

A THEORETICAL FRAMEWORK FOR SUSTAINABLE PRODUCT DESIGN IN THE TEXTILE AND FASHION INDUSTRY

- Based on Ted's 10 & UN Sustainable Development Goals

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Title: A Theoretical Framework For Sustainable Product Design in the Textile And Fashion Industry based on Ted's 10 and UN Sustainable Development Goals

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Abstract

Purpose The purpose of this thesis is to develop a theoretical framework for sustainable product design, targeting aesthetic design elements, as part of product development by applying the Ted's 10 methodology for textile environment and the UN Sustainable Development Goals.

Design/Methodology/approach The thesis follows a deductive and inductive multi – method approach. A systematic literature review gives insights into existing literature on product design; the interviews with two experts evaluate the theoretical framework based on the UN Sustainable Development Goals and the implications and applicability of findings in practice.

Findings It is found that, in comparison to the UN Sustainable Development Goals, the aesthetic design elements in product design from literature have no clear guidelines to restrict environmentally unsustainable practices/ decisions, apart from EU regulations. The theoretical framework, which is built on these gaps by applying the Ted's 10 design methodology, shows suggestions concerning the aesthetic design elements, which have the possibility to reduce the need to consume, chemical impact, waste, and energy and water consumption. Two expert interviews validate the theoretical framework and discuss implications and applicability.

Originality/value It is stated that product design, especially the aesthetic design elements, have a major impact on the environmental sustainability of the final product. Therefore, decision making regarding these elements have the potential to greatly reduce the environmental impact. Moreover, the analysis of the Ted's 10 may contribute to the realization of several UN Sustainable Development Goals. It could communicate the positive environmental impact textile and fashion designers and businesses can have when applying the Ted's 10.

Keywords product design, environmental sustainability, Ted's 10, UN Sustainable Development goals, methodology

Paper type master's thesis

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List of Abbreviations

UN United Nations

UN SDG United Nations Sustainable Development Goal

TED Textile Environment Design

GRI Global Reporting Initiative

PWC PricewaterhouseCoopers

SME Small-medium Enterprise

PD Product Development

FAE Functional Aesthetic and Economic

CAD Computer-aided design

REACH Registration, Evaluation, Authorization and Restriction of Chemical Substances

CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora

POP Persistent Organic Pollutants

DFR Design for recyclability

DFD Design for disassembly

DWR Durable Water Repellents

PCP Pentachlorophenol

PVP Polyvinyl alcohol

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1. Introduction

1.1. Background

Ranging from the individual consumer to various industries, the effect of environmental neglect can be seen worldwide. Global warming, plastic pollution, and the depletion of various resources are only few of the effects that human behavior has triggered. Overconsumption and unsustainable practices are at the beginning of this downward spiral. While there is no easy fix for either of the root causes, it can be considered simpler to implement sustainable practices than to change the mindset of an entire population. At the beginning of manufacturing, selling and consuming a product lies the concept of product development. The process of product development is “the act of advancing a design through the stages of development”, which “combines design, merchandising, and marketing functions with production to introduce products in the market” (Mattson and Dorensen, p.351 2020; Crutsinger et al., 2005). According to the European Commission (2011), within the product development process, already 80% of the final product’s environmental impact is decided in product design (Curwen et al., 2012). The aesthetic design elements that are decided in this phase, such as the material, can be categorized as major contributors to the sustainability of the final product (Curwen et al., 2012). While all industries are harmful to the environment, one industry clearly differentiates itself from others: the fashion and textile industry. In the 2017 Pulse of the Fashion Industry report by the Global Fashion Agenda and the Boston Consulting Group, it was estimated that the textiles and clothing industry was responsible for a consumption on 79 billion cubic meters of water, 1715 million tons of CO₂ emissions and 92 million tons of waste in 2015 (Boston Consulting Group and Global Fashion Agenda, 2017). It is predicted that if consumption continues at this rate, numbers will increase by at least 50% by 2030. To put this into perspective, this is equivalent to 32 million Olympic-size swimming pools, 230 million passenger vehicles driven for a year and 1.6 times the waste the earth can absorb. Moreover, chemical use in the industry already exceeds the safe operating space by 220% (Boston Consulting Group and Global Fashion Agenda, 2017). The projected numbers suggest that consumer and industry behavior will not change but rather intensify, which explains the need for sustainable practices and decision-making opportunities, especially at the beginning in order to positively influence the product’s entire lifecycle. While some fashion and textile brands, such as Levi’s and Adidas already engage in and encourage sustainable practices and thinking, it is a mere drop in the ocean compared to the many companies that have yet a long way to go (Boston Consulting Group and Global Fashion Agenda, 2017). Nevertheless, there is hope as many agree that “Sustainability is no longer optional, [...] [but rather] a must” (Boston

Consulting Group and Global Fashion Agenda, 2017). In 2015, member states of the United Nations agreed upon an agenda for Sustainable Development to “end poverty, fight inequality and justice, and protect the planet” (UN Sustainable Development Goals, 2020). Among the 17 Sustainable Development Goals (SDGs), six are attributed to environmental sustainability. The support and participation of businesses specifically is pointed out, which is based heavily on collaboration between all parties in society (UN Sustainable Development Goals, 2020). As mentioned previously, the decisions taken in the product design stage already influence 80% of the product's environmental impact (Curwen et al., 2012). Product design, as part of product development, is a major activity in textile and fashion companies and thus, a large responsibility of and is mainly affected by decisions of businesses and designers themselves. The Ted's 10 are design strategies that designers can adapt in order to make the product design, in specific the aesthetic design elements, more sustainable (“Aims”, 2020). The aesthetic design elements are material, color, style, and fit (Niniimäki, 2020; Curwen et al., 2012) Therefore, this thesis targets the product design decisions of aesthetic design elements, using the Ted's 10 design strategies, that brands can adopt in product design to improve the sustainability of the design of the final product, as per UN SDGs.

1.2. Research Gap and Problem Statement

This topic of sustainable product design for this thesis stems from an environmental need for change and from a gap in research in the field and can thus be categorized as highly relevant. Although few scientific papers on the topic of sustainable product design in product development exists, most only scrape the surface of product design in combination with sustainability principles such as the UN SDGs and the Ted's 10 goals. Bhamra & Lofthouse (2007) find that the design stages of product development directly influence the final product because in these stages most critical decisions regarding cost, appearance, materials selection, innovation, performance, sustainability and quality are made (as cited in Curwen et al., 2012). These considerations during product design can have vast effects on the apparel and its environmental impact (Curwen et al., 2012). Vezolli (2018) also highlights the need to shift from ‘end-of-pipe’ approaches (fixing the damage) to upstream approaches that prevent the damage: product design. The UN has set several environmental sustainability goals that should either be attained by 2020 or 2030 but are not legally binding (UN Sustainable Development Agenda, 2020). The Ted's 10 design strategies are aimed at textile and fashion designers and suggest approaches how the complexity of sustainability issues can be navigated by designing “better” (‘Aims’, 2020). The thesis will explore how the implementation of the Ted's 10 design

strategies in aesthetic design elements supports the attainment of the UN Sustainable Development Goals. This combination has not been explored before and can thus, be seen as a gap in academic literature in the field of social science. The research problem can be summarized as follows: There is lack of research on the topic of sustainable product design, in specific aesthetic design elements, and an immense need for environmentally sustainable products that can be influenced by product design.

1.3. Purpose Statement

Therefore, the purpose of this thesis is to develop a theoretical framework focused on sustainable product design in the product development process, which serves as the base for designing sustainable products. The Ted's 10 strategies target sustainability in product design and will provide a guide to including environmental sustainability in product design. Furthermore, the theoretical framework will be in accordance with UN Sustainable Development Goals as product design will previously be evaluated using the UN SDGs. As product development entails product design, it will also be regarded to explore product design stages in depth. Product design has a direct influence on the final product as decisions regarding cost, appearance, materials selection, innovation, performance, sustainability and quality are made (Curwen et al., 2012; Lee et al., 2018). The environmental sustainability of the final product refers to the sustainability of the aesthetic design elements. A more complete explanation follows in the 'Frame of Reference'. A main research question and several sub-research questions have been developed in order to reach the intended goal.

