research, specifications and concept. Which illustrates that it is accepted to spend a longer time within conceptual phase, at least, within academia. The arrows going back and forth in some of these models represent the oscillate state of the design decision-making process. However, some models can act as "stage-gate" processes, which work in the way that one stage have to be signed-off by management, before jumping on to the next stage. This varies within companies, as they have either their own variation of the processes, deadlines to uphold, or diverse products that needs to be created.

2.2.3 The apparel design process

Apparel design models are again similar to that of general (engineering) design processes, however, *adapted* to suit the specific needs of the apparel industry, as was explained by Haik and Shahin (2010) earlier. Pahl and Beitz (1996)´s model (Figure 2.6), the "benchmark" model, can easily be applied to the apparel design process. Regan et al., (1998) found a direct relationship between the engineering design process and the apparel design process, and they therefore created a systematic apparel design model based on the engineering design process (Figure 2.7). After observing ten apparel designers they concluded, "the apparel design process is a scientific and problematic building block process" (p. 40). Gam et al., (2009) further outlines from Regan et al., (1998)´s study, "the apparel design process starts with problem recognition where designers initiate their ideas for the product development", continue with the problem definition and ends with the exploration of problems. Do note that this process only defines the conceptual research phase, where the design problem is in question. This model emphases the preliminary stages for creating a design, which is not only limited to trend analysis, but also problem statement and solution generation.

Problem recognition → Problem definition → Exploration of problems

Figure 2.7 Regan et al., (1998)´s systematic apparel design model.

LaBat and Sokolowski (1999) further enriched the research field by creating a three-step design process (Figure 2.8) for the apparel industry. Modeling it in accordance with methods mentioned earlier, they reviewed engineering, architecture, industrial and previous apparel design models, and created a chart displaying the apparel product development process and the engineering design process, which is summarized in Table 2.1. Their model acts as a guideline how "creative thinking evolves into the product design process and suggests approaches for solutions though continual exploration, which is necessary in a sustainable production strategy” (Gam et al., 2009). The study gives you a glimpse into the different roles designers have, and therefore an understanding of the specific tasks and when these tasks are conducted. Further, to be able to view the different models next to each other (see Table 2.2), allow for a simultaneous interpretation. Making it easy to acknowledge what differs and what stays the same. Again, it is evident that most of the models covey the same, however in diverse ways.

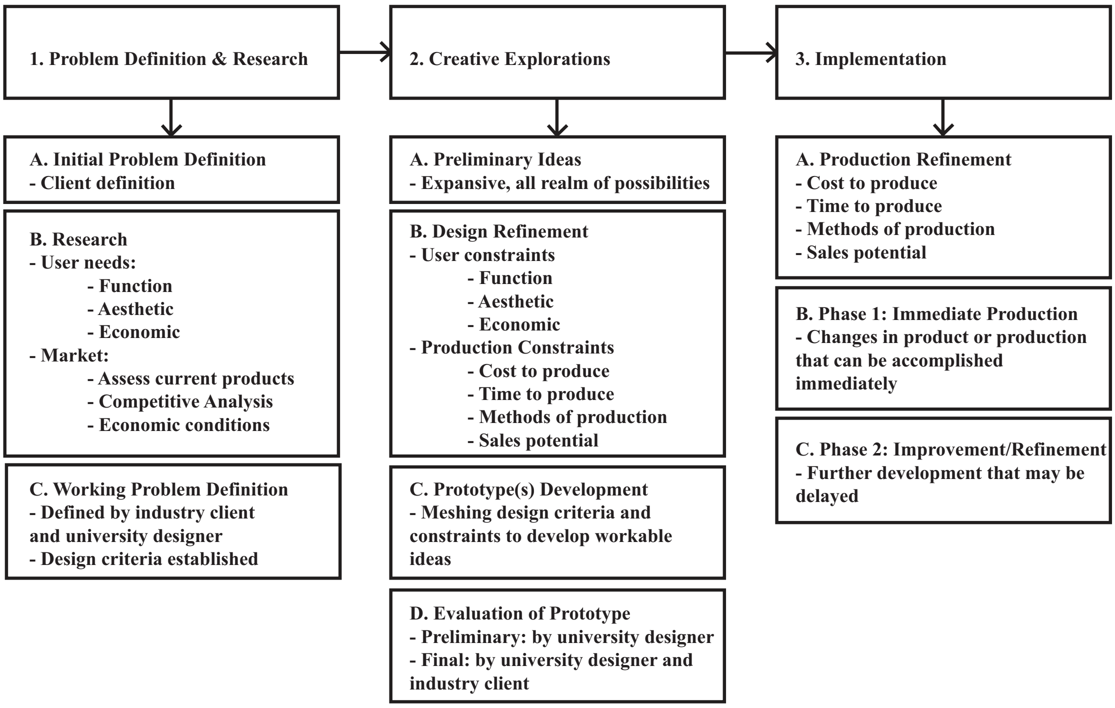

Figure 2.8 The three-step design process created by LaBat and Sokolowski (1999).

Table 2.2 LaBat and Sokolowski (1999) summary of clothing and apparel processes and engineering design processes.

LaBat & Sokolowski (1999)		Problem definition and research	Creative Exploration	Implementation
Clothing and Apparel product development process	Watkins (1988)	- Problem acceptance - Variable analysis	- Definition - Idea generation for solution	- Select solution - Implementation
	Lamb & Kallal (1994)	- Problem identification - Preliminary idea	- Design refinement - Prototype development	- Evaluation - Implementation
	Regan et al., (1998) (used Lewis & Samuel´s model	- Problem recognition - Problem definition	- Exploration of problem - Search for alternatives - Evaluation and decisions	- Specification of solution - Communication of solution
Engineering design process	Lewis & Samuel (1989)	- Problem recognition - Problem definition	- Exploration of problem - Search for alternatives - Evaluation and decisions	- Specification of solution - Communication of solution
	Pahl & Beitz (1994)	- Product planning and task clarification	- Conceptual design	- Embodiment - Detail design

2.2.4 Guidelines, tools and environmental issues

What all of these models have in common is that they leave out environmental issues, concerns or strategies. Environmental issues could however be interpreted within the "specifications" as "identifying problems", which is evident in the "benchmark" model provided by Pahl and Beitz (1996). Still, little research is conducted into the role of designers and their environmental initiatives (Melnyk et al., 2001). However, what little research exists divides environmental concerns, which are integrated within the product design process, into three categories. The first category deals with case studies describing specific companies and their experiences with the incorporation of environmental concerns (e.g. Rice, 1993; Sanders, 1993; Clark, 2009). The second deals with trying to offer specific guidelines and advice for engineers and managers to integrate environmental concerns into the design process (e.g. Cattenach et al., 1995; Epstein, 1996). The third focus on integrating tools into the design process to include environmental concerns, by either identifying the true cost and benefits of incorporating environmental issues or, to help designers identify environmental and cost implication related to alternative material or processes (e.g. Allenby, 1993; Graedel & Allenby, 1995). Fitzgerald et al., (2005) and Melnyk et al., (2001) stress that the greatest opportunity to reduce environmental impacts in product creation lies in the (conceptual) design stage. Consequently, production companies as well as academia have spent a great deal of effort developing environmentally friendly tools and guidelines. Guidelines, tools, biomimicry, C2C and CAD, have here been pulled out to create some structure as well as further highlight the distinctive features and dissimilarities, which they all consist of. It must be noteworthy that some of the guidelines, tools or philosophies discussed overlap, as no distinct line can be drawn that would exclude the other. An LCA tool such as SimaPro could e.g. utilize the philosophy of Cradle-to-Cradle or inhibit the same guidelines as illustrated by the 12 principles of green engineering. The main difference between a guideline and a tool is that a guideline is supposed to educate through guiding, while a tool, is something a designers interacts with, and thereof gets definite answers to their problems.

Guidelines

The twelve principles of green engineering is an example of an environmental guideline aimed at designers. Its purpose is to deliver a structure to create and assess sustainable design opportunities. They have been created for designers and engineers to empower them so that they can utilize these principles to create products, processes, or even systems that have the right set of conditions and circumstances to be more sustainable (Anastas & Zimmerman, 2003, p. 96). Figure 2.9 depicts the 12 principles, and outlines their specific traits. These principles emerged as discussions related to the imminent threat of not minimizing waste, increased recycling and overall approaches to sustainability emerged (Anderson, 1999; McDonough & Braungart, 1999; 2002). Green engineering focus on how one can achieve sustainability through science and technology (Ehrenfeld, 1997; Fiksel, 1998; Skerlos, 2001), and "provide a framework for scientists and engineers to engage in when designing new materials, products, processes, and systems that are benign to human health and the environment" (Anastas & Zimmerman, 2003, p. 95). The twelve principles of green engineering are similar to the "Ten Golden Rules" created by Luttropp and Lagersted (2006, p. 1401). The "Ten Golden Rules" can be seen in Figure 2.10, and highlights guidelines (rules) to designers, in how to design more environmentally friendly. Luttropp and Lagersted (2006, p. 1407), conclude "designers always salute the possibility to get a compass course with many possibilities to maneuver/customize on their own". And state that their “Ten Golden Rules” is a quick and easy introduction to sustainable design practices, should be introduced with DfE initiatives and that they should act as a checklist as the design progresses. DfE, could however also be considered a tool, and will therefore be explained within the following pages. (As a guideline, the DfE initiative may be depicted as it has been by Bombardier, see Appendix D).

Inherent Rather Than Circumstantial
Designers need to strive to ensure that all materials and energy inputs and outputs are as inherently nonhazardous as possible.

Prevention Instead of Treatment
It is better to prevent waste than to treat or clean up waste after it is formed.

Design for Separation
Separation and purification operations should be designed to minimize energy consumption and materials use.

Maximize Efficiency
Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.

Output-Pulled Versus Input-Pushed
Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.

Conserve Complexity
Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.

Durability Rather Than Immortality
Targeted durability, not immortality, should be a design goal.

Meet Need, Minimize Excess
Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.

Minimize Material Diversity
Material diversity in multicomponent products should be minimized to promote disassembly and value retention.

Integrate Material and Energy Flows
Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.

Design for Commercial "Afterlife"
Products, processes, and systems should be designed for performance in a commercial "afterlife."

Renewable Rather Than Depleting
Material and energy inputs should be renewable rather than depleting.

Figure 2.9 The twelve Principles of Green Engineering.

1. Do not use toxic substances and utilize closed loops for necessary but toxic ones.
2. Minimize energy and resource consumption in the production phase and transport through improved housekeeping.
3. Use structural features and high quality materials to minimize weight ..in products.. if such choices do not interfere with necessary flexibility, impact strength or other functional priorities.
4. Minimize energy and resource consumption in the usage phase, especially for products with the most significant aspects in the usage phase.
5. Promote repair and upgrading, especially for system-dependent products. (e.g. cell phones, computers and CD players).
6. Promote long life, especially for products with significant environmental aspects outside of the usage phase.
7. Invest in better materials, surface treatments or structural arrangements to protect products from dirt, corrosion and wear, thereby ensuring reduced maintenance and longer product life.
8. Prearrange upgrading, repair and recycling through access ability, labelling, modules, breaking points and manuals.
9. Promote upgrading, repair and recycling by using few, simple, recycled, not blended materials and no alloys.
10. Use as few joining elements as possible and use screws, adhesives, welding, snap fits, geometric locking, etc. according to the life cycle scenario.

Figure 2.10 The Ten Golden Rules (Luttropp & Lagersted 2006, p. 1401).

Tools

Tools, unlike guidelines, have been created for more specific and detailed tasks. There are two major classes of tools, namely DfE (Poyner & Simon, 1995) and LCA (which stands for Life Cycle Assessment) (*ILCD handbook*, 2010). These tools tend to overlap, so to detect a distinct difference is not always that easy. DfE, as briefly mentioned in the previous section, is the abbreviation of Design for Environment, which is a “systematic process by which firms design products and processes in an environmentally conscious way (Lenox et al., 1996). DfE is a technological driven management activity, which captures external and internal environmental considerations to design processes (Shelton, 1994). Basically, DfE seeks to comprehend the life cycle of the product and its effect on various damaging impacts on the environment. It is stressed that DfE must occur early in the design stage to ensure that "the environmental consequences of a product's life cycle are taken into account before any manufacturing decisions are committed" (Rose, 2000). During the conceptual design stage a majority of possible end-of-life costs or yields are committed, therefore it is necessary to provide as much information in regards to environmental concerns as early as possible to proceed with correct design decisions (Al-Salka et al., 1998; Sieger & Salmi, 1997). Graedel and Allenby (1995) state that DfE should be "a component of the product definition and creation cycle", as both internal and external incentives exist for environmentally responsible design. The second tool, Life Cycle Assessment (LCA) or Life Cycle Impact Assessment (LCIA), comprise the notion that one would have to think of the life and impact of the product throughout its entire lifecycle (Guinée, 2002, p.312; Newcomb et al., 1996). It "quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with any goods or services (ILCD handbook, 2010). There are four main parts to an LCA study, namely, (1) the goal and scope definition phase, (2) the inventory analysis phase, (3) the impact assessment phase and the (4) interpretation phase (Subic et al., 2009). To a designer, this means one would have to consider how the "product interacts with the environment in material production, manufacture, transportation and packaging, use and disposal" (Greenwood, 2012). See Figure 2.11 for a generic schematic overview of a products life cycle.

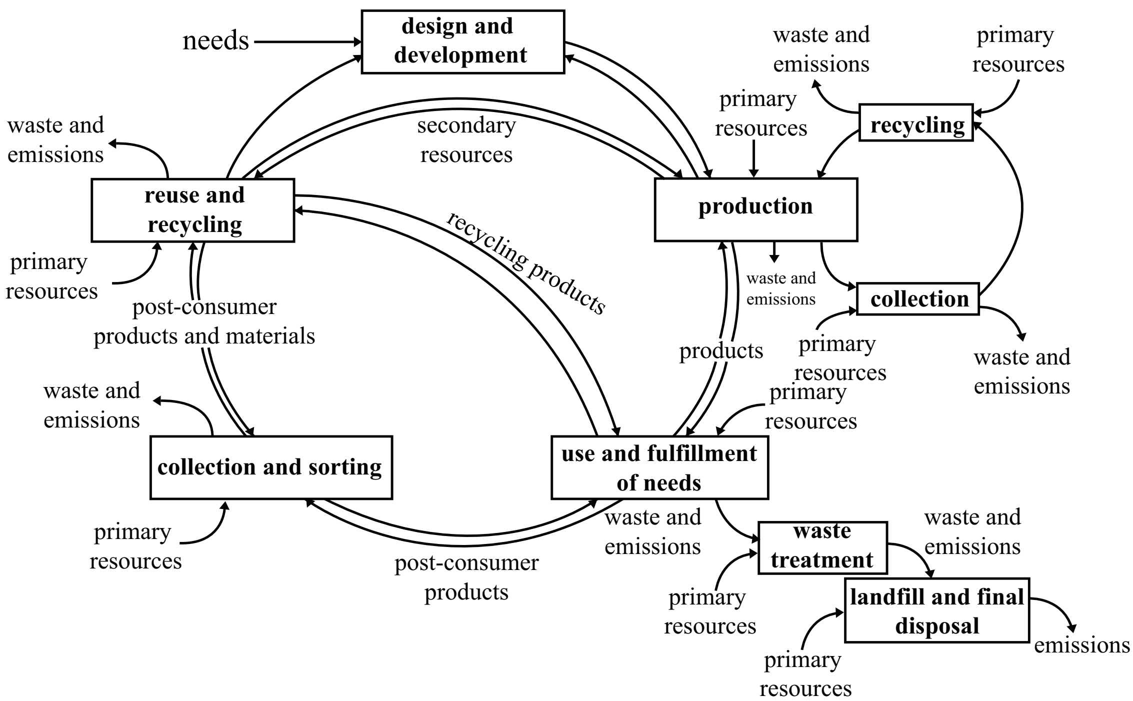

Figure 2.11 Schematic overview of the generic life cycle of a product (Rebitzer et al., 2004, p. 702).

After conducting an LCA, one is left with all the impacts of the product, and from there, one can dive into each section of the entire process to identify environmental improvements. However, as Greenwood (2012) state, a "full LCA can be extremely time consuming and complicated, and so it is often not practical in the high speed product design and development process". LCA's in the sport apparel industry needs to account for versatility, lifespan, durability, certification, material selection, construction, labeling, finishing processes and packaging, to name a few, which again prove that it might overwhelm designers with work (Subic et al., 2009, p. 77). This only goes to show that LCA studies for designers would not be practical. Ayres (1999) also points out that since the first stage in LCA is a quantitative comparison of materials flows and transformations, nevertheless is invaluable in itself, "the data required to accomplish this first step are not normally available from published sources" and "theoretical processes from open sources might not correspond to actual practice". Subic et al., (2009, p. 77) note that "only the products functionality is in principle fixed", therefore, to change the conventional way garments are engineered opens up for more ecological alternatives to be explored. Take for example the 'seam-free' (minimal seam) approach, which generate garments with 10-20% less waste due to innovative construction processes. This process does not only reduce the environmental impact, but also reduce labor processes (Subic et al., 2009, p. 77). One ingenious way to utilize LCA has been through the task of comparing reuse/recycling of textile waste with virgin materials. What process would actually utilize less energy and would therefore prove to be more efficient or environmentally friendly? Domina and Koch (1997) and Woolridge et al., (2006) both conclude that the energy used during the collection and distribution of old textiles is insignificant compared to the use during manufacturing of raw virgin materials. Many obstacles have been identified with the effectiveness of both DfE and LCA (Melnyk et al., 2001). Two of the most noteworthy obstacles are the difficulties acquiring the needed data (Ayres, 1999) and "the challenges developing realistic, appropriate metrics of environmental impact (Melnyk et al., 2001). Therefore, DfE and LCA tools are, generally, not well integrated with other corporate activities or tools that are normally utilized within product development processes (Melnyk et al., 2001). Poyner and Simon (1995)´s study give some insight to where different environmental guidelines or tools would fit into a design process. They have defined the design process to consist of product planning, market research, specification, conceptual design, embodiment design, detailed design and production. What's further interesting to note is that they have adapted a similar design process to that of Pahl and Beitz (1996)´s "benchmark" model, as additional emphasis is laid on the initial research phases. By summarizing in Table 2.3, we see that Diaz-Calderon et al., (1994)´s tool gives the designer relevant environmental design advice by analyzing the design process. Poyner and Simon (1995) claim that this is a powerful method, but this would require a program that is capable of handling a huge input of data. This is however a retroactive task, as advice is only given after the design is completed. Kasshan et al., (1995)´s tool, "Green Design Tool", apply a condensed version of an LCA. Being a condensed version basically means that it is less input challenging for designers, and gives the designer faster feedback. However, with all of these tools, the product needs to have been created upfront, before any environmental considerations may be assessed and later implemented (Poyner & Simon, 1995). None of the tools focus on the conceptual design phase, in which the most environmental influence can be achieved. However, as shown in in Figure 2.12, Poyner and Simon (1995) outline that basic LCA tools might be utilized in the conceptual phase. Previous research mentioned, clearly states that LCA is *not* a conceptual design tool, as it requires an enormous amount of input and time, and does not spark the necessary creativity (Ayres 1999; Subic et al., 2009; Greenwood 2012).