Main research question

How can the aesthetic design elements in product design, as part of the product development process, in the fashion and textile industry be improved considering environmental sustainability using the Ted's 10 methodology and the UN Sustainable Development Goals as a guide?

Sub-research questions

1. What does current product design in product development models in the fashion and textile industry entail?
2. How do aesthetic product design elements in product design compare to environmental sustainability as defined by the UN Sustainable Development Goals?

3. How can aesthetic product design elements in the product development process become more environmentally sustainable using the Ted's 10 goals?

1.4. Scope and Delimitation

Under delimitation only those topics which are not addressed are explained. While this thesis focuses on the environmental sustainability of aesthetic design elements in product design of the textile and fashion industry, it does not consider functional design elements, nor does it include any other steps of product development, nor does it focus on social- or economic sustainability, nor on product development and design models outside of the textile and fashion industry, nor does the research of the systematic literature review entail sustainable product development models. First, functional design elements are not included as the aesthetic design elements contribute most to environmental sustainability (see 'Frame of Reference'). Second, only product design is assessed, all other steps are disregarded because product design is said to have the most impact on the final product and its sustainability (Curwen et al., 2012). This is also reflected in the choice of UN SDGs and Ted's 10, which are all focused on environmental sustainability. Third, the main focus of the analysis is environmental sustainability and not social or economic sustainability. Although sustainability encompasses environmental, social, and economic sustainability, focusing on all three pillars would exceed the scope of this thesis. Fourth, only product development and design models in the textile and fashion industry were applied, models from other industries were disregarded because they do not focus on the textile and fashion industry.

2. Frame of Reference

The 'Frame of Reference' defines the theoretical background of the thesis. It is a "meaning perspective [...] that provides a lens through which we make meaning [...]" (Cranton, 2010). This section provides theories that will be used throughout the thesis and that are referred back to. Therefore, the 'Frame of Reference' is highly relevant for the understanding of the thesis. First, background and definitions regarding product development, product design, and aesthetic design elements are provided. The thesis is focused on the aesthetic design elements which are decided upon in product design. As product design is a part of product development, literature about product development is also relevant for understanding product design. Next, background and definitions concerning sustainability, the Ted's 10 and UN SDGs are given. Because the goal of the thesis is to improve the environmental sustainability of aesthetic design elements, sustainability is first defined. Next, the Ted's 10 and their applicability and relevance to product design are discussed. Lastly, UN SDGs are set, against which environmental sustainability is measured in the analysis and discussion.

2.1. Product Development

When analyzing literature, it becomes apparent that the term 'product development' encompasses 'product development' and 'new product development' (Ievtushenke & Hodge, 2012; Mattson & Dorenson, 2020). According to Powell and Cassill (2006) new product development is "the process of creating new products/ and or services for the market" which moves through the product development pipeline (as cited in Ievtushenko & Hodge, 2012). The formal definition of product development is "the act of advancing a design through the stages of development" and "combin[ing] design[ing], merchandising, and marketing functions with production to introduce products in the market" (Mattson & Dorensen, p.351 2020; Crutsinger et al., 2005). As product development and new product development are found to be almost identical in literature, product development and new product development will be used interchangeably in this thesis. A popular and recognized product development process by to May-Plumlee & Little (1998), called 'No-interval coherently phased product development model for apparel', includes (1) Line Planning and Research, (2) Design/ Concept Development, (3) Design Development and Style Selection, (4) Marketing the Line, (5) Pre-Production. Within this model, two stages can be attributed to product design, namely 'Design/ Concept Development and Design Development and Style Selection (May-Plumlee & Little, 1998). However, LaBat & Sokolowski's (1999) 'Three-Stage Design Process' also entails Problem Definition & Research, and Implementation, which overlaps with May-Plumlee &

Little's stages one and five. Although the product development process and the product design process overlap, the activity of product design is limited to only few stages of the process. Because of this similarity between both processes and the inclusion of product design in product development, literature regarding product development will also be included.

2.2. Product Design

Product design is about “enriching quality of life” and helps businesses ensure that products are created and sold that are appealing to consumers. Designing a product is in essence about answering to unmet needs, enhancing function and appearance and allowing new ways to engage with objects (Rodger & Milton, 2011). Product design is triggered through the identification of a consumer need. This is then converted into a product design that aims to fulfill customer needs (Ashby & Johnson, 2010). Product design in product development is limited to only those stages which are attributed to design. These are Concept Design, Design Development, and Detail Design. Looking at the physical design of the product, decisions regarding design can be made about aesthetic and/or functional design (Ashby & Johnson, 2010). Curwen et al. (2012) underline that in product design for textile and fashion products, decisions regarding cost, appearance, materials selection, innovation, performance, sustainability and quality are made. According to Niinimäki (2020), customer satisfaction with the final product is highly related to the product's life. Therefore, decisions regarding product design must be tailored to consumers in order to prevent negative environmental impact. In product design, decisions about functional and aesthetic elements are taken. Functional elements are those that can be attributed to performance, and safety, ergonomics, etc. Aesthetic elements are style, color, fit, and materials (Niinimäki, 2020; Taha et al., 2013; Curwen et al.; 2012; Lee et al., 2018; Le at al., 2019). Moreover, Shafiq (2020) specifies that design encompasses style, color, fit and materials. Decisions regarding aesthetic design elements are usually taken in the earlier stages of product design and product development and thus specify the overall theme/ concept out of which detailed designs and prototypes evolve (Wickett et al., 1999). Because this thesis focuses solely on the general aesthetic elements, in total four aesthetic design elements are analyzed: (1) style, (2) materials, (3) color, and (4) fit. These are reflected in Table 1.

Table 1 Aesthetic design elements

based on Niinimäki (2020); Taha et al (2013); Le et al. (2019); Lee et al. (2018); Shafiq (2020)

Aesthetic Design Element	Description
<i>Style</i>	Outside appearance/ aesthetics, lines and shapes, fabric construction, attracts customers
<i>Materials</i>	Raw materials, creates silhouette and aesthetics, structure of a fiber shapes final design
<i>Color</i>	Highly important for consumer decision-making, depends on age, culture, gender factors
<i>Fit</i>	Relates to ease of wearer's movement, relationship with the human body

2.3. Sustainability

In 1987, the World Commission on Environment and Development provided a definition for sustainability. The definition states that sustainability is an economic-development activity, which “meets the needs of the present without compromising the ability of future generations to meet their own needs” (as cited in Portney, 2015, pp. 3-4). It is about supporting human population, animals, plants and economic growth at a steady level, which does not threaten their existence. The three E's of sustainability, which stand for environment, economy, and equity, are described as circles that overlap and symbolize the three pillars of sustainability, as defined by the United Nation's World Commission on Environment and Development. The premise is that sustainability can only be reached by protecting the environment, maintaining economic growth, and promoting equity. These three pillars are not mutually exclusive but rather go hand in hand. In other words, one pillar should not be sacrificed for the realization of another (Portney, 2015, pp. 2-7).

Environmental sustainability describes practices and policies that reduce environmental pollution, do not exploit people or natural resources in meeting the lifestyle needs of the present, and do not compromise the future. Sustainability has broad-reaching implications. It encompasses many areas including human rights, energy use, materials use, production, consumption, disposal, and recycling. It addresses both current practices and future implications. Materials and products are made from recyclable materials and renewable resources and do not pollute the environment at any stage of production or processing. Materials are biodegradable. Workers and animals are treated with dignity and respect (Kadolph & Lanford, 2013, p.522). In this thesis, environmental sustainability is measured using the UN Sustainable Development Goals (see 2.5). By aiming at the fulfillment of the UN SDGs, the

practice of product design, specifically aesthetic design elements, will lead to greater environmental sustainability.