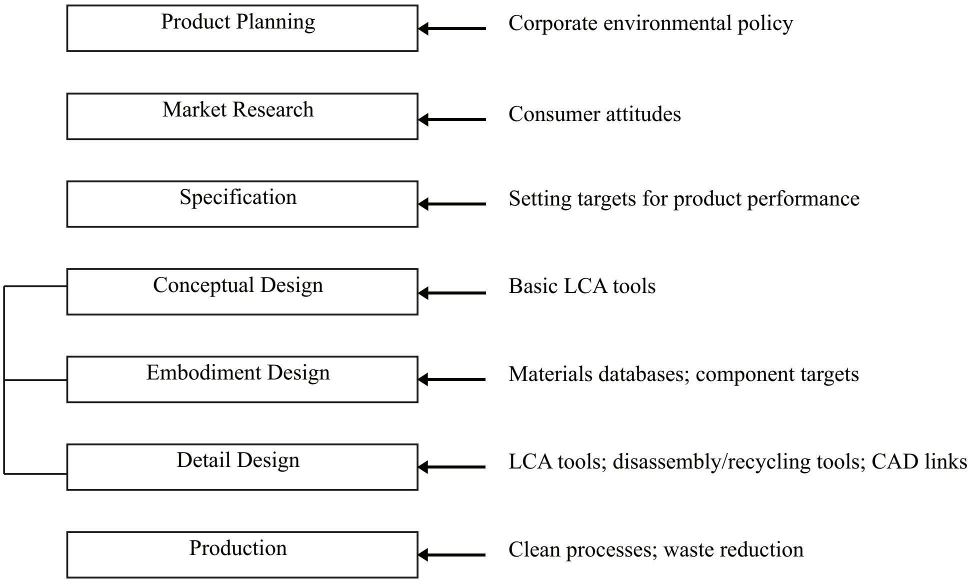

Figure 2.12 Stages of the design process and relevant DfE issues and methods (Poyner & Simon, 1995, p.55).

Table 2.3 Poyner and Simon (1995)´ summary of DfE CAD tools.

Computer Tool	**Scope/Philosophy**	**How the tool is used within the design process**
Design for Environment (DfE), based on DFA/DFS software (Boothroyd & Dwehurst, 1987)	Analyses end-of-life options and life-cycle data for components in an assembly, including disassembly cost and recycling options.	Used during assembly analysis; requires data on assembly relations of all parts and fastening methods to be entered. Links with CAD exist, e.g. Pro-Engineer.
Materials Selection (Chen et al., 1995)	An expert system to enable suitable cost/ environmental material choices to be made based on the input of a products specification. A product can be made from the most suitable "environmental" choice of material.	Used after a product has been specified to enable the designer to arrive at a suitable choice of material based on the required attributes of the product.
Life Cycle Assessment (LCA) (e.g. commercial systems from PIRA / Boustead)	Ecobalance tools that evaluate system inputs and outputs for each life-cycle stage. Most are limited to inventory analysis - flows of material and energy.	Can be used as soon as processes, materials and part weights decided, effectively in embodiment design stage. Do not directly point up design options.
ReStar (Navin & Chandra, 1993)	Performs disassembly analysis on a particular design. Optimising a design using exhaustive search of possible reuse/recycle/etc choices at each step of disassembly	Requires complete geometric assembly relations for the product; hence usable only at detail design stage.
Design for Product Retirement (Ishii et al., 1994)	Based on Design Compatibility Analysis; provides qualitative ratings for designs and cost summaries.	Requires the product structure and fastening methods to be input graphically.
Advisor for Component Design (Diaz-Calderon et al., 1994)	Expert system combined with geometric modeller, gives advice to designers by analysing assemblies.	Used to evaluate geometric models of parts or assemblies for material compatibility and fastening techniques; detail design stage.
Green Design Tool (Kassahan et al., 1995)	The tool analyses a design and associated processes for their "greenness". By measuring the "greenness" of a certain attributes of a design, a designer can try to make improvements to their designs.	Can be used as soon as the basic embodiment of a product has been designed. The output allows the designer to analyse quickly alternative designs and manufacturing methods.

Biomimicry

Biomimicry refers to the imitation of life, and is the combination of the two Greek words bios, meaning life and mimikos, meaning imitation (Lee & Thompson, 2011; Reap et al., 2005). Benyus (2002), describes biomimicry as innovation inspired by nature by taking advantage of 3.8 billion years of evolution in research and development. Vogel (2008) and Holbrook et al., (2010) note that humanity has always looked to duplicate nature, and thereof copied nature to guide innovation in the past. Biomimetic design refers to design that, fully or partially, imitates or evokes some biological phenomenon. Biological phenomena hold a great amount of concepts that could be useful to engineers during design concept generation (Hacco & Shu, 2002, p. 1). Mammals, reptiles and insects have inspired robotics research on gripping devices, carrying and movement (Waldron, 2000), the Eiffel's tower was influenced by skeletal bone structures (Ball, 2001), termite mounds inspired mid-rise buildings with ventilation systems saving 90% of the cost of conventional conditioned buildings (Lefaivre, 2000, p. 89) and Humpback whale fins have inspired fin models to increase lift and reduce drag (Miklosovic et al., 2004), are all examples of biomimetic design. The most famous biomimicry example may be that of Velcro, which "was created in the image of seed hooks that fasten onto objects when they brush up against them" (Reed, 2003). It must be noteworthy that it is not set that the biomimicry approach is more environmentally friendly than its counter parts as its main purpose is to mimic nature. Further, since many engineers usually do not have sufficient background in biology to look for answers to their design problems within nature (Hacco & Shu, 2002, p. 2), it is hard for a designer, that is cramped with time to take the necessary steps to research natural possibilities to design problems.

C2C

Cradle-to-cradle, as the LCA approach, focuses on the whole life cycle of products, however, instead of the conventional cradle to grave mentality, it embraces the cradle-to-cradle philosophy. It provides a "practical design framework for creating products and industrial systems in a positive relationship with ecological health and abundance, and long-term economic growth" (Braungart et al., 2006 p. 1337). According to McDonough and Braungart (2002) the goal of C2C products is to eliminate the concept of waste, and make waste equal food, whether that is food for biological cycles or food for other products (technological nutrients). Due to the initial vague framework of C2C, McDonough and Braungart teamed up with Anastas and Zimmerman, which created the twelve principles of green engineering, in an attempt to combine the two. The C2C is more of a philosophy of "What to do", but in the combination with the twelve principles of green engineering, it answers, "How do I do it?" (McDonough, et al. 2003). It is a fine line between telling designers what to do, and guiding them in the right direction, as either might be discredited (Chen, 2001).

Sustainable CAD

Design tools, which utilize the computer software to solve tasks, are referred to as CAD (Computer Aided Design) programs. Many sustainable CAD software are available. DfE and LCA are both often in CAD form. The Eco-Indicator 99 for example, is such a CAD program, as it utilizes a simple set of "inventory tables and standard impact data for materials and processes", which therefore allows a designer to achieve a basic environmental assessment (Greenwood, 2012). SimaPro is also another CAD software, which follows a similar system to the basic Eco-Indicator 99 method but as a software program it is quick and easy to use, and has a far more comprehensive database of impact categories. It also allows more experienced users to develop their own impact scores for materials and processes not included as standard (Greenwood, 2012). However, for a designer to utilize these tools, it requires time and dedication to learn all the different features, which is precious time that should be spent on the actual design activity. Further, they do not specifically target the conceptual creative design phase. Still, Wang et al., (1994) state that the conceptual design is a very important task in CAD software, but that it is difficult to accomplish due to the fact that knowledge of the design requirements during the early design stage is usually imprecise or incomplete (Hsu & Liu, 2000). According to Wang et al., (2002), the conceptual design phase "need to adopt a more pragmatic and aggressive approach – through collaboration, supported by artificial intelligence, and fuelled by information technologies". And continue by acknowledging the use of the Internet, as it provides instant access to infinite amount of information, in such CAD software. Since research at MIT has found that "the key to effective environmental design is the exchange of information" between diverse departments within firms (Ehrenfeld & Lenox, 1997), it is recognized that not only the designers role is important for the implementation of environmental practices. Managers, marketing and sourcing, all needs to be on board to push environmental progress in the right direction. To support this collaborative design environment, Wang et al., (2002) further stress the importance and impact the Internet may have. They outline three major benefits for a collaborative design environment utilizing the Internet; "(1) access to catalogue and design information on components and sub-assemblies, (2) communication among multidisciplinary design team members in multimedia formats and (3) authenticated access to design tools, services and documents". These benefits all highlight important collaborative factors that would improve with the use of an Internet based design tool.

2.3 Creativity

"Most enjoyable activities are not natural; they demand an effort that initially one is reluctant to make. But once the interaction starts to provide feedback to the person's skills, it usually begins to be intrinsically rewarding."

(Csikszentmihalyi, 1996).

When defining the "soft" nature of creativity, Mooney (1963) states there are four considerably different approaches to creativity, depending on where the user gains his/hers initial stand. This basically refers to the fact that each user might view the definition of creativity differently, as the starting point might differ from person to person. These four definitions, he refers to are; (1) the environment in which the creation comes about, that is, *the creative environment*, (2) *the creative product*, that is, the product of creating (3) *the creative process*, that is, the process of creating and (4) *the creative person*, that is, the person who is creative. To understand the aspects of creativity, the author has chosen to follow the categorization by Mooney (1963), however utilizing the updated version created by Warr and O'Neill (2005), which leave out the creative environment, due to the assigned task of this thesis. Warr and O'Neill (2005, p.126) stress that "social creativity should be more productive than individual creativity", meaning, that a *collaborative* creative design process have higher returns. However, other research points out that creativity may be damped through social interaction due to *product blocking*, meaning individuals share their ideas one at a time, and therefore others might suppress or forget their own, *evaluation apprehension*, meaning fear of criticism and *free riding*, where you have individuals relying merely on others to produce creative ideas (Diehl & Stroebe, 1987; Osborn, 1957; Lamm & Trommsdorff, 1973). Creativity is therefore not always easy to assess, as individuals act and behave differently towards their creative sides.

2.3.1 The Creative Process

Boden (1994) describes the creative process as a person's investigation and alteration of conceptual spaces, were Koestler (1964) proposes that creativity comprises of a "bi-sociative process", where an individual purposely links earlier unrelated "matrices of thought" to construct a creative idea. Warr and O'Neill (2005, p.119) point out that the "matrices of thought", namely the ideas of a single person, when shared within a collaborative space, the generation of creative ideas "are not necessarily in the mind of a single individual but may come from more than one person in the group". Csikszentmihalyi (1996) and Arias et al., (2000) add that much of our intelligence and creativity comes from the interaction with tools and artifacts through a collaborative space, meaning that, individuals that collaborate are more capable to come up with creative ideas, given the right setting.

2.3.2 The Creative Person

Guildford (1950) state that a "creative personality is a matter of those patterns of traits that are characteristic of creative persons", meaning that for the creative individual, the creative process forms more easily than in others, which allows the individual to explore and transform conceptual spaces wider in their minds (Warr & O'Neill, 2005, p.119). However, as Warr and O'Neill (2005, p.119) observe with Guildford's statement above, this gives us no indication to what these traits are. To find these traits, several of creativity tests have been devised to assess individual's personalities, background and behaviors. Take for example the 'Creativity Personality Scale' created by Gough (1965; 1979)(Appendix A), he provides a list of 18 adjectives that positively relate to creativity and 12 adjectives negatively relate to creativity. By describing personal traits, such as "capable (+), artificial (-), clever (+) and cautious (-), test subjects pick adjectives that represent their personalities. The results show individuals divided by personalities, as creative individuals tend to use adjectives related positively to creativity and non-creative individuals tend to utilize the negatively related adjectives (Warr & O'Neill, 2005, p.119; Gough 1965; 1979). Critiques to this test, such as Ward (1947) and Amabile (1983) point out that even though these traits may be important for creativity, they should not be utilized as a global labeling system of creativity.

2.3.3 The Creative Product

The creative product refers, as stated by Warr and O'Neill (2005, p.119), to "the product's inherent property to reflect signs of creativity". Theorists who often define the creative product tend to incorporate the word 'novelty' and 'appropriateness' to explain creativity (Amabile, 1983; Bruner, 1962; Jackson & Messick, 1965). However, Warr and O'Neill (2005, p.120) then question how one would assess a novel idea to be appropriate, and appropriate to what? They see that when being creative, one would usually begin with a design problem. The problem definition is determined and the problem is explored, which allows for the “characteristics potential solutions” to be assessed. The solution is therefore deemed *appropriate* if it corresponds to these characteristics (Warr & O’Neill, 2005, p.120).

2.3.4 The Creative Tool

Sternberg (1999) divides the creative literature up into three intersecting schools, namely the structuralist, the inspirationalist and the situationalist. From this division, Shneiderman (2007, p. 25) gives specific traits to what each school would desire in a creative tool. He state that “structuralist thinking encourages systematic tools that include progress indicators with reminders of what is still needed”, whereas the “inspirationalist view supports development of image libraries, thesauri, sketching interfaces, and concept-mapping tools” and finally, the “situationalist broaden the designers’ view to include email and collaboration tools” as well as features that could track group work. Shneiderman (2007, p. 22), states that “creativity support tools enable new forms of expression for individuals”, and that “they are especially potent in supporting group collaboration and social creativity”. And continue by acknowledging “creativity support tools extend users’ capability to make discoveries or inventions from early stages of gathering information, hypothesis generation, and initial production, through the later stages of refinement, validation, and dissemination”. Therefore, well crafted software tools (CAD) can help creators in generating multiple possibilities, such as showing implications and keeping track of their decisions (Terry et al., 2004). Outstanding interface design, “with rich domain-specific features, are essential for creativity support, as users need to apply their cognitive resources and passions fully to their discoveries and” (Shneiderman 2007, p. 26). Set principles for creativity tools are outlined in Table 2.4, as is discussed by Myers et al., (2000) and Shneiderman et al., (2006; 2007, p. 23, 26).

Table 2.4 Interface design principles.

Support exploratory search - Users should be aware of previous and related work. - Search engines prove helpful, but have much room for improvement.
Search results by; ranking, clustering, partitioning, annotation, tagging and marking. - Viewing many relevant examples at a time. - Dynamic queries and customization.
Enable Collaboration - Collaborate in the early design stages. - Shared views, chat rooms and idea forums. - Safe environment, trust, accurate records and safe exchanges.
Provide history keeping - Users should have a record of what they have tried which allows for comparisons and modifications.
Tools should be easy - Design the usability to suit the needs of the user. - Include a wide range of different services. - Include file conversions, import data sets, try multiple visualizations, run statistical test, include annotations and export subsets of data in desired formats, allow for the user to concentrate on the problem.

To be able to facilitate a viable and prosperous design environment, not only the above need to be taken into consideration, CAD software also needs to "engage users in a dialog-like interaction that encompasses a range of activities, such as geometric and semantic product modeling, design representation, user-interaction and design browsing and retrieval" (Wang et al., 2002). However, Shneiderman (2007, p. 24) states that even though creative tools can be valuable, "they are still only tools" and that "the act of creation is carried out by the users", here being the designers. Appelt and Busbach (1996) created a Web-based BSCW (Basic Support for Cooperative Work) system, which follow the idea that such applications should inform, rather than constrain (Beck & Bellotti, 1993). This shared workspace enhances collaboration through allowing communication, conflict resolution and management. Again, allowing for collaboration in the conceptual design stage as research suggests, will spark creativity. Set principles to CAD software are therefore identified to accomplish a creative collaborative environment that will prosper together with environmental concerns and constrains.

2.4 Background summary

This background chapter has highlighted the importance of awareness of sustainability and environmental issues within the design process. Within the apparel industry, designers find it difficult to assess what is environmentally friendly, as it differs widely from various inputs/outputs over different practices. Many environmental concerns link to the material choice of the individual designer, which illustrates that if the individual designer were given the education to choose better in terms of their product's environmental impact, the environmental impact of the whole manufacturing process would decline. The wide-ranging span of industries linked to the apparel industry makes it further complicated to both assess environmental progress and keep an overview on where the most environmentally hazardous aspect exists. To understand the process designer's conduct while designing, the design process was further discussed in detail. The simplified version of a design process could be explained to consist of three stages, the conceptual stage, the configuration stage and the detailed design stage. Within these stages, the specifications of a design is decided upon, concepts created, functions determined and audience targeted. Through the literature review, it is evident that within the conceptual design stage most of the design is decided upon, and that it is difficult to go back to this stage to re-do wrong decisions. The common trend in most of the environmental help tools, guidelines and philosophies seem that they are either immensely time consuming, confusing (What can I do?), wrought with difficulties acquiring correct data and creating realistic environmental metrics for environmental impacts. As understanding creativity is such a large part of the conceptual design phase, creativity was further investigated. Within this segment it became evident that the common denominator for the creative process/person/product, would be the notion of exploratory problem solving, and if done correctly, new, or if one simply find solutions where others would not, one is looked upon as a creative. Creative stimulus was discussed with the interaction of collaboration and the utilization of Internet based CAD software. It has been identified that an Internet based CAD software proves to be the best way to accommodate all the necessary specifications related to environmental practices, creativity, collaboration and the conceptual design phase. Any tool dealing with creativity should inform and let the individual have some sense of "freedom", customization and ease of use (Shneiderman, 2007).

3 Methods

These methods chapters are divided into three separate segments, namely the questionnaire, the sustainable design model and the proposed solution. Results of the methods section will be divided in the same way, as to understand where what information was found and to follow the same structure for the readers' ease. Primary data is pulled out from the questionnaire, while the sustainable design model utilizes both the results from the questionnaire and secondary data from per reviewed journals and books. The purpose of the questionnaire and the creation of a sustainable design model are to build a bridge to why and how the proposed solution was created.

3.1 Questionnaire

3.1.1 Purpose

As one of the aims of the thesis is to propose a new Internet based CAD tool (a CAD tool which is installed on the individuals designers computers, but utilize the internet to connect them all) for designers, a questionnaire was included as the necessity to understand the perceived needs and thoughts towards such a program and towards sustainability in general by designers has proven crucial. Without an understanding neither on how a designer would greet such a program, nor if a designer would even want to utilize it, one would not know if the program would have a chance of success. The questionnaire was directly linked to the research questions.

3.1.2 Logistics and sampling

Since the target audience is apparel designers, the sampling method is termed purposeful sampling. This refers to a certain strategy in which certain specialized people are selected due to their skill set, here being designers. First, a preliminary questionnaire was developed and presented to five designers. This was conducted in person to acquire adequate information regarding the content of the final questionnaire. Qualitative research was utilized with this pilot phase to generate an understanding of the concepts and theories held by the respondents. Maxwell (1992) refers to this process as the "interpretation" phase. The questionnaire was then reviewed and slightly changed based on the feedback given through the pilot testing. The final questionnaire was then sent out to 30 apparel designers, and 20 designers (67%) completed the full questionnaire. The respondents were mostly European, 45% were men and 55% women. Further, the respondents came from three different sections within the targeted company, namely apparel creation (50% of the respondents), footwear design (45% of the respondents) and accessories (5% of the respondents). Within these subgroups there were 6 women and 4 men within apparel (APP), 5 women and 4 men within footwear (FTW) and 1 man within accessories (ACC). This distinction was made to try to highlight any discrepancies within the respondents according to their sex and according to their BU (Business Unit, refers to where they belong within the company, e.g. footwear soccer or apparel running). Missing data was accounted for, and where prominent made aware. The survey was conducted from the 9th of June to the 18th of July 2012.

3.1.3 Questionnaire design

Questions were partly pre coded, closed (quantitative data source) and partly open (qualitative data source) (refer to Appendix B for full questionnaire). Pre coded refers to e.g. sex: male (1) female (2). Partly open, refers to the utilization of a free text section, however, as free text has statistical difficulties during translation, a visual analogue scale (VAS) was further applied. VAS is a psychometric response scale utilized in questionnaires where subjective characteristics or attitudes that cannot be directly measured are identified. There is evidence showing that visual analogue scales have superior metrical characteristics than discrete scales, thus a wider range of statistical methods can be applied to the measurements (Reips & Funke, 2008; Wewers & Lowe, 1990; Hasson & Arnetz, 2005). Respondents specify their level of agreement to a statement or frequency of an activity by indicating a position along a continuous line between two end-points. The line ranges from 0 to 10cm, where respondents' perceptions are categorized to their agreement level of the asked questions. If a respondent slightly agree, the line would be higher up on the scale (as shown in Figure 3.1), and if the respondent disagree, the line would be lower on the scale. For instance, if the question was; how many times do you consider sustainability? The VAS could range from a frequency from *never* to *very often*. The line drawn could refer to their perceived agreement or disagreement to the question and is considered their *score*. Below in Figure 3.2, you can see the score amount to 5, as the line has been placed in the middle of the scale, referring to a perceived "indifference" to the question from the responder.