2.4. Ted's 10 Goals

The Textile Environment Design (TED) research group, established in 1996, built a sustainable strategy platform, which has the aim of reducing environmental impact by reconsidering the designer's role and responsibilities in product design 10 strategies, as well as tools and frameworks that designers can adopt to render their designs more sustainable were developed (appendix A). The Ted's 10 were chosen as a tool to implement environmental sustainability in product design because of their focus on the design process and the role of the designer. They specifically target the decisions designers can take in order to positively influence the sustainability of the product design. Therefore, they act as a framework that allows the designer to consider different angles in product design and that offers various methodologies that can improve the sustainability of the product's design. Moreover, they are focused on the improving the sustainability position of products in the textile and fashion industry. Therefore, they add value to the newly developed framework in the analysis as they offer improvements that are specifically tailored to textile and fashion products. Out of the 10 goals, 8 are connected to environmental sustainability, namely #1 design to minimize waste, #2 design for cyclability, #3 design to reduce chemical impacts, #4 design to reduce energy and water use, #5 design that explores clean/better technologies, #6 design that takes models from nature & history, #8 design to reduce the need to consumer, #9 design to dematerialize and develop systems & services ('Ted's 10', 2020). Because this thesis focuses solely on environmental sustainability decisions taken in product design, only those goals connect to environmental sustainability are chosen. As explained in the previous section, product design in this thesis are refers to aesthetic design attributes: style, materials, color, and fit. Therefore, only those goals that can impact product design for assessment. The explanation and reasons for which the goals were chosen can be seen in the table 2. For example, Ted's 10 9 'Design to Dematerialize and Develop Systems & Services' was excluded because it concerns e.g. leasing and renting schemes, and the focus of the thesis is to render the final product more sustainable in the product design phase.

Table 2 Chosen Ted's 10 Goals, Explanation & Justification based on 'Ted's 10' (2020)

Ted's 10	Explanation	Justification/ Relevance for aesthetic design elements
<i>#1 Design to minimize waste</i>	Minimize waste pre and post-consumer, e.g. zero waste cutting, recycling, design for long-life, design with “enhanced aesthetic value”	Goal affects style, color and fit to be e.g. timeless/ versatile and prevents disposal
<i>#2 Design for cyclability</i>	Design for recycling/ upcycling, e.g. mono materiality, disassembly for a closed-loop system, re-useable and non-invasive designs	Goal affects style, color and fit to be e.g. timeless/ versatile and prevents disposal
<i>#3 Design to reduce chemical impacts</i>	Material selection with less environmental impact, e.g. dyeing/ printing process	Goal affects dyeing process (colors) and the type of fibers used (synthetic/ cellulose/ natural fibers), fabric construction
<i>#4 Design to reduce energy and water use</i>	Production & use phase less harmful and wasteful technologies (e.g. air-dyeing) e.g. design for no/ low launder, less coatings, informative labelling	Goal affects dyeing process (colors) and the type of fibers used (synthetic/ cellulose/ natural fibers), fabric construction
<i>#8 Design to reduce the need to consume</i>	Long-lasting, adaptable products e.g. durable designs, slow designs, consumer participation	Goal affects style, color and fit to be e.g. timeless/ versatile and prevents disposal

2.5. UN Sustainable Development Goals

The UN has, in corporation with the Global Reporting Initiative (GRI), UN Global Compact and PWC, developed 17 sustainable development goals. Of these goals, six are connected to environmental sustainability. SDG 15 is ‘Life on Land’, 14 is ‘Life below Water’, 13 is ‘Climate Action’, 12 is ‘Responsible Consumption and Production’, 7 is ‘Affordable and Clean Energy’, and 6 is ‘Clean Water and Sanitation’. All Goals have several targets which can be measured by various indicators. All six goals and their targets can be seen in appendix B (UN Sustainable Development Goals, 2020). The UN Sustainable Development Goals were chosen to serve as base for this thesis due to their high importance and acknowledgement worldwide. In accordance with the focus of this thesis on product design, applicable SDGs and their targets were chosen as a guideline for this thesis. Table 3 shows the chosen SDG, targets and the

reasons for which they are applicable. It must be mentioned that the UN SDGs are not legally binding, but institutions, organizations and companies are encouraged to implement measures in order to achieve them (UN Sustainable Development Agenda, 2020).

Table 3 Chosen SDGs, Targets, Explanations & Justification based on UN Sustainable Development Goals (2020)

SDG	Target	Explanation	Justification/ Relevance for Design
<i>#6 Clean Water Sanitation</i>	6.3 improve water quality by reducing pollution through dumping hazardous chemicals	Water usage, treatment and discharge remediation, management of materials and waste, promote water-reuse and recycling	Target affects dyeing process (colors) and the type of fibers used (synthetic/ cellulose/ natural fibers) (Kaldolph & Langford, 2013; McCourt, 2020)
<i>#12 Responsible Consumption and Production</i>	12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse	Tracking waste, circular business models, renewable bio-based recyclable inputs, extending product lifecycles, extending responsibility to post-consumer stage	Target affects design, color and silhouette to be e.g. timeless/ versatile and prevents disposal, (UN Sustainable Development Goals, 2020)
<i>#14 Life below Water</i>	14.1 by 2025 prevent and reduce marine pollution from land-based activities	Reduce wastewater generation, non-degradable materials, waste collection, reuse, recycling, circular models	Target affects design, color and silhouette to be e.g. timeless / versatile and prevents disposal (Kaldolph & Langford, 2013; McCourt, 2020)
<i>#15 Life on Land</i>	15.2 by 2020 promote implementation of sustainable management of all forests, halt deforestation, increase forestation	Use reduced-impact harvesting techniques, forest management certifications of forest products	Target affects type of material derived from forests (cellulose) (McCourt, 2020)

In the first section of the analysis the UN Sustainable Development Goals will be used to identify a lack of environmental sustainability in the product design. By considering the UN SDGs, phases in the product development process which do not contribute to the goals become

apparent. On the basis of uncovering a lack of environmental sustainability pertaining to the UN goals, opportunities for improvement can be identified. Therefore, the second step in the analysis is based on using the above-mentioned Ted's 10 goals to develop a sustainable theoretical framework concentrated on aesthetic design elements in product design. By comparing the UN goals to existing product development and the theoretical framework, designers and companies are able to track their progress towards achieving sustainability and being in line with some environmental targets set by the United Nations. Therefore, this comparison can be seen as relevant for textile and fashion organizations.

3. Methodology

The methodology outlines and explains the procedures chosen to reach the objectives of this research. The methodology includes the research onion by Saunders et al. (2019), data collection and data analysis methods, and a workflow chart. Saunders et al. (2019) research onion was chosen to act as a guideline through this methodology due to its popularity, integrity and recognition in academic research to understand the research philosophy of the master's thesis.

3.1. Research Philosophy

The research onion is composed of the following six layers: (1) philosophies, (2) approach to theory development, (3) methodological choice, (4) strategies, (5) time horizons, and (6) techniques and procedures as depicted below in figure 1. In the consecutive chapters, applicable theories to the research of this paper will be examined.

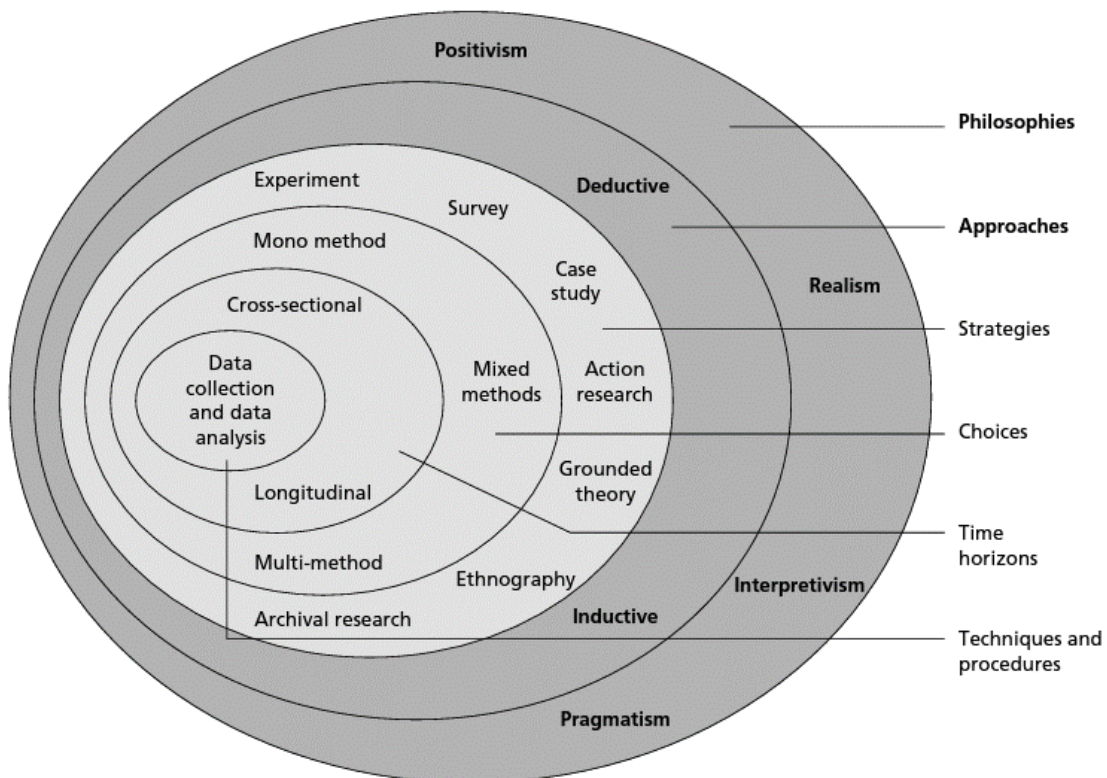


Figure 1 The research onion (Saunders et al, 2009, p. 108)