Figure 3.1 VAS Scale: Respondent slightly agreeing with statement.

Figure 3.2 VAS Scale: Respondent showing his/hers indifference to the question.

The arithmetic mean (average) and the median were then calculated based upon the respondents' score. Both are included as they may vary substantially depending on the distribution of the scores among the respondents. The questionnaire was further constructed in Abode Illustrator, as an effort to increase the response rate. This notion was based upon the fact that Abode Illustrator is a program that is widely used within the apparel industry and is therefore familiar to all designers. Within Adobe Illustrator one can also quickly answer the questionnaire as one is capable to lock certain text and leave other sections open, one can color in text boxes with a single click and one can easily drag lines around. This allows participants to answer the questionnaire in a fast manner, and since it was conducted on their computers, answers were swiftly returned. The questionnaire was administered through email communication.

3.1.4 Purpose of questions

Questions within the questionnaire were chosen to answer the research questions. The two opening questions are asked to give some statistical background of the respondents, their gender and their status in the company. It was also asked to find any potential differences between sexes. Questions 3 and 4 were about the preferred research method of designers, and how often they actually utilize them. This is asked as the initial design phase involves research, and one therefore needs to understand the designers preferred way of conducting it. Initial interviews highlighted four research approaches; these were all coined the same, namely *research methods*, to try not to confuse the participating designers further. Two research methods are however present, namely the act of utilizing local sources such as books, magazines and the Internet, and the interaction aspect through market research. Question 5 tried to map how new technologies usually were integrated, and was stated as an open text question. This was asked, as the main purpose of this thesis is to propose a new design tool, and therefore sought to understand the various elements necessary for both the creation and future success. Questions 6 and 7 both dove into the participants' interest towards sustainability and their own thought of what the main restrictions towards sustainable design could be. These questions were asked to understand if designers actually embraced the idea of sustainability, or if they basically would not have anything to do with it. Further, it aimed to outline their perceived restrictions towards acting sustainably, which could prove crucial in both implementation and the potential success of the future tool. Question 8 was divided into two sections, one asking if the general designer at the company would need help to incorporate sustainable design practices, and second, why and how this could go about. This was interesting to find out as it asks not only your own opinion towards sustainability, but a designer's own perception of what the other designers at the company would require. Question 9 captures the participating designers own involvement of sustainability within the company, as the company already has several sustainable initiatives. This enables mapping if the participants are actually involved with sustainability, unlike question 6, which asks only if they are personally interested in it. Question 9 also asks if designers have taken part in informal sustainability meetings within the company, as a way to map their actual effort towards sustainability. Question 10 bluntly ask if the selected participant would have an interest in utilizing a sustainable design tool in their own work to find out if their answers correlated to question 6. And finally, question 11 captures what features designers would like to see included within a future tool.

3.1.5 Validity

It must be noted that the author both has an education in design and environmental sciences, and that biased data collection or analysis may be distorted by theories, values and preconceptions already embedded within preconceived notions of the author. The preliminary questionnaire contained some bias questions, which lead designers to answer what the author rather would want. Therefore, these questions where changed to be more general and to not lead the designers in a certain direction. It also must be taken into account that answers may be warped as the respondents may have more positive connotations to sustainability, as they chose to answer the questionnaire, than non-respondents. It also should be acknowledged that the survey went out during a holiday break, and a proportion of the non-respondents were simply on leave. The validity of the questionnaire was however strengthened due to partial open text, allowing designers to fully explain what their perceptions were of a certain matter. This is referred to as *rich data* collection (Becker 1970). The questionnaire should however have included the option to answer "don't know", as there were questions which participants chose to not answer at all. It was therefore just assumed that the participant did not know, or did not have a strong opinion either way. Yet, to find out exactly *why* would have been favorable for the overall understanding of the success of the questions. Interviews or in this case, open text, "counter the twin dangers of respondent duplicity and observer bias by making it difficult for respondents to produce data that uniformly support a mistaken conclusion, just as they make it difficult for the observer to restrict his observations so that he sees only what supports his prejudices and expectations" (Becker, 1970, p. 53). Also, pilot testing the questionnaire helped to distinguish certain word formulations that may be perceived as biased. It must further be noted that the "company" is made anonymous due to legal reasons. Another issue that needs to be addressed is the fact that the sample size is rather small (20 designers), and therefore no generalizations towards designers as a whole may be drawn. However, the respondent's answers should rather supplement results and experiences from other studies and projects.

3.2 Sustainable design model

3.2.1 Purpose

The purpose of creating a *new* sustainable design process model is to highlight the importance of the conceptual stage to sustainability. This is further done to give insight towards how the proposed tool would work. It also tries to answer the research question; how would a conceptual environmental design process look like within the apparel industry? This again, is to better understand how one could propose a design tool to be the solution for the inherent sustainable issues within the apparel design industry.

3.2.2 Reference models

The proposed sustainable design model incorporates elements from two design processes; the design process proposed by Pahl and Beitz (1996), which has been coined a benchmark design process model, and the three-step design process by LaBat and Sokolowski (1999). Thus, the model includes sustainable and collaborative aspects in a way to show where the proposed tool would be utilized, and how it therefore would prove beneficial. Only the conceptual design stage was targeted, and it therefore leaves out latter stages of the design process. The sustainability criterion has been based upon other sustainable design tools, processes (discussed within the background chapter) and own experiences working with designers. Further, the results from the questionnaire formed a better understanding on how designers work and engage themselves within the design process.

3.2.3 Steps copied

The following steps within the cited models were incorporated to re-create a sustainable design model. Figure 3.3 depicts the steps provided by Pahl and Beitz (1996) and Figure 3.4 depicts the steps provided by LaBat and Sokolowski (1999). Not to confuse where these steps are gathered from within the models, the "surrounding" steps has been included, however faded down to not take attention away from the actual copied steps.

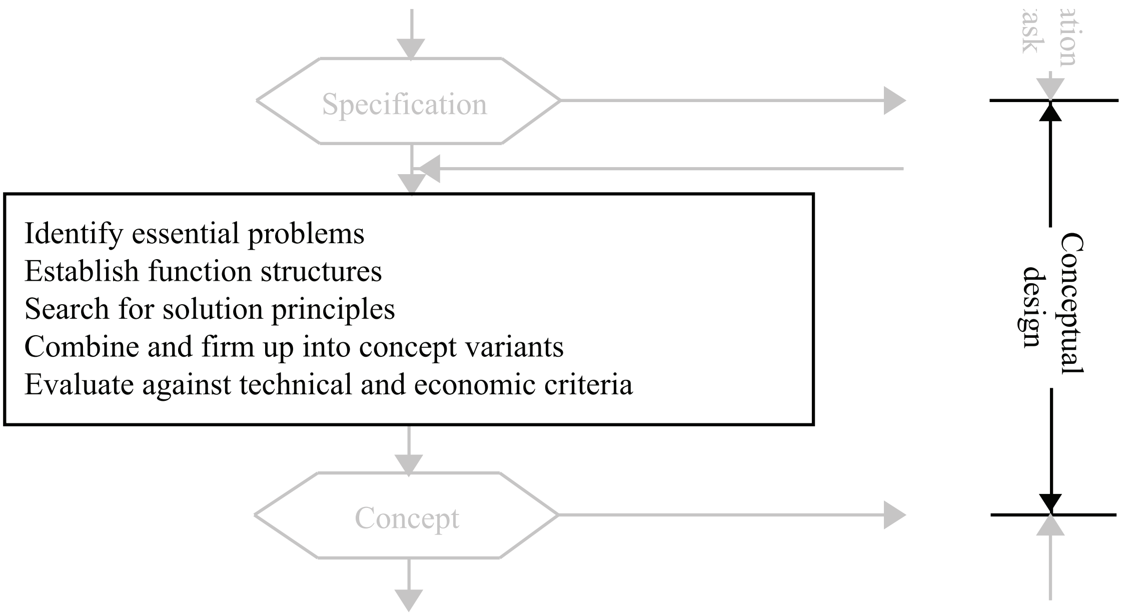

Figure 3.3 Pahl and Beitz (1996) design model: The conceptual phase.

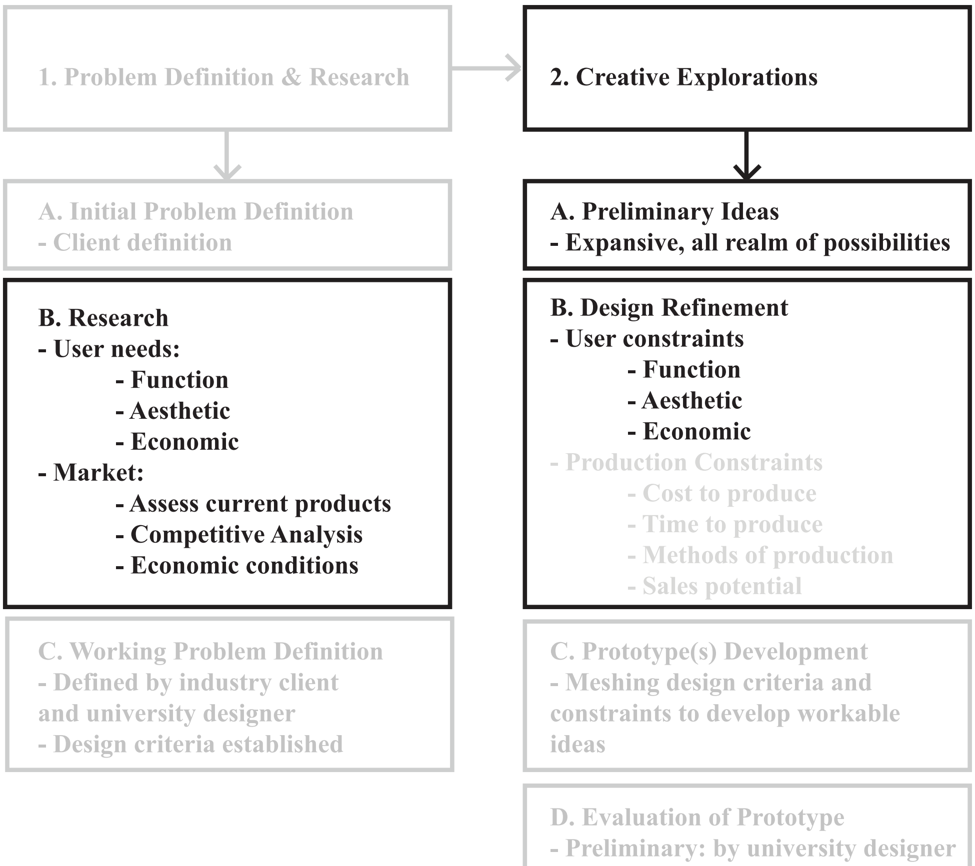

Figure 3.4 LaBat and Sokolowski (1999) three-step design model: The conceptual phase.

3.2.4 Validity

As the model created has not, nor will be tested for the purpose of this thesis, it must be understood that the model only represents how a sustainable design model would have looked if one would incorporate sustainable and collaborative practices within a tool, which targets the conceptual design phase. It should therefore be noted that it should not be utilized for implementation, without testing, nor re-defining for specific purposes. It is also important to note that the derived model is based upon previously made models, however further developed to suit the purpose of this thesis. Still, as the result from the questionnaire do give insights into how designers operate and their perceived needs towards such a process and/or tool, it offers some additional contribution towards both literature and the practice within design. Last, as was mentioned with the validity of the creation of the questionnaire, the author possess an educational background in design and environmental sciences, and therefore some parts are based on prior understanding of these subjects. This is referred to as own background within the result section.

3.3 Proposition

3.3.1 Purpose

The purpose of proposing a potential solution is to guide the creation of a future environmentally focused design tool targeting the conceptual design phase, drawing both on the questionnaire and the model. Proposing solutions to the inherent problems within design both speeds up the creation of a future tool, and gives further insight to what is necessary. Without this pre-research and pre-analysis, the creation of such a tool will be difficult and ambiguous in direction. Common problems, such as creativity and collaboration will be discussed and dealt with accordingly, and specific instructions will be given on how to solve these issues. This therefore gives a good understanding and blueprint on how to further the work conducted as part of this thesis.

3.3.2 The creation of a proposal

Answers from the questionnaire and the sustainable design model, as well as a literature review, shed light on the ideas presented within the proposal. It was evident through the questionnaire what designers felt towards such a tool, and what they would have included within it. The sustainable design model indicated where and when sustainable design issues should be solved, and therefore gave an understanding into what type of solution had to be proposed. In-depth interviews were further conducted with designers to answer any misconceptions and clear any doubts towards the proposed ideas.

3.3.3 Validity

As with any proposed solution which is written by one author alone, the proposition may lack features some design professions would require; the results is however derived from a multitude of individuals, such as design professionals and university academics. Therefore, combining work with others, and expanding on the present work will benefit the future creation of the proposed tool. The proposed solution gives however a good indication to how designers think, what they feel they need, and how one would solve common inherent environmental problems within the design process.

4 Results

4.1 Questionnaire

The questionnaire can be found under Appendix B. As background questions 1 and 2 divided the selected participants up into different sub groups; apparel (APP), footwear (FTW) and accessories (ACC), whereas questions 6, 8 and 10 indicated divided opinions between the sexes within their sub groups. However, as the female to male ratio were almost similar in both the sample size and within their respective BU´s (Business Unit) and that they all provided varied answers, it is believed to have no significant effect on the study. This shows that the interest in sustainability is not dominated by one sex or subgroup in particular but rather shared according to own personal interest or prior education. This is evident in Table 4.1, as the mean to Question 10 did not vary greatly from the different sexes nor subgroups. As there were no female accessories respondents, only one male mean VAS score is present.

Table 4.1 Mean female to male ratio divided by their respective BU´s. Answer to Question 10.

	APP	FTW	ACC
Female	6.98	6.02	
Male	7.2	4.42	7.9

Question 3 asked: On what frequency do you utilize the listed research methods mentioned below? The alternative research methods were given as; web search, books, magazines and market research, as this were concluded through the pilot test to be the most frequent used methods within the company. The scale given indicates the VAS (ranging from 0-10), and represents therefore their scores. Figure 4.1 shows the mean scores of the respondents and indicate that web search would be the preferred method of research. However, magazines and market research (referring to when designers actually interact with a certain market or target group) also scored higher than the mid-VAS score of 5. All graphs presented show the VAS scale on the y-axis, unless stated otherwise.

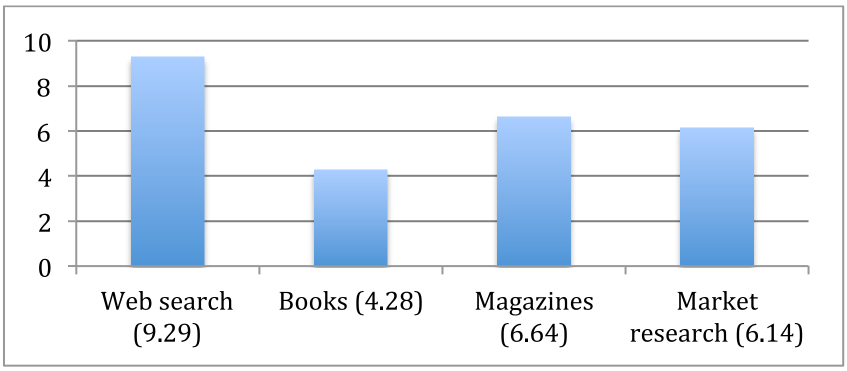

Figure 4.1 Respondent's mean scores to frequency of utilized types of research listed (question 3).

Figure 4.2 shows the median of the respondents in an attempt to distinguish any dissimilarity within the respondent replies. This does not however seem to be the case.

Web search again proved to be the favored method of conducting research. More designers did however perceive web search to be of greater frequency, as the median was 9.75 as compared to the mean of 9.29, meaning, more designers gave it a higher score, but some designers, due to their lower scores, pulled the mean down.

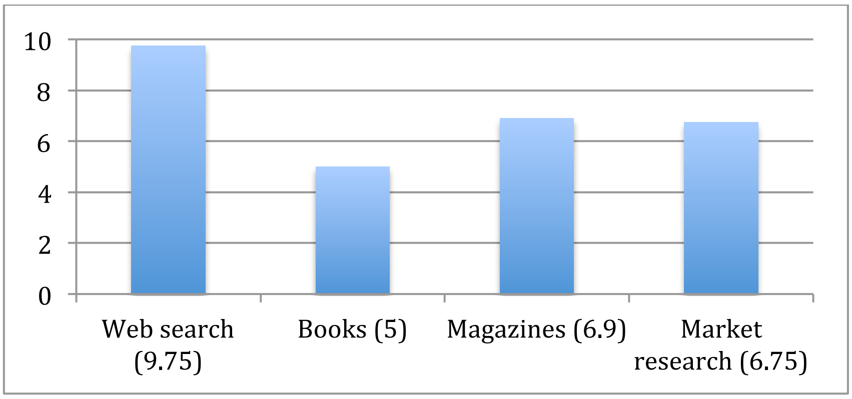

Figure 4.2 Respondent's median scores to frequency of utilized types of research listed (question 3).

Within question 3, there was also an open text box, in which respondents could fill in other research options. Seven (35%) designers chose to fill this in. The most common denominator here was the answer "doing the sport you design for", as 3 (42.8%) of the answers contained such a reply. This was also the same answer that was displayed in question 4´s open text.

Question 4 was aimed at finding out how the designers rate the importance of the mentioned research methods. Just like question 3, the options were given as web search, books, magazines and market research. Figure 4.3 shows the mean answer of the respondents towards the importance of the listed research methods. Again, it is evident that the majority of the designers value web search as the most important research method. Here however, it is further evident that strong emphasis is also put towards the inherent contact between markets and consumers through market research.

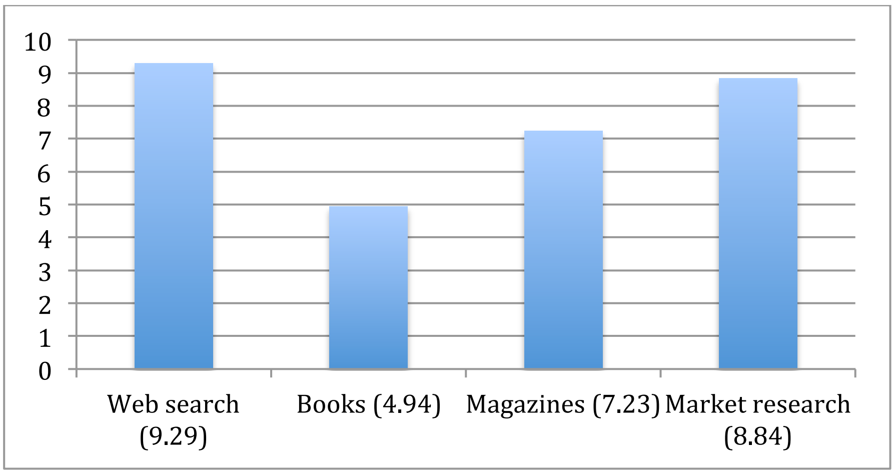

Figure 4.3 Respondent's mean scores to the importance of the listed types of research (question 4).

Figure 4.4 depicts the median answer of question 4. Again, the answers did not differ greatly. However there were more respondents acknowledging the importance of web search as the median score was higher. This was true for all except magazines, where the median actually slightly fell.

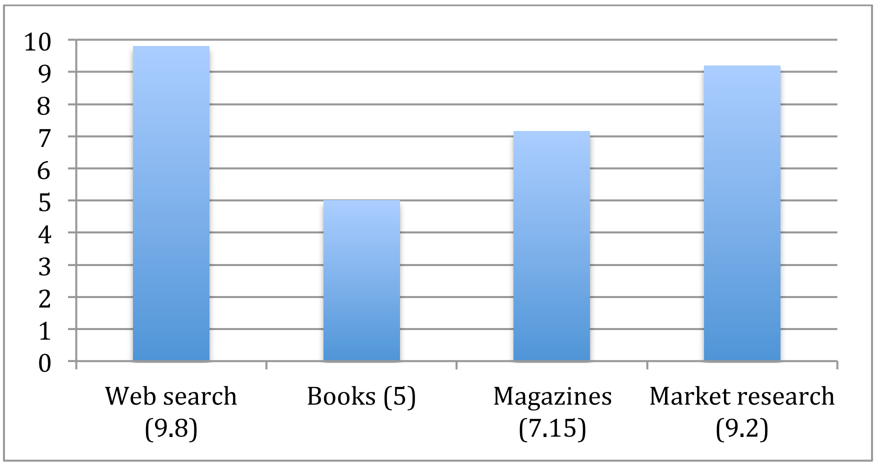

Figure 4.4 Respondent's median scores to the importance of the listed types of research (question 4).

Question 5 assessed how designers integrated new technologies within their work. 13 (65%) designers chose to answer this question. As this was an open question, various answers came about, and some of the comments were pulled out as the most interesting towards the aim behind this thesis. These comments were:

> "Always eager to step up to new ways of working if the working process is improved or a benefit is foreseen".

> "Trying to be key user/first time trainee in order to be able to give input and help to design new tools".

> "Technologies for our daily design work starts mostly around the development phase. I try to learn from past failures".

These three comments show positive attitudes towards the integration of new tools, however, most of the other comments bluntly stated or conveyed that; "it's usually hard to implement" or "I don't know much about it, therefore I only use what I already know, when not forced". The success rate of question 5 was rather poor, and has therefore not been evaluated in further detail.

Question 6 asked if designers were personally interested in sustainability. As seen in Figure 4.5, nine (45%) designers selected a score between 9.1 and 10. Additional four (20%) designers selected a VAS score between 8.1-9, indicating that 65% of the designers chose a very high score rating their interest in sustainability. This shows that most of the respondents are positive towards sustainability. The lowest score was 4.5. The mean equaled to 8.27, while the median equaled 8.55, meaning, again there was not much difference between the participants selected VAS scores. The graph below further highlights the male to female ratio of the responses. The ratio has not any significance as both female and male respondents answered varied, meaning; no clear line was draw between the sexes. The scale below shows the number of respondents on the y-axis.

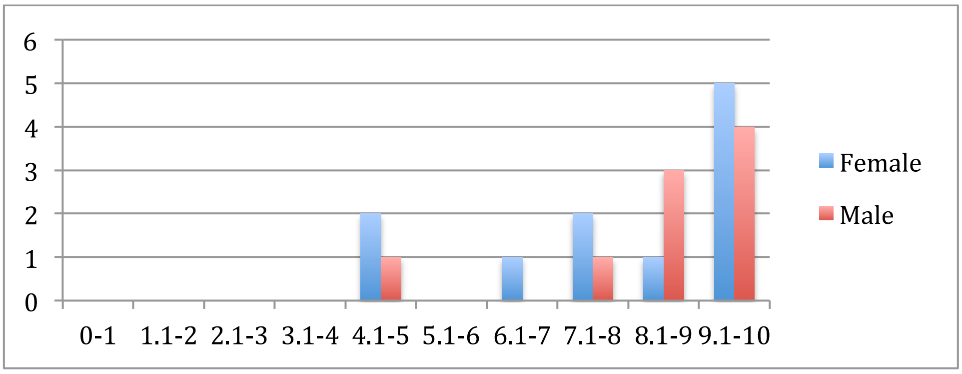

Figure 4.5 Amount of female/male respondents selected VAS scores according to their interest towards sustainability.

Question 7, again an open text alternative, asked the question; what is the most restricting factor to design more sustainably? Classification of the answers showed that eleven (61.1%) of eighteen designers found price to be the key factor for not being able to implement sustainability within their designs. The answers ranged from money, margin to FOB (freight on board), however all answers refer to the fact that monetary value (price) trumps environmental initiatives. Other comments ranged from; "it restricts the looks" to the fact that there are often "no follow up, when trying to be sustainable, nor no incentives to act sustainable".

Question 8 was divided into two separate sections, one containing a VAS and one open text, allowing designers to both score their perception and to fill in why they thought so. Question 8 asked; would you think there is a need to help designers incorporate sustainable design practices? Figure 4.6 depicts the responses, showing that seven (35%) of the designers feel there is a strong need to help designers incorporate sustainable design practices. However, eighteen (90%) of the designers have a score above 5.0. Only two (10%) feel rather indifferent as their scores amounted to a VAS of 3.8 and 5.0, respectively. The graph below is further divided into female to male ratio, to distinguish any dissimilarity between the two sexes. This however does not seem to be the case as female to male ratio is rather wide spread, meaning, sex did not matter for the asked question. Or, it shows that the sample size taken was too narrow. The scale below shows the number of respondents on the y-axis and the VAS on the x-axis.

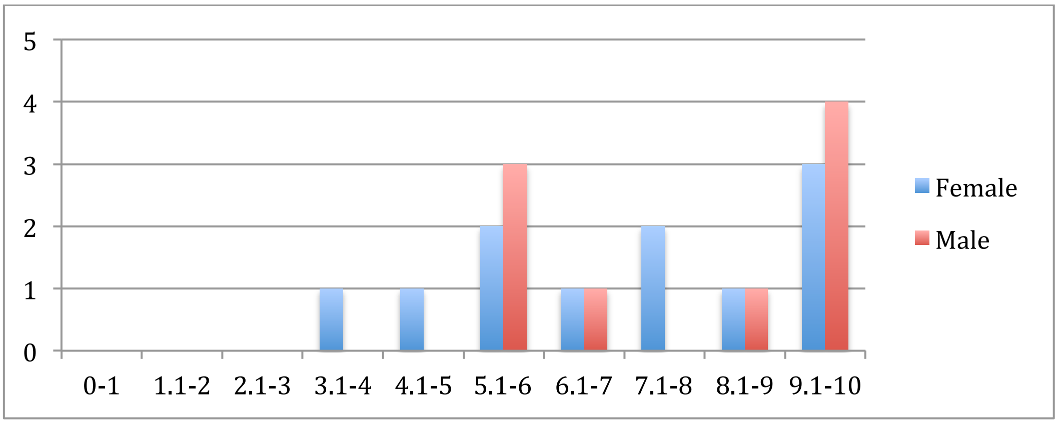

Figure 4.6 Amount of respondents selecting VAS scores according to their perceived thoughts about helping designers incorporating sustainable design practices.

The open text enabling designers to comment on how and why sustainability could/should be incorporated, illustrated that pricing and marketing seemed to be a restricting factor. Marketing here refers to the marketing department, from which design briefs originate. Answers to this question varied greatly, and some interesting comments are worth mentioning:

> "Designers don't know what to do. They would need a person that's an expert (in sustainability). Would need workshops to gain knowledge and more transparency in who knows what and is doing what."

> "Time is short in the design process so we would need a tutor to help us quickly with making our ideas sustainable. We are good at doing stuff the old way, but sustainability means to develop new skills. Help is efficient."

> "I think most designers are conscious about it (sustainability), but creating a sustainable product involves a lot more than just design."

> "People need to be educated and encouraged."

> "Its not rocket science. In the end we need to be offered more variety in choosing sustainable materials and processes still affordable within the FOB."

> "I think its important to be more sustainable, but price often kills that aspect. I think there needs to be more focus on it (sustainability) from higher levels. I also think it would be helpful to educated designers more, through focus groups for example."

> "All designers will have an interest, but they probably don't know how!"

Question 9 mapped the designers' prior engagement with sustainability by asking if they ever had worked with a sustainable project within the company. The results illustrated that 15 (75%) of the 20 designers had previously worked with a sustainable design project. It then asked what type of sustainable tools they referred to the most. Here the answers ranged from an internal scoring system, DfE guidelines and a sustainable material library. There was also room for adding more tools if the designers utilized others through an open text option. In Figure 4.7, showing the mean, it is clearly evident that most sustainable design tools are rarely used. The system most in used proves to be their internal sustainable material library, however, this is still considered to only be utilized at an average of a VAS score of 4.9. The utilization of DfE guidelines seems almost non-existent.

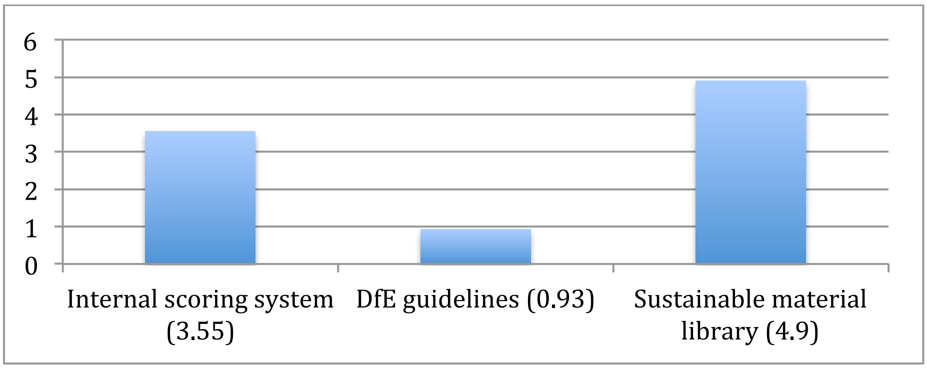

Figure 4.7 Respondent's mean scores to how often they utilized sustainable help tools (question 9).

When looking at Figure 4.8, which depicts the median, one can see that that the answers do not differ greatly from the mean. It must be noted that four (20%) designers did not have an answer for any of the noted sustainable help tools as indicated above, and left the spaces blank. This is however not taken into account when calculating the mean/median, as this would skew the results.

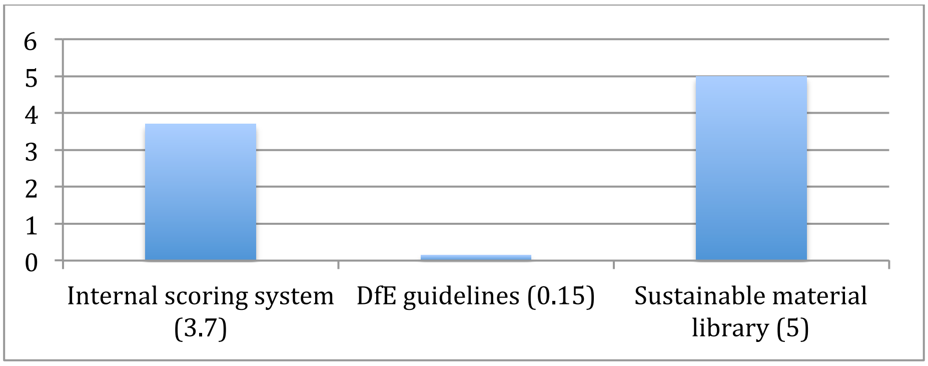

Figure 4.8 Respondent's median scores to how often they utilized sustainable help tools (question 9).

The last question within question 9 (which was a yes/no question), asks if designers had ever taken part in informal sustainability meetings within the company. 13 (65%) of the designer's answer that they have taken part in informal meetings related to sustainability. 6 designers answered that they have not taken part, while 1 designer did not have an answer.

Question 10 asked if the participating designers actually would have an interest in utilizing a sustainable design tool within their design process. Figure 4.9 shows the designer's interest according to their VAS scores. From this figure, it is evident that the answers varied greatly. Still 12 (60%) designers scored a VAS of higher than the middle score of 5. Yet, 8 (40%) designers were either equal or lower than the middle score. The mean VAS score was 6.32, while the median was slightly higher at 7.3. Question 10 also outlines the female to male ratio, however, again it is shown that sex did not matter in this survey. Do note that the scale below shows the number of respondents on the y-axis and the VAS on the x-axis.

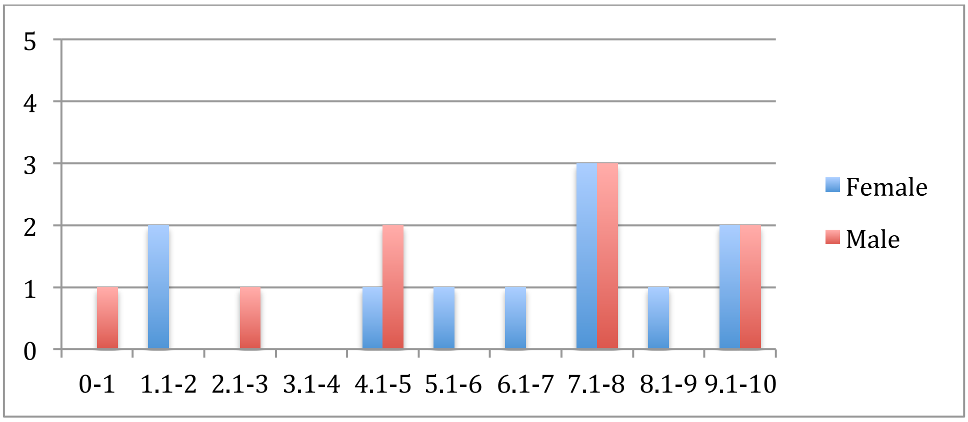

Figure 4.9 Designers interest in utilizing a sustainable design tool in their own work (question 10).

Question 11 continued from question 10 by asking; what features would designers want to see integrated within the new tool? Here the alternatives were the internal scoring system, a sustainable search engine, DfE guidelines, calculations and a data bank/idea corner. The sustainable search engine was further explained as "helping you find information/ideas fast", while the calculations were explained with examples such as LCA or other environmental calculators. The data bank/idea corner was explained as a place where ideas, picture, and/or projects could be shared. Further, an open text option was included to let designers bring their own input. Here again some designers chose not to answer (3 regarding the internal scoring system, 2 regarding the sustainable search engine, 3 regarding the DfE guidelines, 3 regarding the calculations and 4 regarding the data bank/idea corner). These absences are not calculated within the mean or the median. In figure 4.10 it is evident that the most favorable feature was the sustainable search engine, which received a mean VAS score of 8.11. Their internal scoring system, DfE guidelines and the databank/idea corner, all score above the middle VAS score of 5. To include calculations was however not well received throughout, as answers differed greatly (see Figure 4.11). The answers actually ranged from a VAS score of 0.2 to a 10. The internal scoring systems median also differed from the mean, where VAS scores ranged from 2.3 to 9.5. Figure 4.10 and Figure 4.11 both depict varied answers both from within the mean/median, but also to each other. Designers all had various views on what they personally preferred to be included within a new design tool.

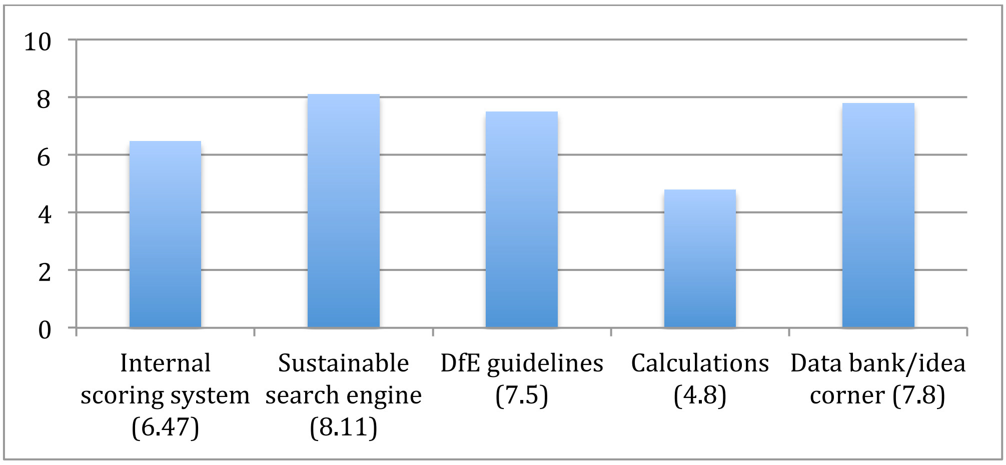

Figure 4.10 Respondent's mean score to their desired features within a sustainable design tool (question 11).

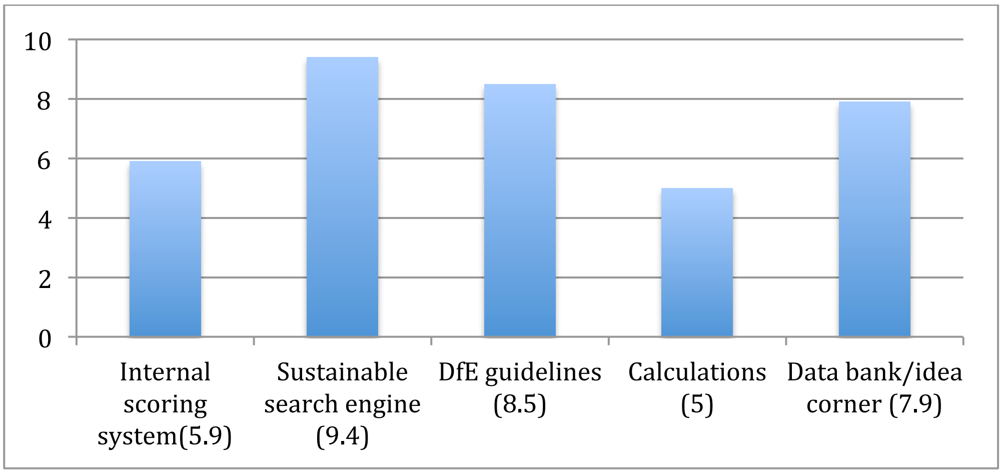

Figure 4.11 Respondent's median score to their desired features within a sustainable design tool (question 11).

4.1.1 Summary: Questionnaire

Whilst summarizing the main findings within the questionnaire, it is evident that answers, however often varied, all illustrated that designers would embrace the notion of increased sustainable design activities. Web search was deemed to be the most prominent research method, due to its availability and mass quantity of various information. It was however also understood that designers really embrace engagement with user groups through market research, and highly value its potential. One would not be able to include market research within a physical design tool, but it should rather be encouraged to achieve its fullest potential. Understanding the whole process of how designers integrate new technologies showed difficult, as all had varied answers. Price was deemed the most restricting factor towards sustainable creativity among designers. Almost all (90%) of the designers questioned reacted positive towards further help with designing more sustainable. Throughout, it was understood that designers wanted more professional help and incentives towards environmental action. It was further noted that when introduced to an actual tool, which would assist their work, the number of participants that initially all was positive, declined to about a half. The most desired feature was a sustainable search engine, followed by a data bank/idea corner and a clearer understanding and inclusion of the DfE guidelines.

4.2 Sustainable design model

The result of the research into existing design models and processes combined with the recognized need for interventional environmental thinking enabled the creation of a sustainable design process model that covers the conceptional design phase whilst fully integrating sustainability in a manner that ensures the designer considers, researches, evaluates, and incorporates sustainability based thinking into their designs before moving forward. The full sustainable design process model can be viewed at the end of the result chapter in Figure 4.17. The created model consists of three different segments, namely research, concept generation and criteria. These three segments will here be described separately, in an attempt to break the following model up for the readers' ease. The individual boxes have been identified with a color-coding scheme, which correlates to the set colors in Figure 4.12. The color-coding refers to which process model individual steps originate from. Whenever there is a box outline colored in red, it originates from the design process model created by Pahl & Beitz (1996), blue refer to the three-step model created by LaBat & Sokolowski, and whenever information comes from both of the two mentioned models the box outline is colored purple. Any information that is not present within both models has been deemed green, which refers to the authors own contribution, as it either comes from own experience or has been derived during the study. These steps are present to highlight sustainable aspects within the model.