3.1.1. Philosophies

In the outer layer of the research model is referred to “a system of beliefs and assumptions about the development of knowledge” (Saunders et al., 2019, p.130). It is the first step in gathering knowledge in a specific area. Five types of philosophies exist, namely: positivism, critical realism, interpretivism, post-modernism, and pragmatism. Each have an ontological, epistemological, and axiological position. Ontology refers to the nature of reality or being, epistemology refers to what constitutes acceptable knowledge and axiology refers to the role of values (Saunders et al., 2019, p.144). The philosophical approach chosen for this thesis is divided into two approaches: critical realism and pragmatism. According to Saunders et al. (2019; p.147) critical realism refers to “what we see and experience, in terms of underlying structures of reality that shape the observable events” (ontology). In critical realism it is believed that a structured and layered ontology is important. Epistemologically, a critical realist sees knowledge as historically situated believes that social facts are “social constructions agreed on by other people rather than existing independently” (Saunders et al., 2019, p.148). The axiological position is that knowledge of reality is a result of social conditioning. This means that a researcher adapting this approach is aware of its biases (e.g. background, experiences) and seeks to minimize these biases and be as objective as possible. Typical methods are “in-depth historically situated analysis of pre-existing structures” and a range of methods can be used in this philosophy (e.g. qualitative, quantitative, mixed) (Saunders et al., 2019, p.144). The systematic literature review has a critical realism philosophy as it builds on pre-existing knowledge that it seeks to critically and objectively analyze. The second part of the thesis follows a pragmatist philosophy. Pragmatism refers to concepts only being relevant when they support action by combining both objectivism with subjectivism. A pragmatist begins research with a problem and aims to find practical solutions that inform future practice. A pragmatists ontological position is that reality is the consequence of ideas, experiences and practices. Epistemologically, a pragmatist focuses on problem solving and on informing future practice by making a contribution. The axiology of a pragmatists is a value-driven research that is initiated by the researcher’s doubts and beliefs. Typical methods are following a research problem and research question and conducting various types of studies (e.g. qualitative, quantitative, action research, mixed) (Saunders et al., 2019, pp.145 -151). The second part after the systematic literature review follows a pragmatist philosophy because it aims to find a theoretical and practical solution for incorporating environmental sustainability in the process of product development by stating a research problem and a research question. Moreover, this

research serves as a base for future research in developing an environmentally sustainable product development model.

3.1.2. Approach to theory development

The second layer is concerned with the development of theory either through inductive, deductive or abductive reasoning. This research follows a deductive and inductive approach due to applying two data collection and analysis techniques. In the systematic literature review, the deductive approach was applied by “basing analysis on pre-existing theory” (as cited in Azungah, 2018). The deductive approach in the systematic literature follows a highly structured methodology, which ensures replication. Moreover, the researcher should be independent and objective about the topic (Saunders et al., 2009, p.125). Because the systematic review follows a clear guideline and sets in- and exclusion criteria, as well as extracts the same type of information from literature using a standardized data extraction form, it can be categorized as a deductive approach. Furthermore, the interviews follow an inductive approach. Data is first collected through the interviews and then themes, or issues are explored (Saunders et al., 2009, p.490).

3.1.3. Methodological choice

The third layer of Saunders research onion refers to the choice between quantitative, qualitative, and mixed, and multi methods in gathering primary data. In this thesis a multi method, namely a systematic literature review method that is conducted in a qualitative method and qualitative research is selected. A multi method is one that uses multiple qualitative data collection techniques and analysis procedures at the same time or sequentially but that does not combine them (Saunders et al., 2009, p. 152). The first method concerns the systematic literature review. Because the analysis and synthesis follow a narrative method, the systematic review is conducted in a qualitative manner. Next, non-numeric data in form of interviews was collected to validate the theoretical framework, which is also a qualitative method. Due to the low number of interviews (two expert interviews), qualitative research gives more in-depth insights than quantitative research. The choice of the interviewees will be further explained in the ‘Primary Data’ (see 3.1.7) layer of the research onion.

3.1.4. Strategies

The strategical choice of methods is closely related to the purpose of research design. Studies are either exploratory, descriptive, explanatory, evaluative or have a joint purpose (Saunders et al., 2009, p.139) This thesis’ purpose is of descriptive and exploratory nature because it aims

at finding existing information and analyzing and synthesizing literature in the systematic literature review and it is exploratory because it also aims to seek new insights and to assess phenomena in a new light (sustainability).

Eight different types of research strategies have been identified by Saunders, Lewis and Thornhill: experiment, survey, archival and documentary research, case study, ethnography, action research, grounded theory, and narrative inquiry, systematic literature review. The first part of the thesis follows the systematic literature review approach as described in 'Systematic Literature Review'. The second part follows a case-study strategy because it "is an empirical investigation of a particular contemporary phenomenon according to Yin (2003) (as cited in Saunders et al., 2009, p. 145). A case-study does not necessarily mean a specific practical case is being studied but can also be used as a strategy when a topic is being studied. The case study design is most used in explanatory and exploratory research. It also enables the researcher to challenge and existing theory and provide new research directions (Saunders et al., 2009 p. 147). The second part can be seen as following a case-study design because it builds on a topic which is being studied and proposes a new research direction (theoretical framework). Furthermore, Yin defines four case strategies that differentiate between two dimensions: single case and multiple case and holistic case and embedded case (as cited in Saunders et al., 2009, p.146). This case-study strategy is a single and embedded case because a phenomenon is observed and analyzed that few have considered before (sustainability in the product design). It is also embedded because multiple stages of the topic (product design) are concerned (Saunders et al., 2009, p.146).

3.1.5. Time horizons

The time horizon of a project can either be cross-sectional or longitudinal. They determine a period of time dedicated to a research project (Saunders et al., 2009, p. 155). The time frame given by the University of Borås to complete this project is ten weeks. As the project is set to start and finish at a particular time, the time horizon is categorized as cross-sectional.

3.1.6. Secondary data

Secondary data includes "raw data and published summaries" in order to "provide a useful source from which to answer [a] research question" (Saunders et al., 2009, p.256). Secondary data is used to answer sub-questions one, two and three. In sub-question two and three, secondary data provides information that supports the implementation of sustainability in

product design. Two of the University of Borås' databases are used, namely Scopus and Web of Science.

3.1.7. Primary data

Primary data will be collected in the form of interviews, which enables the researcher to explore the answers given. In addition to secondary research, primary data is collected to answer sub-research question four. Table 4 shows the primary data collection methods applied in this thesis.

Table 4 Primary Data Collection

<i>Interviewee(s)</i>	<i>Reason</i>	<i>Type of Primary Data</i>	<i>Date</i>
Ahsan Shafiq	Lecturer at the University of Borås, extensive practical knowledge in the field of product development, theoretical knowledge in product development proven by teaching the course 'Product Development' as part of the M.Sc. Textile Management curriculum.	Semi-structured, zoom	05.05.2020 audio-taped
Jonas Larsson	Lecturer at the University of Borås, extensive practical knowledge in the field of product development, knowledge of UN SDG's due to extensive work	Semi-structured, zoom	08.05.2020 audio-taped

As the aim of the thesis is to assess evaluate the sustainable framework based on the UN SDGs, two experts in the field were interviewed. These were chosen carefully and based on their vast knowledge and experience. Therefore, purposive sampling, which is common in case study research, has been chosen (Saunders et al., 2009, p.237). A semi-structured interview with Ahsan Shafiq and Jonas Larsson was conducted because the questions determined beforehand set the direction of the interview but also allow room for connected topics and follow-up questions that the interviewee finds of importance.

3.1.8. Data analysis

Once secondary data using the systematic literature review approach is found, it is analyzed and synthesized. A data extraction form will be used to extract relevant information from all articles systematically. After primary data has been collected it must be analyzed. Interviews are transcribed and coded in order to display main findings and draw conclusions (appendix C). This procedure from Miles et al. (1994) consists of the following steps: data reduction, data display, and drawing and verifying conclusions (as cited in Saunders et al., 2009, p.503).

3.1.9. Validity

The validity of the report highly influences the quality of the project as it “is concerned with whether the findings are really about what they appear to be about” (Saunders et al., 2009, p. 157). In the interviews, follow-up questions, probing questions and interpreting questions were asked to ensure validity and reduce interviewer bias (Bryman, 2012, p. 478). For example, in the interview with Larsson (2020) and Shafiq (2020), the interviewer asked follow-up questions like “Do you mean...? What do you mean by...?”, that enabled the interviewees to confirm their statements and allowed the interviewer to understand their arguments more accurately.

3.1.10. Reliability

The reliability of sources is ensured through consistency and replication (Saunders et al., 2015, p. 202). The systematic literature can be categorized as highly reliable because of a strict and clear methodological guide that allows exact replication of the research. Moreover, in the data analysis of the systematic literature, only those product design/ development models were used, which showed a high level of reliability because they had been used and referenced in multiple articles. Because it is difficult to ensure reliability in qualitative research, the interviews are audio-taped (Saunders et al., 2009, p.276).

3.1.11. Ethics

By acting upon ethical standards, the project includes all parties involved appropriately. Integrity and objectivity is applied throughout this research to ensure the highest possible quality of outcomes. Furthermore, privacy of those partaking in the study is guaranteed if anonymity is wished. A signed copy of the GDPR form by all interviewees is attached in the appendices (appendix D).

3.2. Data Collection

3.2.1. Systematic Literature Review

A systematic literature review concerns a specific question, uses detailed and clear methods to conduct a thorough literature search and critical appraisal of studies, draws conclusions about current information and a potential lack of information about a question or topic. It is systematic because the researcher follows a clear research design which is documented in detail. Benefits are the systematic and replicable approach, which indicate the study's high reliability considering the present knowledge of the question it aims to accumulate information for. Systematic reviews follow five principle steps: (1) planning the review, (2) locating the studies, (3) appraising contributions, (4) analyzing and synthesizing information, and (5) reporting “best

evidence". In comparison to a traditional literature review, Tranfield et al. (2003) find that the systematic approach is replicable, scientific, and transparent, which "aims to minimize bias through exhaustive literature searches of published and unpublished studies and by providing an audit trail of the reviewers' decisions, procedures and conclusions" (as cited in Briner and Denyer, 2012). Gough (2007) also notes that limitations of a systematic review are acknowledged because of the clear documentation of the review method, which allows critical evaluation thereof (as cited in Briner and Denyer, 2012). Although systematic reviews are widely used in the field of medicine and health care, they also have the potential to benefit the practice of management. Systematic reviews allow for an effective accumulation of evidence of previous research, which lacks in management as emphasis is placed on empirical contributions instead of reviews or syntheses. To further specify the five principle steps of a systematic review figure 2 shows the combination of a 11-step model by Petticrew and Roberts (2006) and the 12-step framework by Kable et al. (2012). By combining the two models, several steps overlap but also show a more complete guide for the researcher's systematic literature review.

First, the review question must be identified. It must be precise, answerable, and meaningful and guides the review because it defines which studies should be included, what the search study must be and what data must be extracted from each study. Counsell (1997) stresses that these characteristics are difficult to achieve fully but are crucial to ensure to produce a strong review (as cited in Briner and Denyer, 2012). Kable et al. (2012) also stress the importance of providing a purpose statement to describe the question. Second, techniques to formulate the research question are either using an advisory group of experts or to test the questions logically. Discussing the purpose of the review with experts may render the question more answerable and specific. The question can be tested logically by examining whether question makes sense, is specific enough, if it will support the review method, and if it allows clear judgements about what kind of data from which type of source can answer the question. Third, types of studies and data appropriate for the review question should be determined. The researcher decides at this stage what types of data, from which type of research design and from which source are included in the research (Briner and Denyer, 2012; Kable et al., 2012). Fourth, relevant studies are located. Before the search starts, a project protocol must be established. This entails a description of the review question, the proposed methods, details of how different types of studies will be located, appraised and synthesized. Inclusion and exclusion criteria are set to ensure a methodical review of articles and databases and relevant search terms (keywords) are identified (Briner and Denyer, 2012; Kable et al, 2012).

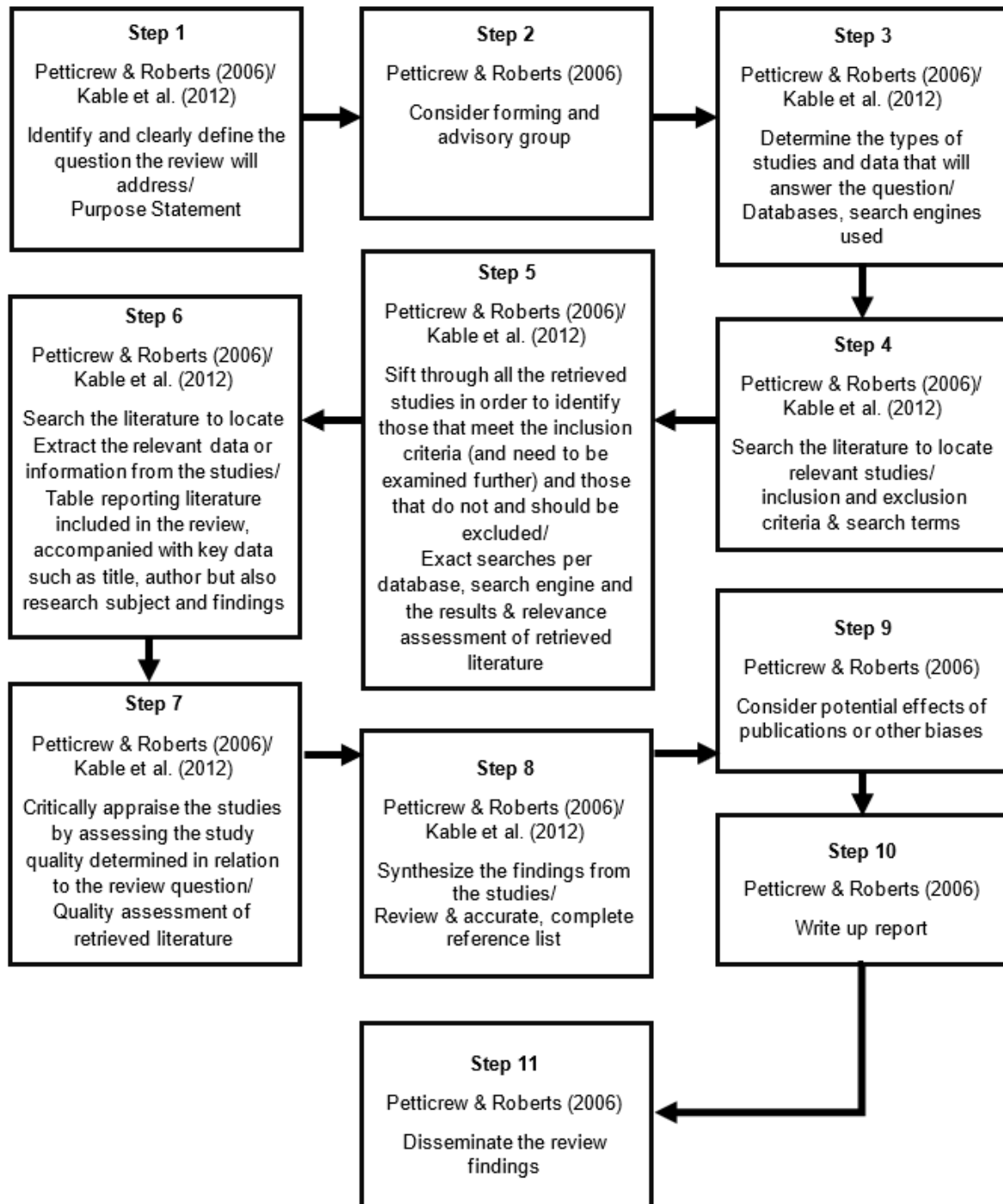


Figure 2 Combination of a 11-step model adopted from Petticrew and Roberts 2006 (as cited in Briner and Denyer (2012) and a 12-step model adopted from Kable et al. (2012) for a Systematic Literature Review