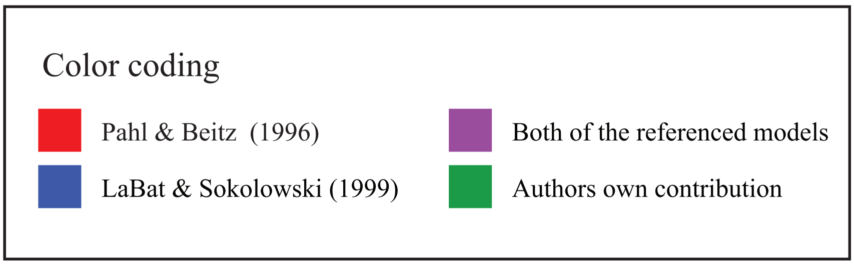

Figure 4.12 Color coding within the sustainable design model

4.2.1 The research phase

The first segment within the model has been named the *research* phase. This phase covers the initial research phase based upon the given design specifications, as is seen in Figure 4.13. When starting research, one has to understand the underlying problems; therefore, to identify the essential problems has here been outlined as the initial step. When the initial problems have been assessed, the user's needs in regards to function, aesthetic and economic factors have to be considered. These steps refer to issues such as; who is the market group, what is the function of the product, what color schemes would the targeted market group prefer and who, in the end, would be able to afford the product? The market group is often addressed within the design brief itself (specifications), so this step is rather doing research towards the selected target group. When assessing the current market, one would research similar products, competitor products, activities and economic conditions, which goes further into understanding the target group. Here, an additional step is added, namely researching existing sustainable products and processes to get an understanding into the larger environmental impact the proposed product may or may not have. When all of the above stages have been completed, the next step in the model (the diamond shape) ensures that the designer has conducted the necessary steps, and from there, one either move forward within the model, or show that one would have to reassess the research. These steps are commonly referred to as *gut checks*, and are a stage in the design process where designers meet, and discuss their progress, designs and direction, to assess their current state. If the design team is satisfied with the current research, the next step moves to the next segment, namely the concept generation.

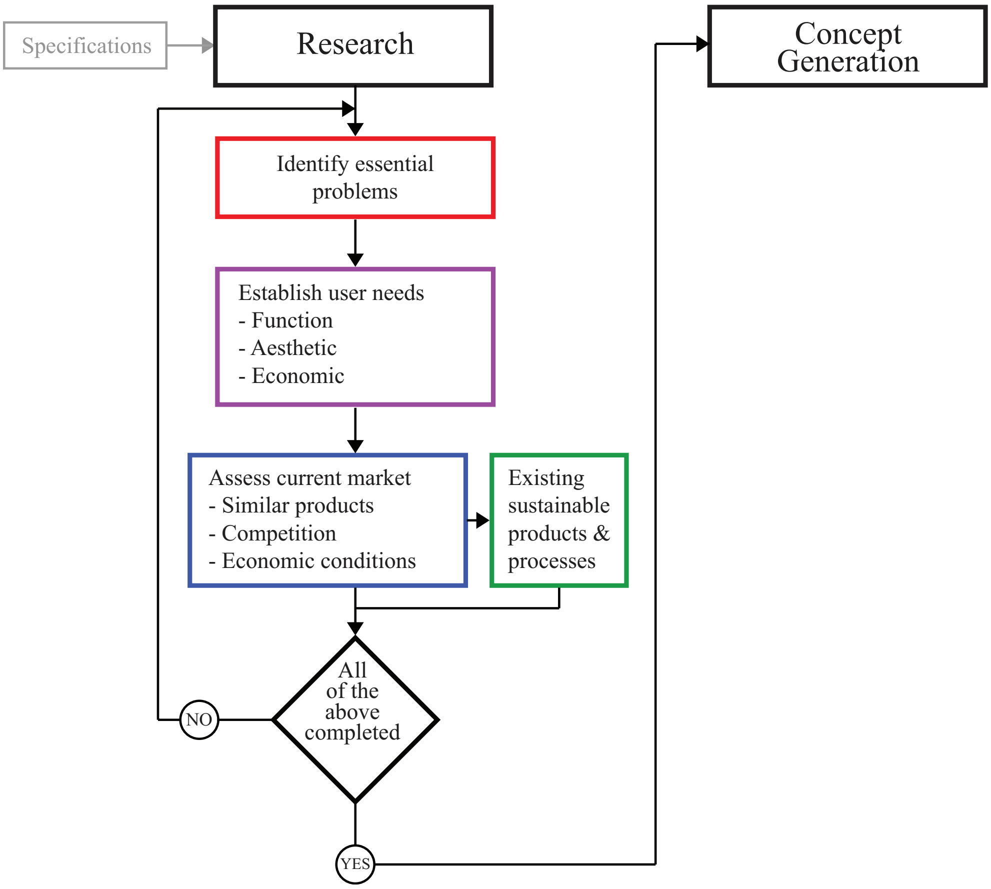

Figure 4.13 The first segment in the created model: The research phase.

4.2.2 The concept generation phase

The second segment is here coined as the concept generation phase, as seen in Figure 4.14, below. Within step one, the creation of concepts refers to the generation of ideas. Before a design is chosen, a multitude of variants need to be assessed. Having a multitude of variants increases the success rate of the final product, as it shows that all aspects and versions have been considered before choosing the most appropriate solutions towards the design brief and the target market. This step is often conducted individually before coming together and discussing the variants of the concepts. Collaboration within the concept generation phase is essential to build diverse innovative concepts. Step two is here coined as design refinements, and is the stage in the process where all the loose concepts are gathered and translated into more tangible ideas. Sketches, storyboards and color themes are all ways of communicating loose concept ideas. These concepts are usually communicated to a larger team and/or “higher ups” to approve of the selected concepts. The next step (the diamond shape), as the previous phase, ensures that the designer has conducted the necessary steps.

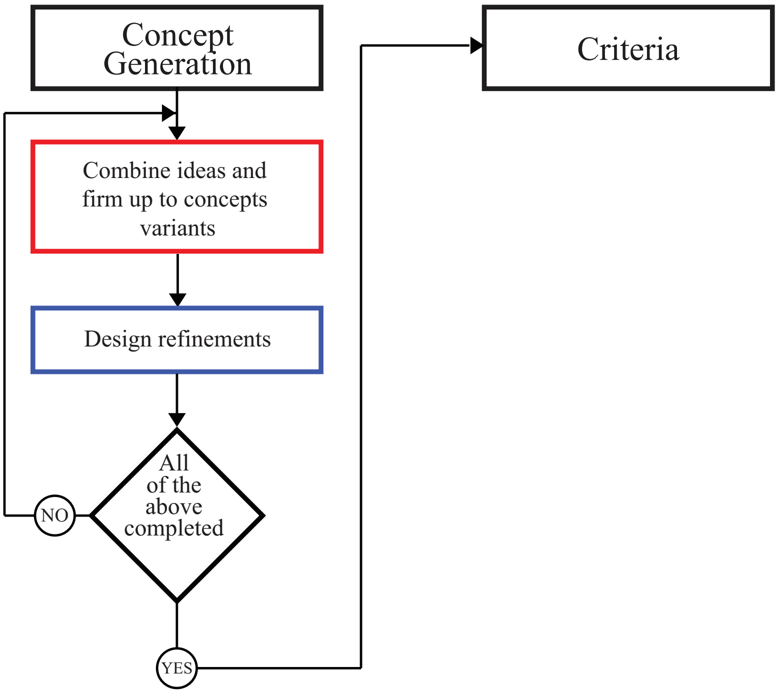

Figure 4.14 The second segment in the created model: The concept generation phase.

4.2.3 The criteria stage

The final segment is dubbed the criteria phase, as shown in Figure 4.15. This is the stage where the final criteria are re-checked and assessed in regards to the existing specifications, to then be able to move forward within the design process. Three steps have here been outlined as the most crucial. The functional step is to ensure that all that the initially planned and intended functional features of the product actually exits in the final design. Take for example the creation of a basketball, if it does not bounce, its function, namely playing basketball fails, and therefore the product fails. Functions are essential to any success of a created product. The economic stage would deal with the overall cost of the creation of the product, as well as the intended sale prices towards the targeted market group and country. The sustainable stage is added here to emphasize the importance of the environmental criteria that should be addressed within the conceptual phase. The environmental factors that needs to be addressed range from the production process to the utilization of materials. When all of these criteria's have been assessed and met, the process model jumps to the next segment of the production process, namely the embodiment design. However, if these steps have been deemed unsatisfactory (gut check), the conceptual design phase needs to be reevaluated, by revisiting the first or the second phase.

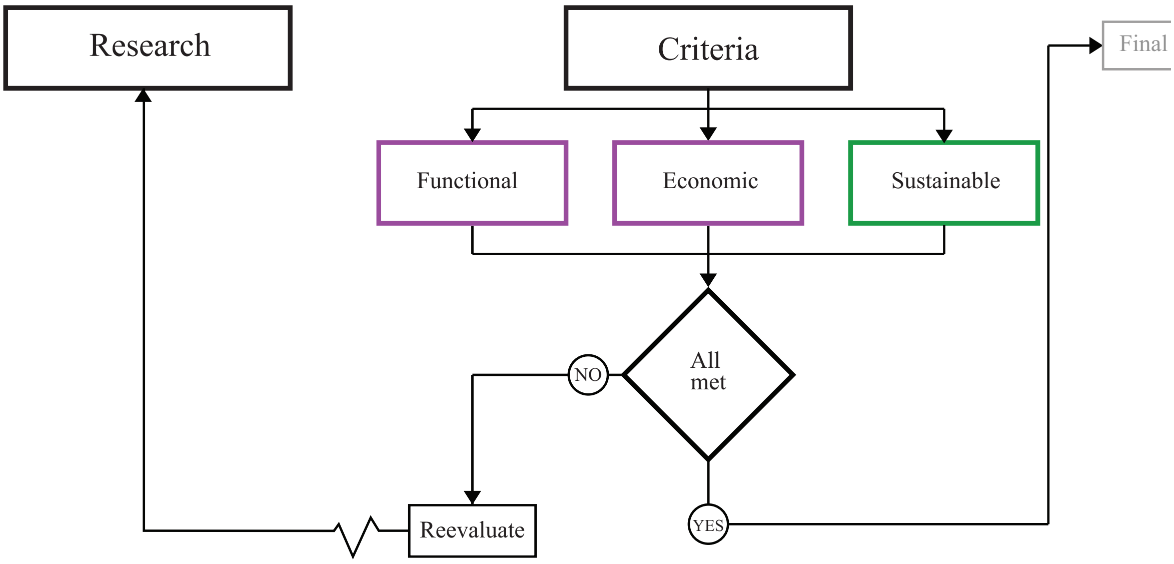

Figure 4.15 The third segment in the created model: The criteria phase.

4.2.4 Design tool intervention

Figure 4.16 depicts the different segments within the created sustainable design model, including what kind of strategies or tools that could be beneficial for those certain steps. Within the *research* phase, numeral studies outline specific sustainable search engines as highly valuable; the use of these therefore gives the designers the advantage of getting the right information at a desired speed. Also, the inclusion of teaching tools or guidelines would give designers ideas regarding where to look, or more specifically what to look after while conducting research towards previous existing products, solutions or processes. Figure 4.16 helps explain how the proposed tool would work, and in what stages of the process different features would be useful.

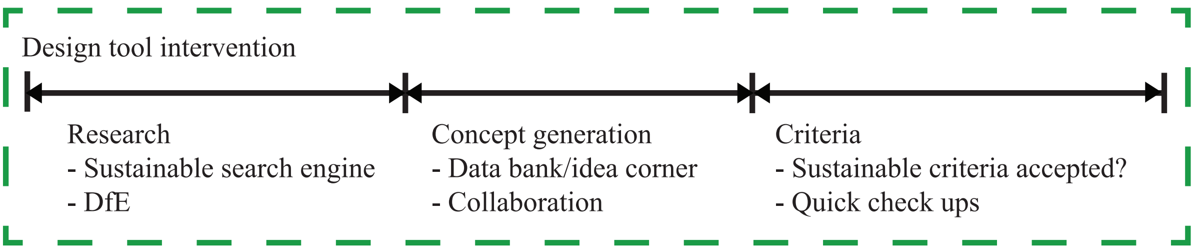

Figure 4.16 Design tool intervention: The three segments.

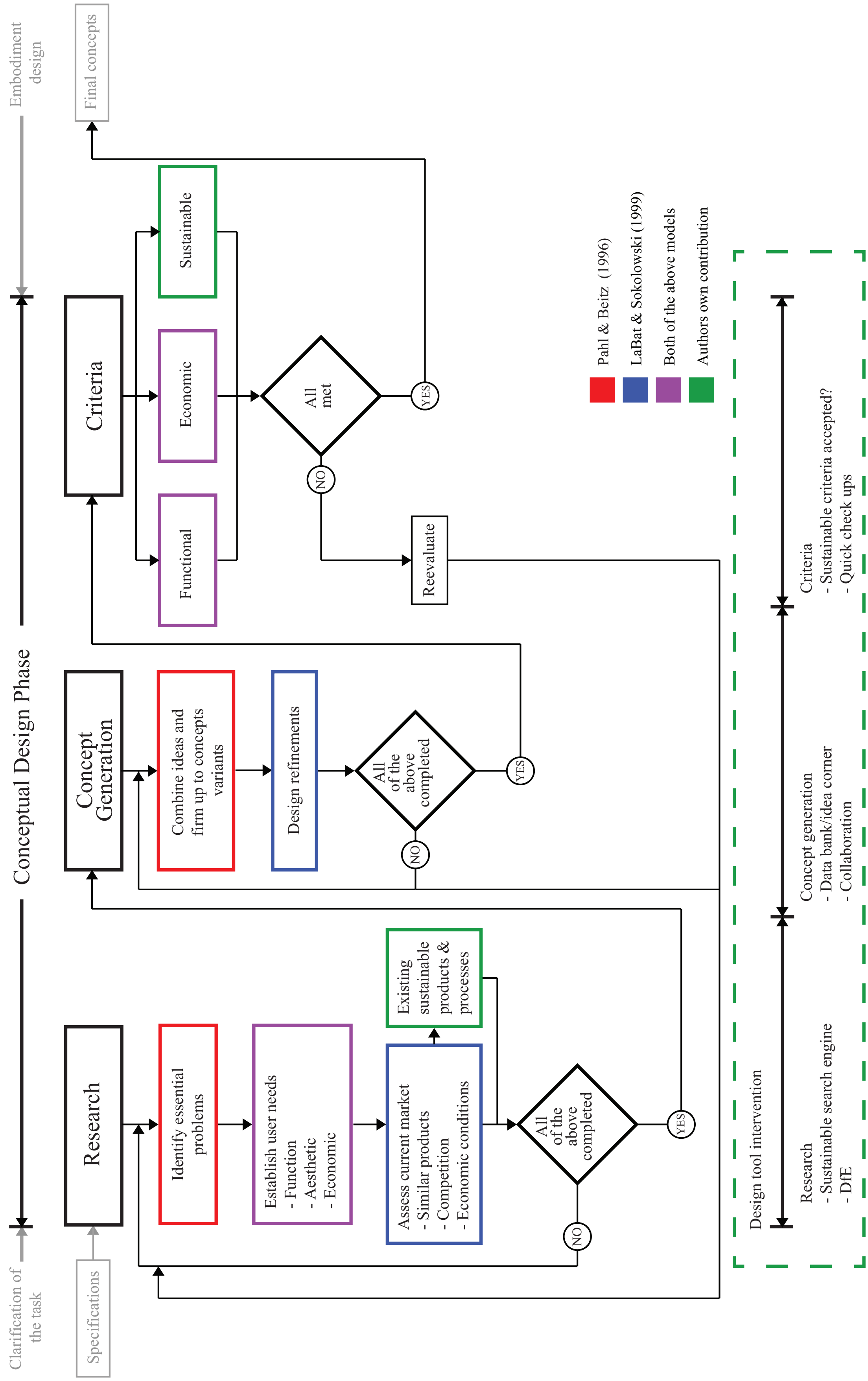

Figure 4.17 The sustainable design model.

4.3 Proposition

A proposed solution is discussed below to give future studies and/or private companies the insight to what would be needed within a sustainable design tool, targeting the conceptual design phase. As it was identified that an Internet based CAD software proves to be the best way to accommodate all the necessary specifications related to environmental practices, creativity, collaboration and the conceptual design phase, the proposed solutions suggest an Internet CAD tool that embodies these notions. The following section depicts numerous of considerations towards the creation of a successful conceptual collaborative sustainable design tool. Research, learning and collaboration have been pulled out as the main contributors towards a successful sustainable conceptual design tool, and have therefore been assessed individually. All figures within this section are meant to represent a potential solution, however, they have only been created to help explain potential solutions, and should therefore not be utilized as a final guide in the creation of a future tool. All of the created images are the authors' own work. Figure 4.18 depicts a simplified "main page" for the tool, in order to gain some initial understanding towards the potential layout of the tool. Imagine that this is your main page; this is how it looks like when starting up the tool.

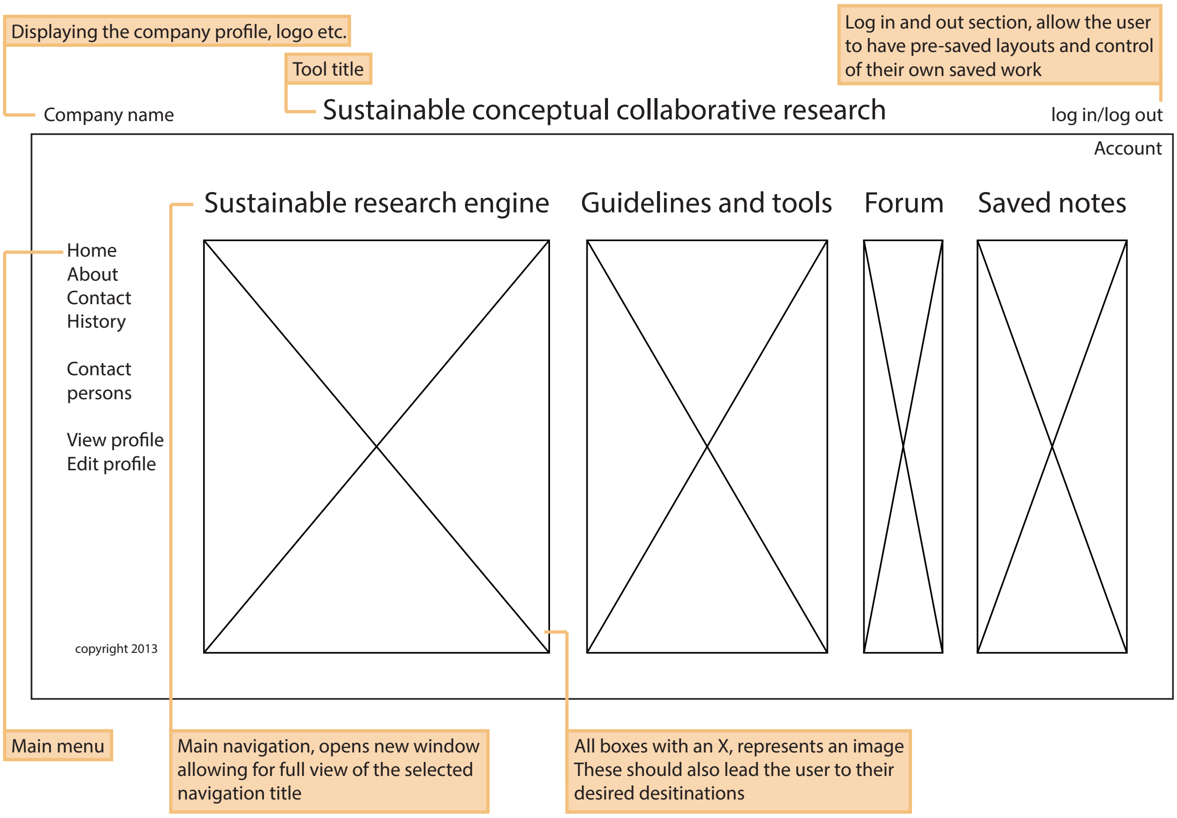

Figure 4.18 Simplified main page

4.3.1 Research

Exploratory sustainable research

Any tool that is created for the purpose of encouraging sustainability must allow designers to quickly understand and get updated with news on sustainability, sustainability practices and processes, to then be able to apply them within their creative work. It is therefore suggested that a search engine with a pre-defined sustainability search criteria to be implemented within the tool. The pre-defined criteria should be accessible for customization by the individual user, however, for the ease of use, it should also contain up to three different pre-set criteria's, as e.g. (1) focusing on sustainability in general, (2) focusing on materials and (3) focusing on processes. To give an example (Figure 4.19), if a user would search for the word *yellow*, within criteria 1, search results should highlight anything which deal with the color yellow; such as sustainable dying processes, new inventions towards the color, existing sustainable yellow material and research in the design, technology and biology field. Imagery as well as journals and web pages should be easily accessible and also further customizable according to the desired outcome, as seen in Figure 4.20. Search results should be presented by ranking, clustering, partitioning, annotation, tagging and marking. Viewing many relevant search examples at the same time is also good practice as it allows for instant recognition of the desired outcome. Numerous journals and the present questionnaire highlight that exploratory sustainable search engine is a must for any new tool targeting the conceptual design phase as it allow designers to research quick, and get their desired outcome in a fast an precise manner. Conducting research online is therefore deemed the most appropriate due to its hasty speed acquiring research and the limited time span a designer actually can spend on research.