The protocol ensures that the review is systematic, transparent and replicable. Kable et al. (2012) also highlight the importance of specifying the search limits, such as dates and language. Next, a scoping study is conducted to assess whether the search strategy is effective in finding relevant studies using exclusion and inclusion criteria. Once all requirements are set, retrieved articles are assessed for relevance (Kable et al., 2012). Bettany-Saltikov (2010) proposes to assess the findings in regard to the inclusion and exclusion criteria in three steps. First, all

articles with titles that are in accordance with the inclusion and exclusion criteria are saved. Out of those, the abstract is read, and appropriate articles are saved. Lastly, all remaining articles are read and kept if they meet the criteria. The search terms used should be listed in a table as well as the articles approved in each step (Kable et al., 2012). Following step 6, relevant data is extracted and made available for analysis and synthesis. All articles that will be used are summarized in a table of included articles (Kable et al., 2012). In step 7, the selected studies are critically appraised in terms of quality. Quality criteria such as research ethics, theoretical and practical importance of the research, clarity and coherence of the study report, should be set in advance. An overall quality score or rating is produced, and studies are ranked. This process must also be documented and explained in detail so others can easily replicate the research (Briner and Denyer, 2012; Kabel et al. 2012). In step 8 findings are analyzed and synthesized. The aim of the analysis is to “examine and dissect individual studies and explore how the components relate to one another”. According to Denyer and Tranfield (2009), the aim of the synthesis is to put together the findings from individual studies “into a new or different arrangement and develop[...] knowledge that is not apparent from reading the individual studies in isolation” (as cited in Briner and Denyer, 2012). The analysis begins with extracting data from the studies and collecting this data in a data collection form. The data extraction form includes general information, the type of outcome, research strategy, data collection method, and common themes. This summary provides the reader with a useful overview of the field of research. Next, data is synthesized. The researcher can choose between four synthesis approaches: aggregative, integrative, interpretation or explanation or narrative. Ohlsson (1994) finds that the aggregative method quantitatively combines multiple studies using statistics e.g. meta-analysis (as cited in Briner and Denyer, 2012). According to Roberts et al. (2002), the integrative approach incorporates qualitative and quantitative studies and compares the findings of both studies (as cited in Briner and Denyer, 2012). Noblitt & Hare (1988) find that the interpretative methods in concerned with “translating and comparing the data across studies to develop categories and higher-level themes” (as cited in Briner and Denyer, 2012). The explanatory approach finds causal mechanisms in data and explain how they work and in which circumstances (Pawson, 2006; as cited Briner and Denyer, 2012). Lastly the narrative method is a flexible and critical method which collects studies that address different aspects of the same phenomenon and build them into a bigger picture. The researcher can choose between either method but must justify why the chosen method is appropriate for the study (Briner and Denyer, 2012). Kable et al. (2012) add that literature should be reviewed and synthesized critically and that the reference list should be checked for accuracy. In step 9, the researcher identifies

potential biases and limitations of the review method. In step 10, the report is written. In step 11, disseminate the review findings, the researcher must ensure the accessibility of the review to all who need to know about the research (Briner and Denyer, 2012).

Systematic Literature Review

The following question and sub-questions are related to the systematic literature review.

Table 5 Systematic Literature Review Questions

WHAT DOES CURRENT PRODUCT DESIGN IN PRODUCT DEVELOPMENT MODELS IN THE FASHION AND TEXTILE INDUSTRY ENTAIL?

Sub-question 1 (Extraction)	Which product development and design models in the textile and fashion industry can be found?
Sub-question 2 (Analysis)	Which product design/ development models in the textile and fashion industry are most relevant in light of product design?
Sub-question 3 (Synthesis)	What can be examined when synthesizing all models?

Search Strategy

In order to develop an effective search strategy as part of the systematic literature review a combination of two frameworks developed by Kable et al (2012) and Briner and Denyer (2012) was applied. The following limitations were made.

Table 6 Search Limitations

SEARCH	LIMIT	JUSTIFICATION
Databases	<i>Web of Science Scopus</i>	double- blinded, multi-disciplinary research platforms, peer-reviewed topics, relevant scientific and academic papers
Reliability	<i>Peer-reviewed</i>	High quality of articles, appropriate base for the systematic literature review
Date	<i>1990-2019</i>	Quantity of relevant articles, currency of development of product development of today's fashion and textile industry
Language	<i>English language</i>	in line with the language spoken in the M.Sc. Textile Management program
Document type	<i>article</i>	only articles are used
Search in	<i>article title</i>	search keywords must be reflected in the title due to high importance of finding models

Relevance assessment

Inclusion and exclusion criteria were set in order to determine which articles have the potential to be most relevant. In each of the three steps, following Bettany-Saltikov's (2011) model, the inclusion and exclusion criteria were applied. Following this approach, this had the effect of excluding several studies in each step.

Table 7 Inclusion Criteria

INCLUSION CRITERIA	JUSTIFICATION
Article must include a product development or design model/ process	focus of the literature search and review
Article must be a qualitative study	to examine and evaluate product development models, provides in-depth information
Article must be from or for the textile and fashion industry	thesis focuses on the product development in these industries
product development or design model/ process must be explained	must be explained in detail to allow analyzing for limitations of sustainability

Table 8 Exclusion Criteria

EXCLUSION CRITERIA

product development/ design plays an inferior role	Not in line with the aim of the SLR
product development is analyzed based on sustainability	makes the aim of the thesis redundant
model is not applicable in the fashion or textile industry	does not contribute to developing ideas for the concerned industry
model is general	no connection to the textile and fashion industry
study is quantitative (focus should be on how the model works (qualitative) not on statistics)	the model must be explained in-depth, which is not given in a quantitative study, statistical measures do not add value in assessing a topic in depth
pilot studies	has not been tested in a relevant environment yet

It is important to mention that quantitative studies were disregarded because of their focus on statistical analyses. For example, the article “Barrier to customer integration into new product development process: A case of apparel industry in Pakistan” by Sheikh & Awan (2013) was excluded because the focus was to use exploratory factory analysis, correlation analysis, ANOVA and descriptive statistics from a survey to 25 small to medium companies (SME) to uncover the potential barriers of customer input in product design within product development. While the topic of customer integration is already irrelevant to this research, a quantitative analysis would only statistically prove a strong or weak correlation between product design e.g. lack of awareness in the case of this study (Sheik & Awan, 2013). Because the focus is to understand product design in-depth, a quantitative analysis would only show that there is a correlation but not why.

Search terms

For the search terms three different steps of keyword combinations were used. In the first step all the variations of product development were searched. In the second step all the combinations of textile were used. In the third step all the synonyms for model were inserted. These steps are

combined with an AND or OR in the search string. Furthermore the *(asterisk) was used to find all the plural and derivative words.

Table 9 Keyword Variations

THEMES	KEYWORDS
<i>Product development</i>	<i>product design* OR product innovation* OR product lifecycle* OR development of product*</i>
AND	
<i>Textile</i>	<i>textil* OR fashion* OR fabric* OR garment* OR apparel* OR cloth*</i>
AND	
<i>Industry</i>	<i>industr* OR compan* OR brand* OR product*</i>
AND	
<i>Model</i>	<i>model* OR process* OR cycle* OR step* OR stage* OR method*</i>

Search Process Documentation

Following Bettany Saltikov's (2011) model, the inclusion and exclusion criteria were deployed in each step. Unfortunately, five articles believed applicable for this research were not accessible through any databased provided by the University of Borås at the time of research. Appendix E shows a complete list of the chosen articles and of those that were not accessible. Nevertheless, the following results were yielded.

Table 10 Search Process Findings

STEP	RESULTS
<i>Initial search</i>	Scopus: 32 articles found Web of Science: 25 articles found
<i>Unique articles</i>	Total: 48 articles
<i>Title</i>	Scopus: 17 articles approved, 6 deleted Web of Science: 17 articles approved, 8 deleted
<i>Abstract</i>	Scopus: 12 articles approved, 5 deleted Web of Science: 10 articles approved, 7 deleted
<i>Article</i>	Scopus: 6 approved Web of Science: 6 approved

Quality appraisal

Because this systematic literature review includes only peer-reviewed articles from two reliable databases, no further quality assessment needs to be undertaken.

Data analysis

After all relevant articles are found, articles are reviewed critically. This includes data extraction, data analysis and synthesis.

1. Data extraction

Relevant data of all articles is extracted and summarized in a data extraction form. This allows comparing all data. The categories used for data extraction in this report are general information (title, author, publication year, type of publication, publishing country, database), study characteristics (study design, research strategy) and content (number of processes found, publication year of processes, authors, number of steps in process, steps attributed to product design). The data extraction form can be found in appendix F.

2. Data analysis

All data was compiled on the basis of the data extraction form, which allowed for a critical assessment and comparison of data. Steps attributed to product design were filtered out based on the explanations of models. The 'Frame of Reference' gives more insight into the definition of the aesthetic design elements and product design. General and content information were analyzed. General information refers to the publication trend of the chosen articles and to the type of research studies applied. Content information was analyzed by assessing the number of models found, the time span of publication of the models, the number of times specific author's models were referred to, and the number of steps attributed to product design.

3. Synthesis

Data synthesis follows the narrative method. Studies are collected that address different aspects of product design (the phenomenon of this thesis). The results are built into a bigger picture that allows further critical reflection. This synthesis compiles data to examine what the similarities and differences between the chosen product design/ development models, in specific the aesthetic design elements, are and combines the findings into one model which focuses on aesthetic design elements in product design. Based on the data analysis only the most relevant models are included in the synthesis. Table 11 (p.30) depicts all models found within the articles.

3.2.2. Qualitative Interviews

According to Saunders et al. (2009) qualitative interviews can be structured, unstructured, or semi-structured. In this thesis, semi-structured interview guide is applied in order to receive in-depth information and “understand the participant’s explanations and meanings” (Saunders et al., 2009, p.334). During the interview, different type of questions allowed the researcher to increase validity of the answers. Open questions allowed the interviewees to give an extensive answer, which allows for follow up questions (Saunders et al., 2009, p.337). Probing questions were used to examine whether responses are of high significance to the research topic. Moreover, they allowed the researcher to seek further explanation and thus, avoid misunderstandings (Saunders et al., 2009, p.338). McGrath et al. (2018) developed 12 tips for successfully conducting qualitative research interviews (see figure 3). Tip 1 refers to including the right number of participants as needed who are suitable to answer the questions e.g. based on their insights or experience concerning the phenomenon to be explored (McGrath et al., 2018). The interviews in this thesis are based on the expertise and experience of the interviewees. Tip 2 refers to conceptual and practical preparations of the interviewer (McGrath et al., 2018). Questions should be planned around the subject of the research question and the interviewer should be knowledgeable about the topic. Moreover, practical preparations should be in place such as data recording devices, setting, time and place and ethical approval/ consent. The questions for the interviews in this thesis are planned around the analysis from a sustainability and a practical perspective. The researcher is knowledgeable of the topic as she has previously collected literature on the topic of sustainable product design and has conducted the systematic literature review in order to compile a background base. Moreover, the researcher/interviewer has prepared the interviews in that an audio-taping device was set up, a meeting with the interviewees was scheduled via Zoom, and a GDPR form was prepared and signed by both interviewees to consent to the use of collected data during the interview. Tip 3 refers to constructing an interview guide and conducting a test interview (McGrath et al., 2018). An initial interview was held with Larsson on 5th May 2020, whereupon questions were modified, and which was not included in the findings. This trial interview poses as a test interview. After refining questions and improving the explanation about this thesis, an interview with Shafiq and Larsson were held subsequently in the afternoon of 5th May and 8th May 2020. Several interview questions were determined beforehand and can be seen in the interview guide in appendix G. However, as the interviews were semi-structured, additional questions were asked or rephrased. Tip 4 refers to power dimensions in the interviews (McGrath et al., 2018). It is considered that a power imbalance might exist because the researcher’s professors/

lecturers were interviewed. However, because the questions are asked clearly and objectively without underlying implying and because they are targeted at the interviewee's area of expertise, the impact of a power imbalance was reduced. Tip 5 refers to establishing comfortable interactions (McGrath et al., 2018). Prior to the interview, interviewees were sent an invitation for the interview including a description of the interview purpose and theme. Therefore, interviewees were informed beforehand of the expectations. Tip 6 refers to acknowledging the influence that the interviewer has during the interview (McGrath et al., 2018). By asking follow-up, probing and open questions the interviewer actively lead the interview. However, in order to reduce interviewer bias, questions were merely targeted at collecting in-depth information and clarifying misunderstandings. Tip 7 refers to allowing the interviewees to express themselves (McGrath et al., 2018). During the two expert interviews, the researcher only asked questions without giving feedback or adding to the content that the interviewees expressed. Tip 8 refers to flexibility concerning the interview guide (McGrath et al., 2018). The interview questions were refined after the trial interview but also during the interviews by rephrasing the questions for better explanation. Tip 9 refers to unanticipated emotions (McGrath et al., 2018). The researcher tried to ask questions are objectively and clearly as possible in order to avoid provoking negative emotions. For example, during the interview with Larsson, the researcher acknowledged the timing of the interview (Friday afternoon) and decided to rephrase a question into several short questions in order to retain as much information as possible. Tip 10 refers to transcription of interviews (McGrath et al., 2018). The researcher transcribed interviews at latest one week after the last interview in order to "identify analytical structures and find similarities and differences" as soon as possible (McGrath et al., 2018). Tip 11 refers to checking data, which can be in the form of member check, participant validation, or during interviews (McGrath et al., 2018). The researcher purposely asked probing questions to increase validity of answers. Tip 12 refers to initiating analysis early because the amount of transcribed data can be overwhelming (McGrath et al., 2018). The analysis was initiated immediately after the transcription but also partly during the interviews.