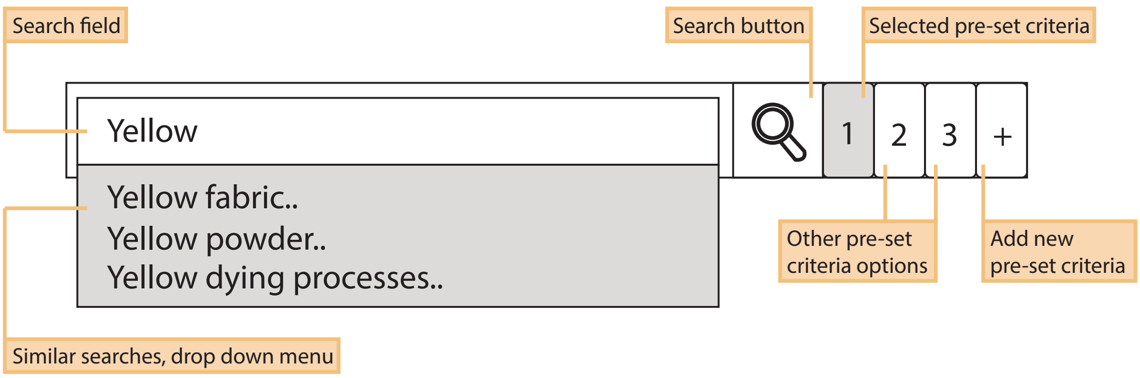

Figure 4.19 Sustainable search engine proposal step 1.

Figure 4.19 depicts a "+" button, this button represent the option to add new pre-set criteria, this could either be done by the individual designers or conducted by the design community or the design firm, and then shared within. The pre-set criteria should be open for individual edits and customization.

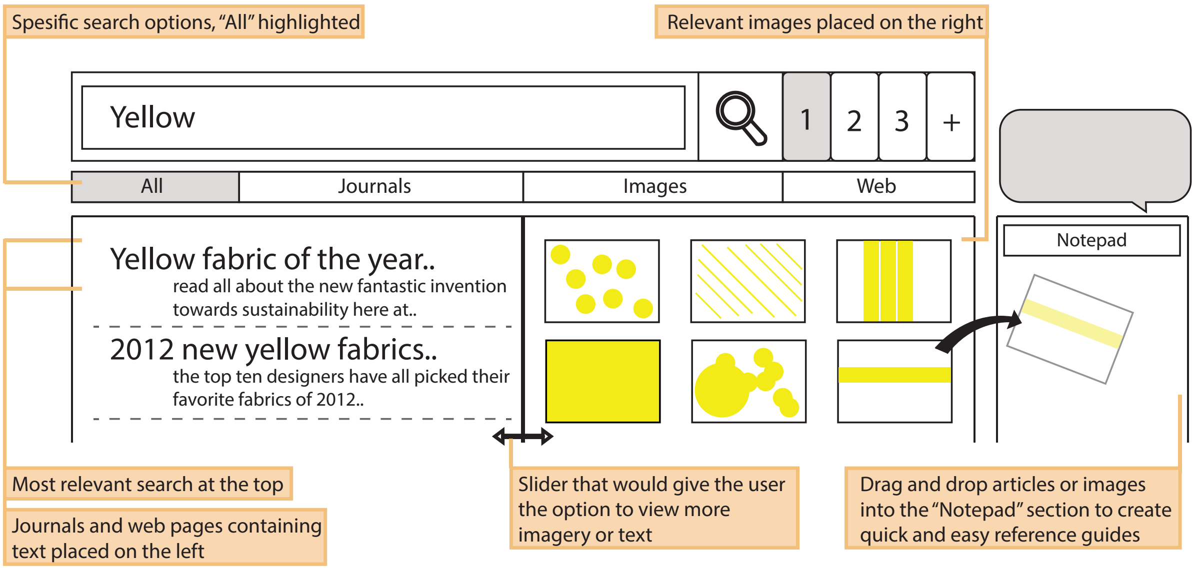

Figure 4.20 Sustainable search engine proposal step 2.

Figure 4.20 display a "Notepad" section, in which designers can drag either images or links to create their own *thought* boards. This gives them the option to create, save and share their sustainability research thoughts in a quick and easy manner, allowing for enhanced collaboration within the research phase and shared creativity. The overall layout should be easy and understandable, and should therefore either mimic other search engines that are familiar to designers, or contain the same hierarchy and order for the users ease.

4.3.2 Learning

Guidelines

Within a tool, the user should be able to get helpful tips towards potential solutions, not only through thorough research but also through educated help. It is therefore suggested that the *12 principles of green engineering* and the *Ten golden rules*, together with the DfE initiative, subtly teach designers towards better practices and research possibilities. It is suggested that the three guidelines would be easily accessible within the portal as images or documents (giving option for a numerous of file formats such as .png, .jpg or .pdf to name a few), but also as "tips" which would occur whenever the portal would either load (if necessary to recover large quantities of data), or on the side, when research criteria would be similar to any of the guidelines within (as seen in Figure 4.21). Within the "tips bubble", tips from all three guidelines may be present, depending on which would best match the search criteria (this would have to be coded within the portal). Together with the guidelines, it is suggested that not only the individual statements on how to be more sustainable to be present, but the tool should also highlight solutions to these statements, as often statements may not be that easy to decipher for a designer without prior education in sustainability.

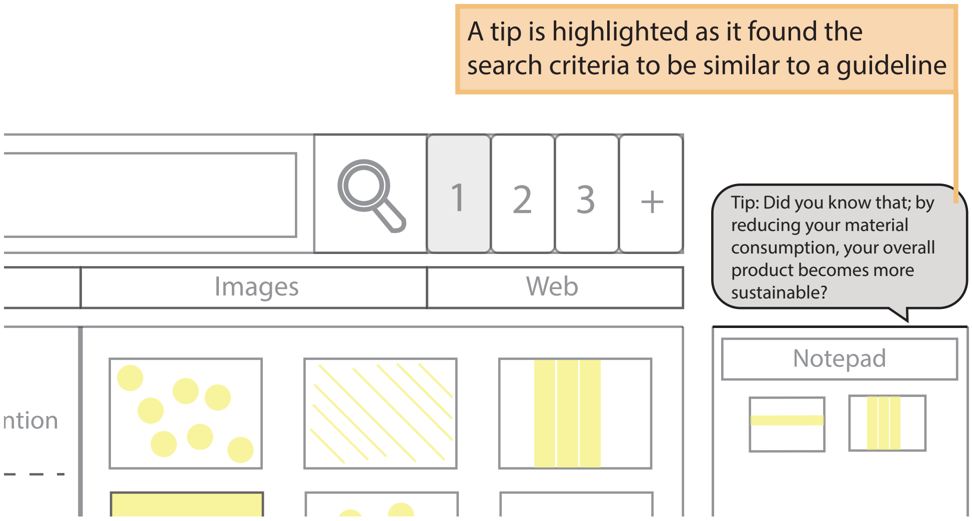

Figure 4.21 Potential solution to subtly teaching designers about environmental solutions.

To achieve a successful implementation of learning through guidelines, it is important that set goals are easy to define for the designers, to understand what is necessary to implement within their design. This way, designers understand what guidelines are relevant and what they should try to achieve. It is further necessary that designers can ask an expert in sustainability direct questions, either in person or through the online community, which can help with pressing and often troubling issues. It is therefore suggested that the online portal, within the forum deploy pre-set *threads* (main titles within a forum, explaining its purpose), which e.g. would contain a Q&A (questions and answers) where designers would be able to reach an expert as well as the entire online community of designers with their questions. If issues are pressing, experts should have their contact information such as company email and phone number easily accessible. The forum is here thought to be similar to that of a data bank/idea corner, a place where ideas are shared and questions answered.

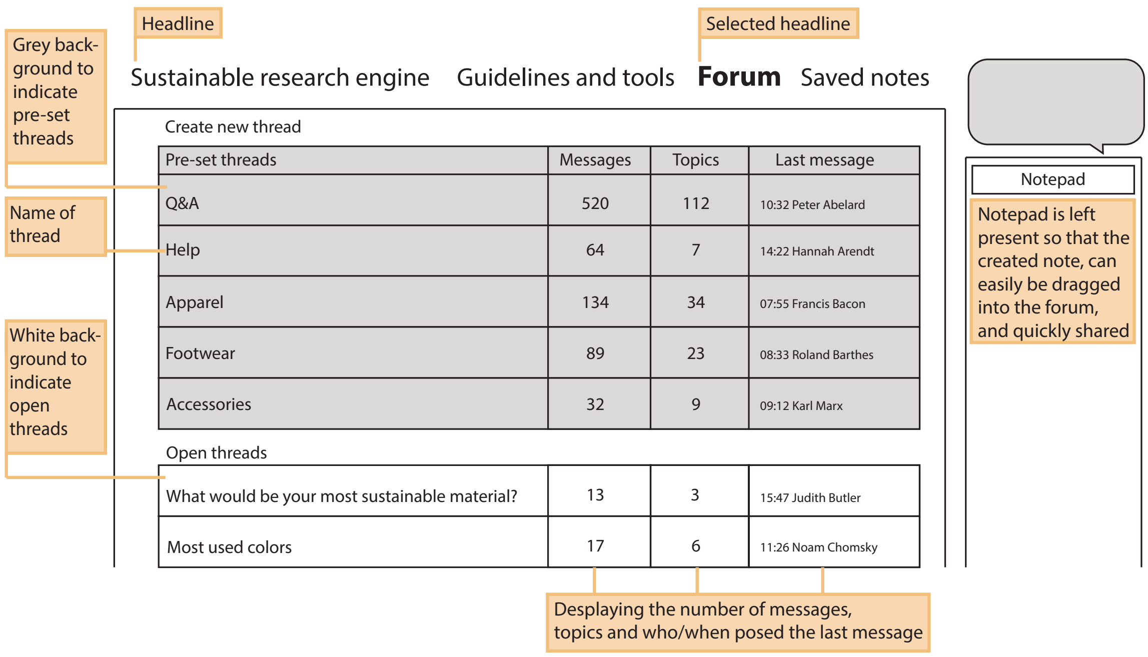

Figure 4.22 Displaying a potential layout for a Forum within the portal.

Figure 4.22 illustrates how a potential forum could look like. Here, pre-set threads are presented at the top section and are further indicated with a slightly grey background color. This forum is further divided into the main parts of how a company could be structured, such as an apparel department, footwear department and accessories department. This allows designers to easily find threads that are relevant to their specific work. The present notepad section is still visible to allow designers to move back and forth within the portal without loosing their created research notes, and to then be easily able to share it with others without saving it (it is also suggested that it auto-saves, in case of sudden computer crashes or other troubles that might occur).

Ease of use

Even though it is quite obvious, attention must be spent on how the user navigates and interact with the tool. Failure to capture how the user interacts with the tool might prove catastrophic for the potential success of the tool. Therefore, the usability must suit the needs of the user. It is common that the development team neglects the way the designers interact with the tool, and only focus on how they work with it; this may further prevent designers from adapting the tool (Narayanan, 2001). The user should also be given the option to customize the interface and features after the users specific needs. By doing so, the user gains a sense of power and freedom towards the tool, and with it, a stronger desire to utilize it towards the intended use. It is suggested that basic design principles to be utilized, such a common grid patterns, color coding, unity, balance, scale and hierarchy. Further, to involve the designers that will actually be utilizing the tool is highly recommended, as the designers then feel included and empowered. Designers already aware of the tool and the "look" would be more engaged with it initially as they have helped develop it, and therefore know how it works. This also reflects the view of one designer from the questionnaire, which answered the below statement to question 5:

> "Trying to be key user/first time trainee in order to be able to give input and help to design new tools".

4.3.3 Collaboration

Collaboration without borders

As collaboration has been established as an important aspect towards enhanced creativity, collaboration should be embraced and its challenges solved. Dealing with collaborating activities can, for some, be challenging, as creativity may not come as easy for everyone, as individuals share their ideas one at a time, and therefore others might suppress or forget their own, fear of criticism and free riding may all hinder the creative collaborative approach (Diehl & Stroebe, 1987; Osborn, 1957; Lamm & Trommsdorff, 1973). To tackle these problems, this thesis proposes the utilization of a collaborative environment through the use of an Internet portal. Many of these common challenges can be dealt with through the use of collaboration conducted through an Internet portal, be it forums, chat rooms or shared views towards projects. Projects should give the option to save, share, and from there it would have the capability to reach around the globe within seconds. Briefs should be visible to a multitude of designers with different skillsets, which from there has the option to choose to contribute with their specialized skillset. It is then easy to discuss the problems that occur, fast and precise, as comments and feedback can be discussed online before a potential final meeting in which the decided upon concepts would be brought up, collaboratively. With this, attendees would already have an idea of what the project would be about, the problems that occurred, and from there see how the solution evolved though the help of a group effort. This does not only enhance the creativity, and raise the confidence within a team, but also saves valuable time. Further, within a portal/forum in which the project would be shared, the different steps and contributions are indicated, as the record history is kept, and one can therefore re-trace who contributed to what, which allows for comparisons and potential modifications. If problems arise in the future which embodies the same problems, individual designers would know who to contact for help, and therefore speed up their design processes. With sustainability, as mentioned within the implementation chapter, it is encouraged that a couple of sustainability experts to be available for help and feedback. These experts should be highly engaged within the online forums to get ideas bouncing from designer to designer.

Incentives and recognition

Throughout the research, the questionnaire and in-depth discussions with designers, it became evident that designers wanted recognition when actually going out of their way to design more sustainably, as it is viewed as “extra” work. The questionnaire gave a couple of answers towards the desire to be motivated and get recognition; they all amounted to the same answer:

> “…someone needs to get credit for it as motivation”.

In theory, one might see this as a negative trend, as designer’s view sustainability mainly as extra work. However, one can also try tackle this problem, first off all by deeming sustainability a norm rather the exception, and from there, reward designers for exemplary efforts towards sustainable ideas, contributions and collaborations towards final sustainable products through the proposed tool. The point is not to only bring forth bonuses through gifts and monetary incentives, but to create a culture that regards the efforts of the individual designers as valuable, and thereof gain a thriving sustainable culture as a result. This thesis proposes a scoring system, where others can rate the importance of the individual designers own work, or contributions towards a final product. Points could also be earned through engaging with the tool e.g. time spent “logged in”, comments posted, threads started, files shared, ideas generated etc. The end result would then amount to designers obtaining their own scores, showing how much effort they have put towards sustainable efforts. Lists could from this be created to highlight the most educated and engaged designers, in an attempt to create sustainable designer leaders and a quick and easy way for other designers to know whom to contact with sustainable issues.

5 Discussion

This section discusses the results of the questionnaire, the sustainable design model and the proposed solution to give insight into why certain decisions were taken. It also offers a short segment on potential implementation strategies.

5.1 Questionnaire

Several research questions were asked at the beginning of this thesis; these were all answered throughout the research based on the provided questionnaire and face-to-face follow up questions with the participating apparel designers. The following discussion provides a further understanding towards why designers answered as they did.

Research question 1 asked; how do designers perceive sustainability? This question was asked to assess how designers actually feel towards environmental practices, as without any interest, the proposed solution and further research towards the topic of this thesis would be deemed unsatisfactory. The results illustrated that the majority of designers had an interest towards sustainable design, and its practices. The participants' engagement with sustainable design aspects was further mapped to indicate their perceptions. However, perception towards sustainability cannot necessarily be deemed positive if designers show an interest. They could show interest merely because they know they *have* to, as they may be forced upon design briefs that they would perhaps rather not undertake. Therefore, to measure the designer's perception regards sustainability proved to be more advanced than the author initially perceived. Still, through face-to-face follow up questions among several of the participating designers and a weekly voluntary sustainable design meeting, the author, based on his experience would state that the participating designers perception about the future of sustainable design to be positive. The questionnaire also managed to illustrate how many of the selected participants that felt they themselves, or others needed help towards improving their sustainable design practices. A large majority of the participants acknowledged that further help, through tools or experts would be highly beneficial to improve the environmental aspects within their designs.

Research question 2 addressed how designers conduct research, and gather their information to be able to both complete their designs, but to also defend their choices. It therefore asked; how do designers usually conduct research and how would they rate the importance of their research methods? First it must be understood again that there are only two research methods actually present, as web search, books and magazines are considered to be *one* and market research, the other. They were all called research methods due to ease of classification within the questionnaire. Therefore, of the outlined research methods, web search was concluded to be the most favored, both in most used and importance. This was concluded to be due to the availability, the hasty speed in which web search research is conducted and being able to get the latest information. Designers do not have to leave their chair to research, as the Internet allows for instant access to a million of informational sources. This preferred method is also highly linked to the time constraints put upon the individual designer. From the results it is also evident that designers highly value market research. As this involves traveling to your intended market, this method takes considerably much more time, and can therefore not be utilized in the same way as a quick web search. However, the pay off might be even greater with market research, in terms of connecting with the culture, feelings and the desires of the studied market group. Yet, when it comes to conducting research on environmental solutions and sustainable design practices, market research would perhaps not offer much more than a simple web search. This is due to the fact that within the conceptual design phase, the target market has already been determined, and designers therefore know how to reach these. Still, to uphold sustainable design requirements, they would stumble upon specific issues related to their designs. This is when web search would be considered more valuable than market research.

Having tried to understand the designer's interest and will towards sustainable design, as well as their current research methods, it was interesting to learn why designers would not always try to implement sustainable design practices within their designs. They all had various sustainable design incentives available such as the DfE guidelines, a sustainable design library and an internal scoring system, and having showed interest, why were these not utilized? They all seemed to only occasionally be utilized. Therefore, research question 3 asked; what is the most restricting factor for sustainable design in their daily design practices? Most of the designers mentioned price, their set FOB (freight on board) as the main reason why they often disregarded the notion to add environmental features within their designs. Several follow up questions gave the author the understanding that what they truly meant was that changing their material, towards more sustainable materials, often increased their FOB (freight on board). Having personally worked within the material library on several projects, the author could easily check the given statements. The author did find that most sustainable materials, when similar in structure, fiber and properties, all had a raised price tag. Still, the material choice was their only reason why price was deemed as the most de-motivating factor and there was no indication that they believed other sustainable initiatives (such as trying to minimize use of seams, simplify construction etc.) would be more costly. As research question 3 dealt with obstacles, it further asked; how does new technologies (such as new tools) get integrated with the design process? This question was unfortunately too vague in its explanation, and therefore created a numerous different variables, which was hard to draw statistical information from, and to determine a common trend towards integration was therefore unsuccessful.

Having established an interest, it was crucial to understand how designers would embrace a new tool, as such, research question 4 asked; how would designers embrace an environmental design tool targeting their conceptual design phase? The questionnaire managed to get a wide response from the participating designers. Even though most had stated earlier that they were all in favor for more environmental initiatives and that they viewed sustainable design practices as positive, they now, with the question if they would utilize such a tool, answered more broadly, showing that more designers were reluctant to actually utilize a new tool. Therefore it seems that if asking in general if someone would be interested in sustainability, one would get higher scores than when participants actually had to get involved themselves in the actual tool. This was expected, as the saying "it's easier said than done", surely demonstrates its accuracy. This shows that the participating designers perhaps think another tool would only put more strain on their own work, and not help them further. This is true, if sustainable options would not outcompete conventional ones and if the higher-ups within the organization do not put sustainability on the agenda as set-criteria. The ratio was however 12/8 in favor of utilizing a new tool, but it was not as high as initially expected and hoped.

The last research question, which was intended to be answered by the questionnaire (research question 5) asked; what kind of existing design features would designers have integrated into Internet CAD software to further their understanding and improve their skills towards better sustainable practices? This question basically meant to map what kind of features designers would like to be implemented within a new tool. These answers were highly individual, which show that it would be hard to create a generic tool for sustainable design. One solution to this, as was also outlined within the literature review within the background, was to have customizable design tools, which allow for individual preferences to be upheld. Where tools, features and layouts are customizable, usage is easier, as the individual can set up their own tool to their own set desires and needs. The most desired features were the sustainable search engine and the data bank/idea corner. This also correlates to previous studies stating that allowing or including specified search engines could prove to be crucial for the creation of a new collaborative research tools (Shneiderman 2007). The data bank/idea corner idea rose when discussing the subject at hand with various different designers, and is also further evident through the questionnaire, as there was a consensus to improve transparency, regarding projects and who within the company holds what skill. The data bank/idea corner would therefore let designers with sustainable ideas post them e.g. within a forum, and others, with similar thoughts could contribute and come with other valuable skill sets. From there, a new project could be commenced, with a sustainable base and a collaborative effort. There was also a consensus that DfE guidelines should be included, which shows that even though they are not regularly used, their format might be the problem (here being on paper). Going from paper to digital might solve the issue. The least wanted feature included calculations. This would perhaps be due to the connotations calculations come with, namely mathematically intensive and difficult complex equations.

Last, it must be understood that to give direct scientific answers towards perceptions given by designers proved to be difficult, mostly due to the highly interdisciplinary and creative client base that was questioned. As such, it was understood that design cannot be treated as one would e.g. treat math, there are often no obvious correct answers, as most designers initially act on gut feelings towards how certain problems should be dealt with. Yet, through the utilization of the VAS methodology, perceptions were captured, and are therefore suggested as s potential methodology to be utilized in other studies. VAS however, is usually utilized in regards to medical research (perception of degree of pain in patient etc.) The author found VAS to be a good tool to capture perceptions and see its potential in sustainability and its aspects in an effort to determine its progress. It must be understood that with any perception based methodology, it can be a biased process and attention must be taken to observe and note all actions taken.

5.2 Sustainable design model

For the sustainable design model, only one research question was asked, namely; how can a conceptual environmental design process look like within the apparel industry? This was asked due to the apparent lack of existing design processes incorporating sustainability within the conceptual phase. The new sustainable design model portrays a conceptual design phase incorporating environmental factors, and by doing so, it gives a sense to where and when in the process decisions needs to be taken before continuing with the design process, and where certain design strategies or tools would be utilized. This model's main function is to be able to view the conceptual design phase in its entirety. Implementing sustainable design practices should therefore be easier to understand, as it is evident where they should be considered. The author feels this model gives an improved understanding compared to process models that already exists, as the existing processes all take on general attributes, and it is therefore up to the user to adapt and manage what they would feel is necessary. Following this simple model, other specific design processes could be adapted to suit the existing environmental needs of different companies or industries. It is still important to understand that the provided model has not been tested, and as such, should not be utilized until reevaluated and further testing is conducted.

5.3 Proposition

Given the result section provided above, it is again necessary to understand that there most likely will be many more innovative solutions towards the inherent environmental problems within design, and towards the conceptual design process. This should be discussed and solved within a collaborate environment, to cater successful innovative ideas and to further understand the needs and desires of designers. To improve and expand on the given proposition is highly encouraged. However, creation and implementation of the provided proposition would mean that designers would have to consider the environment as a creative factor within the ideation phase along with all other factors that are usually considered such, as function, color and shape, flow and texture etc. Two distinct results occur through implementation of the proposed tool, first; the environmental benefit is evident as re-designing and re-thinking design processes towards environmentally friendly practices would save on raw materials and thereof waste, and create cleaner production processes, as extra thought is put into how products are made and what they consist of. More sustainable products would therefore hit the market, which would benefit our future ecological diversity and as a result also benefit out own health. Second, which could definitely be either argued against or for, depending on your own personal convictions, are the possible effects on profits. Due to increased customer demand, profits may rise due to increased reputation and an imbedded belief that the product is more valuable. Companies directly engaged with their production processes would also save money on treatment of waste, as hopefully, either less material is utilized, smarter ways of joining and cutting material is thought of, and less harmful chemicals utilized. However, production processes may be too new and expensive, and as a result more time could be spent on the design process, which could lead to losses. To further the work completed in this thesis, it is necessary to create a pilot (test) tool, for designers to interact with, and from there, valuable information would be pulled out for further understanding the design process and the problems which arise when including sustainable design practices within already know processes. Engaging designers with the developers, which would have the assigned task to create the specific tool is also highly encouraged, as this will give designers their own voices towards what they actually want and need. After all, it is the designers that will utilize the tool to their benefit.

5.3.1 Potential implementation requirements

First of all, a successful implementation requires the user to be positive towards the tool and its purpose. From the questionnaire, it was evident that 65% had a positive attitude towards sustainability, 90% see further help as potentially beneficial, and 75% had already worked with a sustainable project within the company. All of these answers show that the interest is there, yet, what was evident when the designers were confronted with the potential tool to further help them, the answers were not that straightforward. 60% of the designers scored a VAS higher than 5.0, but 40% scored either a 5.0 or lower. Which suggests that the actual motivation towards the tool might diminish if the tool does not hold the key features the designers require. The most restricting factor for designers was *price*. 61.1% (11/18) designers highlighted the hindrance price has towards their potential sustainable solutions. Three key findings need to be highlighted. First, management needs to be involved with pushing sustainability on the agenda and finding solutions together to the inherent problems. Project managers therefore need to see a "clear and compelling advantage to adopting formal tools, beyond just enhanced coverage and incremental efficiency" (Narayanan, 2001). This is evident through question 8 as well as a responded answered:

> "Yes, but its not up to design. It is controlled by marketing and profit margins. There could be a range of products dedicated 100% to sustainability, which a lot of competitors are already doing, but our company is too afraid to loose money".

Second, there needs to be either a contact person or an expert that the designers can go to with specific environmental questions. Or as one of the answers to the open text within question 8 stated:

> "Designers don't know what to do. They would need a person that's an expert (in sustainability). Would need workshops to gain knowledge and more transparency in who knows what and is doing what."

Third, there is a need to stress incentives to act and increase sustainable design. Designers need to see their efforts facilitate encouragement, recognition and valuable feedback from their superiors and peers (Shneiderman, 2007, p. 26). Or as one of the answers to the open text within question 8 reflect:

> "People need to be educated and encouraged."

Designers need to feel their work is appreciated, and especially if extra effort is put in to make sure sustainable feats are achieved. The implementation of a new sustainable design tool should take all the designers considerations into account, to achieve the potential success imbedded within a collaborative support tool.

6 Conclusion

This thesis saw the lack of considering sustainability imperative to the potential success of the conceptual design phase's inherent ability to transform the entire design process into a sustainable practice as crucial. As it was established that up to 80% of decisions are decided upon within the (conceptual) design phase, and that no existing conceptual design phase truly embraced the notion of sustainability, this thesis saw the blueprint of a conceptual design process embedded with a sustainable mindset created. The purpose of the creation of a sustainable conceptual design process was to allow the author to propose potential features to a design tool, which would assist and educate designers towards creativity, collaboration and sustainability. Numerous features towards a potential future design tool have been presented within this thesis, as well as necessary implementation criteria. There is however always an opportunity for improvement and alteration, and it is therefore suggested that future work would further assess designer's needs, interest and passion towards sustainable design and its tools. Interacting with the designers proved crucial for the creation of this thesis. It is therefore suggested that a hands on approach towards interviews and questionnaires should be utilized (qualitative assessment), as the gathered information will give other researchers a better understanding into processes and mindsets of designers. This may reduce the sample size, and prove to offer less statistical information, yet it will give more room for exploration and creativity towards the final goal, which would be to improve the sustainable aspect of the conceptual design phase. Designers, at least the ones examined within this thesis, all had a will to design more sustainably. However, potential future success of incorporating sustainability within the conceptual design phase is based on available tools incentives and a management willing to see through the implementation requirements listed above.

There is no denying the crucial importance of rethinking production processes. Continuing our consumption and waste patterns will only put further strain on the environment, and eventually affect our own well-being. When we have the know-how to act, to improve design and creative processes, why would we not embrace these notions to the fullest? The simple answer, which was also pointed out by many of the participants, was price. The price of acting, designing and creating is too high, that whenever challenged, incentives for sustainable design seem to loose. Still, this leaves us to the question, what would be the price of *not* acting, designing and creating sustainably in the long run? Are we not here to stay? The author would like to give the reader a final thought brought to you by a quote of the philosophy of William McDonough and Michael Braungart (2002, p16):

> "We see a world of abundance, not limits. In the midst of a great deal of talk about reducing the human ecological footprint, we offer a different vision. What if humans designed products and systems that celebrate an abundance of human creativity, culture, and productivity? That are so intelligent and safe, our species leaves an ecological footprint to delight in, not lament?".
>
> (McDonough & Braungart, 2002, p16).

References

Al-Salka, M. A., Cartmell, M. P., & Hardy, S. J. (1998). A framework for a generalized computer-based support environment for conceptual engineering design. Journal of Engineering Design, 9(1), 57-88.

Allenby, B. (1993). Supporting Environmental Quality: Developing an Infrastructure for Design. Total Quality Environmental Management, 2(3), 303-308.

Allenby, B. R., & Graedel, T. E. (1995). Industrial Ecology. Englewood Cliffs, NJ: Prentice Hall.

Allwood, J. M., Laursen, S. E., Malavido de Rodrigues, C., & Bocken, N. M. P. (2006). Well dressed? The Present and Future Sustainability of Clothing and Textiles in the United Kingdom. University of Cambridge, Institute for Manufacturing: Cambridge.

Altieri, M. A. (1995). Agroecology: The science of Sustainable Agriculture (2nd ed.). Boulder: Westview Press.

Amabile, T. M. (1983). The Social Psychology of Creativity. New York: Springer-Verlag.

Anastas, P. T., & Zimmerman, J. B. (2003). Design through the Twelve Principles of Green Engineering. Environmental Science & Technology, 37(5), 94-101.

Anderson, R. (1999). Mid-course correction: Toward a sustainable enterprise: The interface mode. Chelsea Green: White River Junction, VT.

Appelt, W., & Busbach, U. (1996). The BSCW system: a WWW-based application to support cooperation of distributed groups. Paper presented at the In Proceedings of the IEEE Workshops on Enabling Technologies Infrastructure for Collaborative Enterprises St. Augustin.

Arias, E. G., Eden, H., Fischer, G., Gorman, A., & Scharff, E. (2000). Transcending the individual human mind - Creating a shared understanding through collaborative design. Communications of the ACM, 7(1), 84-113.

Austin, S. A., Steele, J., Macmillan, S., Kirby, P., & Spence, R. (2001). Mapping the conceptual design activity of interdisciplinary teams. Design Studies, 22(3), 211-232.

Ayres, R. U. (1995). Resources, Conservation and Recycling. Life Cycle Management, 14(3-4), 199-223.

Ball, P. (2001). Life's lessons in design. Nature, 409, 413-416.

Baugh, G. (2008). Social Responsibility: Polyester vs. Cotton - Which is better for the environment? Fiber: Online Journal of the International Fashion and Apparel Industry(2).

Beck, E., & Bellotti, V. (1993). Informed opportunism as strategy: Supporting coordination in collaborative writing. Paper presented at the Third European Conference on Computer Supported Cooperative Work, Milan, Italy.

Becker, H. S. (1970). Sociology work: Method and substance: New Brunswick, NJ: Transaction Books.

Benyus, J. M. (2002). Biomimicry: Innovation Inspired by Nature: Perennial.

Boden, M. (1994). The Dimensions of Creativity. Cambridge, London.

Botkin, D. B., & Keller, E. A. (2010). Environmental Science: Earth as a Living Planet (Vol. 7): John Wiley & Sons, INC.

Bowman, S. A. (1996, November 24-26). Design for the Environment: Tools and Techniques. Paper presented at the Decision Sciences Institute, Orlando, FL.

Brundtland, G. H. (1987). Our Common Future. Oslo: United Nations.

Bruner, J. (1962). Contemporary approaches to creative thinking: Terrell & Wertheimer.

Cattanach, R. E., Holdreith, J. M., Reinke, D. P., & Sibik, L. K. (1995). The Handbook for Environmentally Conscious Manufacturing: From Design and Production to Labeling and Recycling. Chicago, IL: Richard D. Irwin.

Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H. G., & Gautam, R. (2006). The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. Eclogical Economics, 60, 186-203.

Chen, C. (2001). Design for the Environment: A Quality-Based Model for Green Product Development. Management Science, 47(2), 250-263.

Cherrett, N., Barret, J., Clemett, A., Chadwick, M., & Chadwick, M. J. (2005). Ecological Footprint and Water Analysis of Cotton, Hemp and Polyester: Stockholm Environment Institute.

Clark, G., Kosoris, J., Hong, L. N., & Crul, M. (2009). Design for Sustainability: Current Trends in Sustainable Product Design and Development. Sustainability, 1, 409-424.

Crofton, F. S. (2000). Educationg for sustainability: opportunities in undergraduate engineering. Journal of Cleaner Production, 8(5), 379-405.

Csikszentmihalyi, M. (1996). Creativity: Flow and the Psychology of Discovery and Invention. New York: HarperCollins.

Deng, J., Han, X., & Zeng, X. (2002). Product conceptual design-theories, methods and technologies (Vol. 5). Beijing: China Machine Press.

Design for Environment Guidelines. (2004). Retrieved November 21, 2012, from www.bombardier.com

Diaz-Calderon, A., Fenves, S., Hon, M., Garrett, J., & Hendrickson, C. (1994). Computer Based Advisors For Environmentally Conscious “Green” Product Design: Engineering Design Research Center.

Diehl, M., & Stroebe, W. (1987). Productivity Loss in Brainstorming Groups: Toward the Solution of a Riddle. Journal of Personality and Social Psychology, 53, 497-509.

Domina, T., & Koch, K. (1997). The textile waste lifecycle. Clothing and Textile Research Journal, 15(2), 96-102.

Dorst, K., & Cross, N. (2001). Creativity in the design process: co-evolution of problem-solution. Design Studies, 22(5), 425-437.

Dym, C. L. (1994). Engineering Design: A Synthesis of Views. Cambridge, UK: Cambridge University Press.

Ehrenfeld, J. (1997). Industrial ecology: a framework for product and process design. Journal of Cleaner Production, 5(1-2), 87-95 85.

Ehrenfeld, J., & Lenox, M. J. (1997). The development and implementation of DfE programmes. The Journal of Sustainable Product Design(1), 17-27.

Eide, A., R. Jenison, L. Mashaw, & L. Northup. (2002). Engineering: Fundamentals and Problem Solving. New York: McGraw-Hill Companies Inc.

EPA. (1996). Best management practices for pollution prevention in the textile industry. Retrieved May 24, 2012, from http://infohouse.p2ric.org/ref/02/01099/0109900.pdf

EPA. (2000). Interim Registration Eligibility Decision (IRED) for Tribufos. Retrieved May 24, 2012, from http://www.epa.gov/REDs/2145ired.pdf

EPA. (2009). Sustainable Materials Management: The Road Ahead. Retrieved May 24, 2012, from http://www.epa.gov/osw/inforesources/pubs/vision2.pdf

Epstein, M. J. (1996). Measuring Corporate Environmental Performance: Best Practices for Costing and Managing an Effective Environmental Strategy. Chicago, IL: Richard D. Irwin.

Fiksel, J. (1998). Design for Environment: Creating Eco-Efficient Products and Processes. New York: McGraw-Hill.

Fiskel, J. (1993). Quality Metrics in Design for Environment. Total Quality Environmental Management, 3, p. 181-192.

Fitzgerald, D. P., Herrmann, J. W., A., S. P., & Schmidt, L. C. (2005). Beyond Tools: A Design for Environment Process. International Journal of Performability Engineering, 1 (2), 105-120.

Gam, H. J., Cao, H., Farr, C., & Heine, L. (2009). C2CAD: a sustainable apparel design and production model. International Journal of Clothing Science and Technology, 21(4), 166-179.

Gladwin, T. N., Kennelly, J. J., & Krause, T.-S. (1995). Shifting Paradigms for Sustainable Development: Implications for Management Theory and Research. The Academy of Management Review, 20(4), 874-907.

Goan, M.-J. K. (1996). An integrated approach to environmentally conscious design and manufacturing. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Gough, H. G. (1979). A Creative Personality Scale for the Adjective Check List. Personality and Social Psychology, 37(8), 1398-1405.

Gough, H. G., & Heilbrun, A. B., Jr. (1965). The Adjective Check List manual. Palo Alto, CA: Psychologists Press.

Graedel, T. E., & Allenby, B. (1995). Industrial Ecology. NJ: Prentice Hall.

Greenpeace. (2003). The poison plastic. Retrieved May 24, 2012, from http://www.greenpeace.org/international/en/campaigns/toxics/polyvinyl-chloride/the-poison-plastic/

Greenwood, T. (2012). Tools. Retrieved June 5 2012, from http://www.espdesign.org/sustainable-design-guide/tools/

Gu, P. (1998). Recent development in design theory and methodology research. Paper presented at the Proceedings of International Conference on Manufacturing Sciences, Wuhan, China.

Guildford, J. P. (1950). Creativity (5 ed.): American Psychologist.

Guinée, J. B., Gorée M., Heijungs R., Huppes G., Kleijn R., Koning A. de, et al. (2002). Handbook on Life Cycle Assessment (Vol. 7): Kluwer Academic Publishers.

Gupta, B., Revagade, N., & Hilborn, J. (2007). Poly (lactic acid) fiber: An overview. Progress in Polymer Science, 32(4), 455-482.

Hacco, E., & Shu, L. H. (2002). Biomimetic concept generation applied to design for remanufacture. Paper presented at the Proceedings of DETC'02 ASME 2002 Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Montreal, Canada.

Haik, Y., & Shahin, T. (2010). Engineering Design Process: Cengage Learning.

Hakkio, S., & Lassksonen, P. (1998). Relationships in marketing channels: examining communication abilities through cognitive structures. Psychology & Marketing, 15(3), 215-240.

Hasson, D., & Arnetz, B. B. (2005). Validation and Findings Comparing VAS vs. Likert Scales for Psychosocial Measurements. International Electronic Journal of Health Education, 8, 178-192.

Hendrickx, I. (1995). Pollution prevention studies in the textile wet processing industry. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Holbrook, C. T., Clark, M. R., Moore, D., & Overson, R. P. (2010). Social insects inspire human design. Biology Letters, 6(4431-433).

Hsu, W., & Liu, B. (2000). Conceptual design: issues and challenges. Computer-Aided Design, 32, 849-850.

ILCD handbook. (2010). European Commission: Joint Research Centre.

Jackson, P. W., & Messick, S. (1965). The Person, the product, and the Response: Conceptual Problems in the Assessment of Creativity. Journal of Personality, 33(3).

Johnson, R. C. (1980). Optimum design of mechanical elements: Wiley.

Jones, J. C. (1992). Design Methods: John Wiley & Sons.

Kadolph, S. J., & Langford, A. L. (2002). Textiles: New Jersey: Prentice Hall.

Kamila, A. Y. (2003). How three green businesses survive in the U.S. textile industry collapse. In business, 25(3), 10-11.

Kasshan, B., Saminathan, M., & Sekutowski, J. (1995). Green Design Tool. Paper presented at the IEEE Symposium on Electronics & the Environment, Orlando, FL.

Koestler, A. (1964). The act of creation. Dell, New York.

LaBat, K. L., & Sokolowski, S. L. (1999). A three-stage Design Process applied to an industry-university textile production design project. Clothing and Textile Research Journal, 17(1), 11-20.

Lamm, H., & Trommsdorff, G. (1973). Group versus individual performance on tasks requiring ideational proficiency (brainstorming). European Journal of Social Psychology, 361-387.

Lampkin, N. (1998). Organic Farming. Ipswich: Farming Press.

Lee, D., & Thompson, M. (2011). Biomimicry: Inventions Inspired by Nature: Kids Can Press.

Lefaivre, L. (2000). Making a Midrise out of a Termite Hill. Architecture, 89(11).

Lenox, M., Jordan, B., & Ehrenfeld, J. (1996). The Diffusion of DfE: A Survey of Current Practice. Paper presented at the IEEE Symposium on Electronics and the Environment.

Lodha, P., & Netravali, A. N. (2005). Characterization of stearic acid modified soy protein isolate resin and ramie fiber reinforced 'green' composites. Composites Science and Technology, 65, 1211-1225.

Lumsden, R. J. (2003). Sustainability Assessment: The way ahead for corporate reporting. Retrieved from http://www.thesustainabilitysociety.org.nz/conference/2004/Session5/27%20Lumsden.pdf

Luttropp, C., & Lagersted, J. (2006). EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. Journal of Cleaner Production, 14, 1396-1408.

Mackenzie, D. (1997). Green Design: Design for the environment (2nd ed.). London: Laurence King.

Marquardt, S. (2001, January 9-13). Organic Cotton: Production and Marketing Trends. Paper presented at the Beltwide Cotton Conference, Anaheim, CA.

Matthews, G. A., & Tunstall, J. P. (1994). Insect Pest of Cotton: Wallingford: CAB International.

Maxwell, J. A. (1992). Understanding and validity in qualitative research. Harvard Educational Review, 62, 297-300.

May-Plumlee, T., & Little, T. J. (1998). No-interval coherently phased product development model for apparel. International Journal of Clothing Science and Technology, 10(5), 342-364.

McDonough, W., & Braungart, M. (1999). The Next Industrial Revolution. Sheffield, UK: Greenleaf Publishing.

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

McDonough, W., Braungart, M., Anastas, P. T., & Zimmerman, J. B. (2003). Applying the principles of green engineering to cradle to cradle design. Environmental Science & Technology., 37(23), 434A-441A.

McDonough, W., Braungart, M., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions - a strategy for eco-effective product and system design. Journal of Cleaner Production, 15, 1337-1348.

Meadows, D. H., Meadows, D. L., & Randers, J. (1992). Beyond the limits: confronting global collapse, envisioning a sustainable future: Chelsea Green Pub.

Mekonnen, M. M., & Hoekstra, A. Y. (2011). The green, blue, and grey water footprint of crops and derived crop products. Hydrology and Earth System Sciences 15, 1577-1600.

Melnyk, S. A., Calantone, R. J., & Curkovic, S. (2001). Integrating environmental concerns into the design process: the gap between theory and practice. IEEE Transactions on Engineering Management, 48(2), 189-208.

Miklosovic, D. S., Murray, M. M., Howle, L. E., & Fish, F. E. (2004). Leading-edge tubercles delay stall on humpback whale (Megaptera novaeangliae) flippers. Physics of Fluids, 16(5), 39-42.

Mooney, R. L. (1963). A conceptual model for integrating four approaches to the identification of creative talent New York: Wiley.

Müzzinoğlu, A. (1998). Air pollutant emission potentials of cotton textile manufacturing industry. Journal of Cleaner Production, 6, 339-347.

Myers, B. A., Hudson, S. E., & Pausch, R. (2000). Past, present and future of user interface software tools. Communications of the ACM, 7(1), 3-28.

Narayanan, K., Abadir, M. S., Martin, A. K., & Abraham, J. A. (2001). Design and Development Paradigm for Industrial Formal Verification CAD Tools. IEEE Design & Test of Computers, 26-35.

Newcomb, P. J., Bras, B., & Rosen, D. W. (1996). Implications of modularity on product design for the life cycle. Paper presented at the 1996 ASME Design Engineering Technical Conferences and Computers in Engineering Conference, Irvine, California.

Osborn, A. F. (1957). Applied Imagination: Principles and procedures of creative thinking. New York: Scribeners and Sons.

Otto, K. N. (1996). Forming product design specifications. Paper presented at the Proceedings of DETC'96, 96-DETC/DTM-1517.

Otto, K. N., & Wood, K. L. (2001). Product Design: Techniques in Reverse Engineering and New Product Development. New Jersey: Prentice Hall.

Our Common Future, Chapter 7: Energy: Choices for Environment and Development. (2007). United Nations.

Pahl, G., & Beitz, W. (1996). Engineering Design: A Systematic Approach. New York: Springer-Verlag.

Papanek, V. J. (1984). Design for the real world: human ecology and social change: Van Nostrand Reinhold Co.

Poyner, J. R., & Simon., M. (1995). Integration of DfE tools with product development. Paper presented at the Clean Electronics Products and Technology.

Reagan, C. L., Kincade, D. H., & Sheldon, G. (1998). Applicability of the engineering design process theory in the apparel design process. Clothing and Textile Research Journal, 16(1), 36-46.

Reap, J., Baumeister, D., & Bras, B. (2005). Holism, Biomimicry and Sustainable Engineering. Paper presented at the Proceedings of IMECE2005 2005 ASME International Mechanical Engineering Conference and Exposition, Orlando, FL, USA.

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., et al. (2004). Life cycle assessment Part 1: Framework, goal and scope definition, inventory analysis, and applications. Environmental International, 30, 701-720.

Reed, P. A. (2003). A paradigm shift: biomimicry. Technology Teacher, 63(4), 23-27.

Reips, U. D., & Funke, F. (2008). Interval level measurement with visual analogue scale in Internet-based research: VAS Generator. Behavior Research Methods, 40(3), 699-704.

Ren, X. (2000). Development of environmental performance indicators for textile process and product. Journal of Cleaner Production, 8, 473-481.

Rice, F. (1993). Who Scores Best on the Environment. Fortune.

Rose, C. M. (2000). Design for Environment: A Method for Formulating Product End-of-Life Strategies. Standford University, Standford.

Sanders, T. (1993). Green is Black. New York: Harper Collins.

Shedroff, N. (2011). Design Is The Problem: Rosenfeld Media.

Shelton, R. (1994). Hitting the Green Wall: Why Corporate Programmes Get Stalled. The Journal of Corporate Environmental Strategy, 2.

Shiva, V. (2005). Organic Farming : The Real Green Revolution for Removal Of Poverty, Hunger And Ecological Insecurity. Paper presented at the 5th Annual Conference of the German Council for Sustainable Development. Retrieved from http://www.nachhaltigkeitsrat.de/fileadmin/user_upload/dokumente/jahreskongress/2005/Speech_Shiva_Annual_Conference_05-09-06.pdf

Shneiderman, B. (2007). Creativity Support Tools. Communications of the ACM, 50(12), 20-32.

Sieger, D. B., & Salmi, R. E. (1997). Conceptual design tool for the systematic design method. Concurrent Product Design and Environmentally Conscious Manufacturing, 5, 145-152.

Simpson, P. (2006). Global trends in fibre proces, production and consumption. Textiles Outlook International, 125, 82-106.

Skerlos, S. J., Adriaens, P., Hayes, K., Rihana, A., Kurabayashi, K., Takayama, S., et al. (2001). Challenges to Achieving Sustainable Aqueous Systems: A Case Study in Metalworking Fluids. Paper presented at the Proceedings of EcoDesign 2001: 2nd International Symposium on Environmentally Conscious Design and Inverse Manufacturing.

Smith, A. (1976). The Wealth of Nations. Chicago.

Sollaci, L., & Pereira, M. (2004). The introduction, methods, results, and discussion (IMRAD) structure: a fifty-year survey. Journal Medical Library Association, 92(3), 364-371.

Starik, M., & Rands, G. P. (1995). Weaving an Integrated Web: Multilevel and Multisystem Perspectives of Ecologically Sustainable Organizations. The Academy of Management Review, 20(4), 908-935.

Sternberg, R. J. (1999). Handbook of Creativity: Cambridge University Press.

Subic, A. (2009). Transdiciplinary dimensions of sustainable design practice. International Journal of Sustainable Design, 1(2), 127-130.

Subic, A., Mouritz, A., & Troynikov, O. (2009). Sustainable design and environmental impact of materials in sports products. Sports Technology, 2(3-4), 67-79.

Taylor, D. W., Berry, P. C., & Block C. H. (1958). Does Group Participation When Using Brainstorming Facilitate or Inhibit Creative Thinking? Administrative Science Quarterly, 3(1), 23-47.

Terry, M., Mynatt, E. D., Nakakoji, K., & Yamamoto, Y. (2004). Variation in element and action: Supporting simultaneous development of alternative solutions. Paper presented at the Conference on Human Factors in Computing Systems, New York.

The worlds worst toxic pollution problems. (2011). New York: Blacksmith Institute.

UNFPA. (2011). On 31 October, world population reaches 7 billion. Retrieved October 30, 2011, from http://www.7billionactions.org/

Unger, D., & Eppinger, S. (2011). Improving product development process design: a method for managing information flows, risks, and iterations. Journal of Engineering Design, 22(10), 689-699.

Vogel, S. (2008). Cats' Paws and Catapults: Mechanical Worlds of Nature and People: Paw Prints.

Waldron, K. J. (2000). A Brief History of Biomimetic Robotics. Cassino, Italy,: Kluwar Academic Publishers,.

Walsh, J. A. H., & Brown, M. S. (1995). Pricing environmental impacts: a tale of two T-shirts. Illahee, 11(3-4), 175-182.

Wang, L., Shen, W., Xie, H., Neelamkavil, J., & Pardasani, A. (2002). Collaborative conceptual design: state of the art and future trends. Computer-Aided Design, 34, 981-996.

Wang, Q., Rao, M., & Zhou, J. (1994). Intelligent systems for conceptual design of mechanical products. In: Mital A, Anand S, editors. Handbook of expert systems applications in manufacturing: structures and rules New York: Chapman & Hall.

Ward, W. (1947). Creativity in Young Children. Journal of Creative Behaviour, 8, 101-106.

Warr, A., & O´Neill, E. (2005). Understanding Design as a Social Creative Process. Human-Computer Interaction Group.

Wewers, M. E., & Lowe, N. K. (1990). A critical review of visual analogue scales in the measurement of clinical phenomena. Nursing and Health, 13, 227-236.

Wilson, A., & Mowbray, J. (2008). Eco-textile labeling. A guide for manufacturers, retailers and brands. Mowbray Communications, 14-15.

Woolridge, A., Ward, G., Phillips, P., Collins, M., & Gandy, S. (2006). Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: An UK energy saving perspective Resources, Conservation and Recycling, 46(1), 94-103.

Workman, J. E., Caldwell, L. F., & Kallal, M. J. (1999). Development of a test to measure spatial abilities associated with apparel design and product development. Clothing and Textile Research Journal, 17(3), 128-133.

Xu, Y., Lu, Z., & Tang, R. (2007). Structure and thermal properties of bamboo viscose, Tencel and conventional viscose fiber. Journal of Thermal Analysis and Calorimetry, 89(1), 197-201.

Zeander, J. Å. (2009). Fact sheet environmental week. Retrieved May 24, 2012, from http://www.naturskyddsforeningen.se/upload/Foreningsdokument/Faktadokument/Fact%20sheet%20-%20Fabric%20or%20fabricated.pdf

Zebedin, H. (2000). Design for disassembly and recycling for small and medium sized companies for the next generation. Computer Science. Computer Aided Systems Theory, 1798, 282-300.

Zeng, Y., & Gu, P. (1999). A science-based approach to product design theory Part I: formulation and formalization of design process. Robotics and Computer Integrated Manufacturing, 15, 331-339.

Appendix A

Reference: Gough (1979).
The Gough Personality Scale. Please indicate which of the following adjectives best describe yourself. Check all that apply.

______ Capable	______ Honest
______ Artificial	______ Intelligent
______ Clever	______ Well-mannered
______ Cautious	______ Wide interests
______ Confident	______ Inventive
______ Egotistical	______ Original
______ Commonplace	______ Narrow interests
______ Humorous	______ Reflective
______ Conservative	______ Sincere
______ Individualistic	______ Resourceful
______ Conventional	______ Self-confident
______ Informal	______ Sexy
______ Dissatisfied	______ Submissive
______ Insightful	______ Snobbish
______ Suspicious	______ Unconventional

Scoring Key:

___+___ Capable	___-___ Honest
___-___ Artificial	___+___ Intelligent
___+___ Clever	___-___ Well-mannered
___-___ Cautious	___+___ Wide interests
___+___ Confident	___+___ Inventive
___+___ Egotistical	___+___ Original
___-___ Commonplace	___-___ Narrow interests
___+___ Humorous	___+___ Reflective
___-___ Conservative	___-___ Sincere
___+___ Individualistic	___+___ Resourceful
___-___ Conventional	___+___ Self-confident
___+___ Informal	___+___ Sexy
___-___ Dissatisfied	___-___ Submissive
___+___ Insightful	___+___ Snobbish
___-___ Suspicious	___+___ Unconventional

Appendix B

Reference: Own work

Questionnaire: Sustainability and Perception

Results will be presented anonymously

Note: Feel free do write any comments or questions wherever there is some free space or outside the outlined A4

Thank you for taking a few minutes out of your busy work schedule to complete this questionnaire!

1. Gender — Male ☐ Female ☐
Please put a fill within the box to indicate your answer

2. Where do you belong? APP ☐ ACC ☐ FTW ☐ Other ☐

3. On what frequency do you utilize the listed research methods mentioned below? copy and drag me over ⟶
Please drag the indicated red line over the black lines on the right to give your answer

almost never — very often

- Websearch
- Books
- Magazines
- Market research
- Other (please specify) Click me and type here

4. How would you rate the importance of the listed research methods below? copy and drag me over ⟶

not important — very important

- Websearch
- Books
- Magazines
- Market research
- Other (please specify) Click me and type here

5. How do you normally integrate new technologies in your design work? (e.g. DMT, ai. practices, Better Place)

Type here

6. Are you personally interested in sustainable design? copy and drag me over ⟶

not at all interested — very interested

7. What is the most restricting factor to design more sustainable?

Click me and type here

8. Would you think there is a need to help designers to incorporate sustainable design practices? copy and drag me over ⟶

no need — strong need

Why and how?
Click me and type here

9. Have you ever worked on a sustainable project within your company? Yes ☐ No ☐ copy and drag me over ⟶

If so, how often do you refer to: never — often

- Internal Scoring System
- DfE guidelines
- Sustainable material library
- Other Click me and type here

Have you ever taken part in informal sustainability meetings/discussions within your company?
Yes ☐ No ☐

10. Would you have an interest in using a new sustainability tool in your design work?

no interest — yes, strong interest

11. If so, to what extent would you like the below features to be integrated within? copy and drag me over ⟶

not at all — large extent

- Internal Scoring System
- Sustainable search engine; helping you find information/ideas fast
- DfE guidelines; learning tips/tricks to achieve sustainablitiy
- Calculations; LCA, calculator
- Data bank/idea corner; sharing ideas/pictures/projects
- Other Click me and type here

Is it OK that I get back to you if any follow up questions are necessary? Please tick me if yes ☐

Karl Martin Kjaerheim | Thank you for your time! | 2012

Example:

1, Gender
Please put a fill within the box to indicate your answer

- [x] Male
- [ ] Female

5. On what frequency do you utilize the listed research methods mentioned below?
Please drag the indicated red line over the black lines on the right to give your answer

copy and drag me over

almost never — very often

Websearch
Books
Magazines
Market research
Other (please specify) Own hobby, climbing

If you have more to write in any of the indicated questions to the left, please utilize to text boxes below

3. On what frequency do you utilize the listed research methods mentioned below?

Other (please specify) Click me and type here

4. How would you rate the importance of the listed research methods below?

Other (please specify) Click me and type here

5. How do you normally integrate new technologies in your design work? (e.g. DMT, ai. Practices, Better Place)

Click me and type here

7. What is the most restricting factor to design more sustainable?

Click me and type here

8. Would you think there is a need to help designers to incorporate sustainable design practices?

Why and how?
Click me and type here

11. Any other features/comments you would see added within, please write them down below:

Click me and type here

Appendix C

Reference: Bombardier (2004), based upon Luttropp and Lagerstedt (2006) article.

Design for Environment Guidelines		My own action plan
Hazardous  Don't use hazardous substances and arrange closed loops for necessary ones	☐ Don't use materials on BT's lists of Prohibited and Restricted substances ☐ Try to find solutions involving non hazardous substances, which does not jeopardise the functionality and cost limitations of the product ☐ If a hazardous substance cannot be substituted consider if closed loops can be arranged i.e. recycled and taken care of at end-of-life	
House-keeping  Minimise energy and resource consumption in production phase and transport through housekeeping	☐ Reuse parts and components if they can still guarantee the same quality ☐ Optimise and plan procurement and logistics e.g. no half empty trucks, choose less energy consuming distribution, optimise packaging ☐ Reduce use of consumables e.g. spill of oils ☐ Sort waste in recycling bins	
Weight  Use structural features, light weight and high strength materials to minimise weight	☐ Minimise quantity of material ☐ Use light weight materials. If Aluminium is used, make sure it is recycled ☐ Try to find an optimal lightweight solution using for example reinforcements, rails, frames or folds, which is especially important for frequently accelerating vehicles	
Energy  Minimise energy and resource consumption in the use phase	☐ Select sustainable energy sources e.g. renewable fuels like solar cells and fuel cells ☐ Reduce aerodynamic drag ☐ Choose electronic components with high efficiency ☐ Install stand-by functions where applicable ☐ Facilitate energy efficient driving e.g. install energy meters ☐ Make use of losses from e.g. traction equipment	
Upgrade  Promote repair and upgrading, especially for system dependent products	☐ Strive to increase reparability and upgrading if it is economically feasible ☐ Make sure that parts that need to be upgraded are easily identified, separated and repaired or replaced e.g. in easily accessible modules ☐ Use a modularized design to allow for upgrading ☐ Try to incorporate in the module design instructions for replacement or upgrading	

Design for Environment Guidelines		My own action plan
Lifetime  Optimise the design for estimated lifetime	☐ Create classic industrial design (allows for long life) ☐ Create strong user-product relation to reduce chances of the product being replaced before it reaches its physical lifetime ☐ Optimise maintenance intervals ☐ Design for easy refurbishing ☐ Design for flexibility ☐ Strive to increase durability for long-life parts and components	
Protect  Invest in strong and resistant materials and suitable surface treatments to protect products	☐ Reduce emissions from wear ☐ Choose corrosion-resistant materials to avoid diffuse emissions ☐ Isolate parts and components including hazardous substances and chemicals (e.g. oil and lubricants) and protect them from leakage or corrosion ☐ Favour manufacturing processes with no or low emissions to air, water and soil ☐ Protect waste water from chemicals and strive for closed systems	
Information  Prearrange for upgrading, repair and recycling through easy accessibility, labelling, modules and manuals	☐ Promote easy identification of parts that will be recycled, especially parts containing hazardous substances e.g. by labelling or marking ☐ Use the product form & markers to facilitate disassembly ☐ Mark polymers according to ISO11469 ☐ Make sure that recycling descriptions are included in maintenance manuals	
Mix  Promote upgrading, repair and recycling by using few, simple and recycled materials	☐ Use as few different materials as possible ☐ Choose homogenous materials ☐ Do not use paint and surface treatments if not absolutely needed ☐ Keep polymers "clean" e.g. avoid painting, gluing and polymers containing adhesives ☐ Select renewable materials	
Structure  Use as few joining elements as possible for ease of recycling and repair	☐ Reduce the number of fasteners and separation points ☐ Standardise separation points (i.e. easy to understand where to separate) ☐ Avoid gluing ☐ For reuse of parts and components use structures that allow non-destructive disassembly ☐ Use screws, welding, snap fits and geometric locking	

(Based on The 10 Golden DfE Rules by Luttropp C and Lagerstedt J., Dep. Of Machine Design, KTH, figures by Luttropp B)