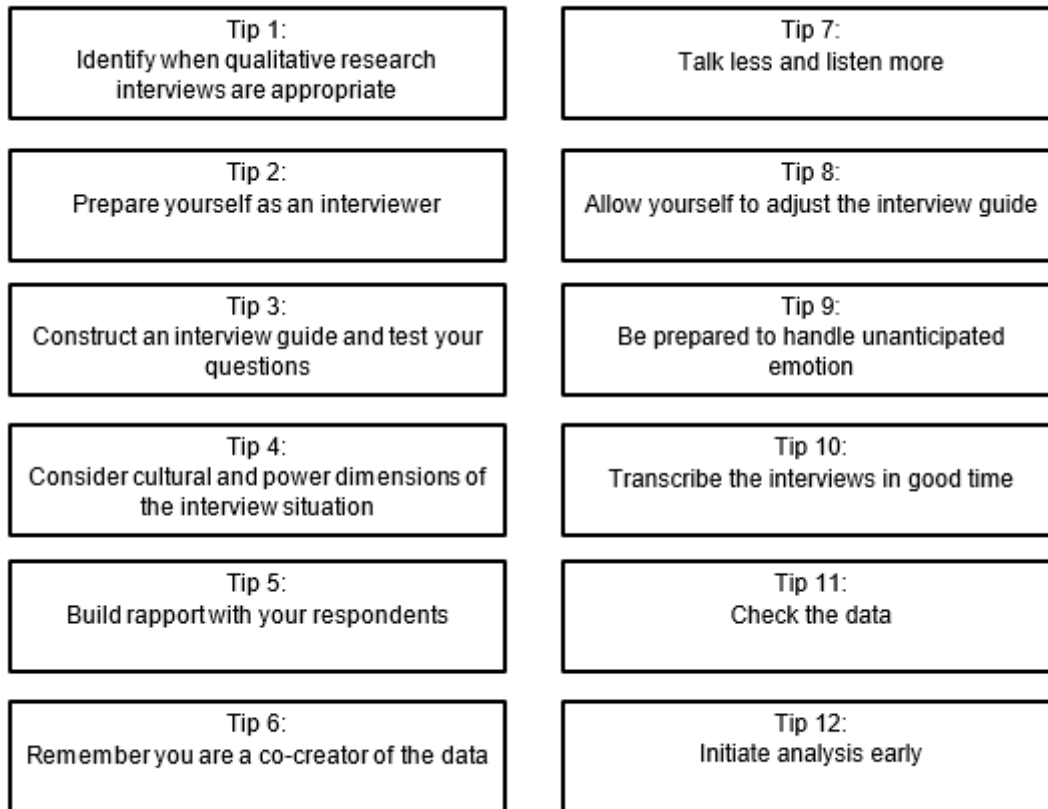


Figure 3 Conducting qualitative research interviews based on McGrath et al. (2018)

3.3. Workflow Chart/ Conceptual Model

A conceptual model supports the research in that it helps to understand and explain to external stakeholders “what is going on in the research setting [that is being] studied” (Saunders et al., 2009, p.296). Moreover, the conceptual framework is linked to the research question and the objective (Saunders et al., 2009, p.525). In contrast to quantitative research, qualitative research is guided by a conceptual framework rather than a theoretical framework. This is because in quantitative research, usually following a deductive approach, theory is tested using variables and statistics. However, in qualitative research a conceptual model is more appropriate as information is gathered first, followed by exploring different common themes. The conceptual framework/model identifies relationships in data and develops questions to test these; the theory emerges from data collection and analysis (Saunders et al., 2009, p.490). The conceptual model developed for this thesis shows the steps necessary to be undertaken in order to develop a sustainable theoretical framework.

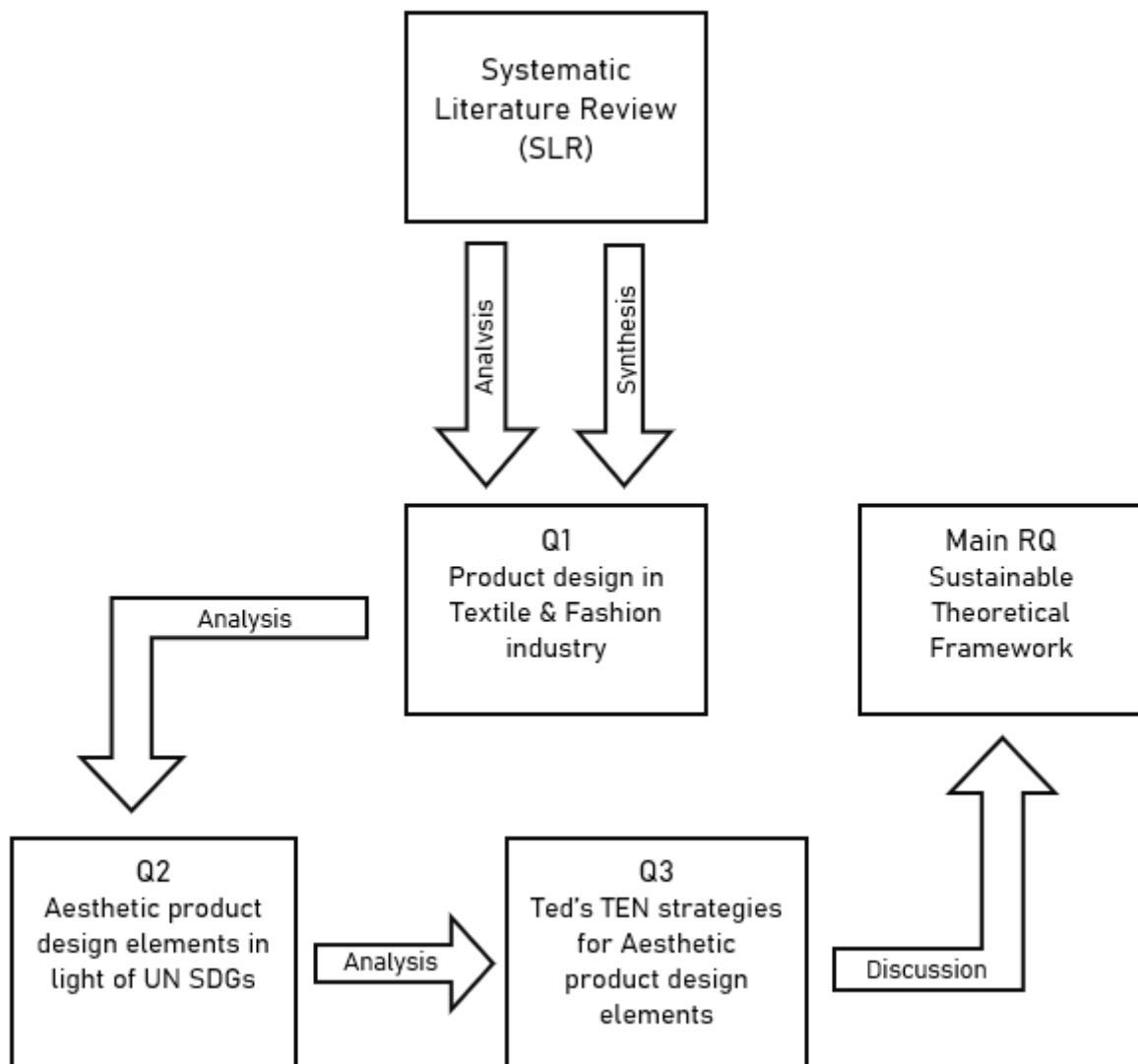


Figure 4 Workflow Chart/ Conceptual Model (own figure)

The systematic literature review allows the researcher to find relevant theoretical knowledge, which serves as a base for analysis and further, the development of the theoretical framework (Q1). The underlying premise of the main research question “How can the aesthetic design elements in product design, as part of the product development process, in the fashion and textile industry be improved considering environmental sustainability using the Ted’s 10 methodology and the UN Sustainable Development Goals as a guide?” is that the environmental sustainability position in the textile and fashion industry needs to be improved. By analyzing knowledge from the systematic literature review, the underlying premise is validated by comparing the current state of product design with the UN SDGs (Q2). Lastly, the Ted’s 10 are applied in order to support the practice of product design to reach several UN SDGs (Q3). These suggestions in the analysis are presented in the theoretical framework.

4. Findings

In the findings section, data from the systematic literature review and from the two interviews is analyzed and synthesized. The analysis encompasses the general analysis and content specific analysis. The synthesis encompasses the product development and design description and the similarities and differences in product design. Furthermore, the findings of the interviews are displayed. Based on the findings, the analysis is conducted. The findings section already answers sub-research question 1, which will be discussed further in the discussion.

4.1. Data Analysis

The data analysis is divided into two parts: the general analysis and the content analysis. The general analysis analyses the nature of the product development and product design articles found in the literature; the article publications and the research strategy in the papers. Both show general information of all articles. The content analysis focuses on the product development and product design models found within these articles. Although only 12 articles were found, within those 12 articles, 36 unique product design/ development models were found. These were analyzed based on the relevance and contribution to the topic of this thesis. First, the publication frame where most models were published was evaluated, the number of times these models were mentioned were assessed, and lastly the number of steps that focus on product design within product development were measured. Based on this analysis, suitable product design/ development models were chosen.

4.1.1. General Analysis

The general analysis of the literature found in the systematic literature review entails an assessment on the publication time frame and the research designs. Figure 4 shows the time frame. Although the search limits prior to the literature search were set to 1990 until 2019, the graph indicates that articles concerning product development models in the textile and fashion industry were published between 1998 and 2019. In this time frame, most articles were published between 1999 and 2016. Therefore, it can be said that most information that is relevant for today's product design in product development in the textile and fashion industry was compiled and generated between 1999 and 2016.

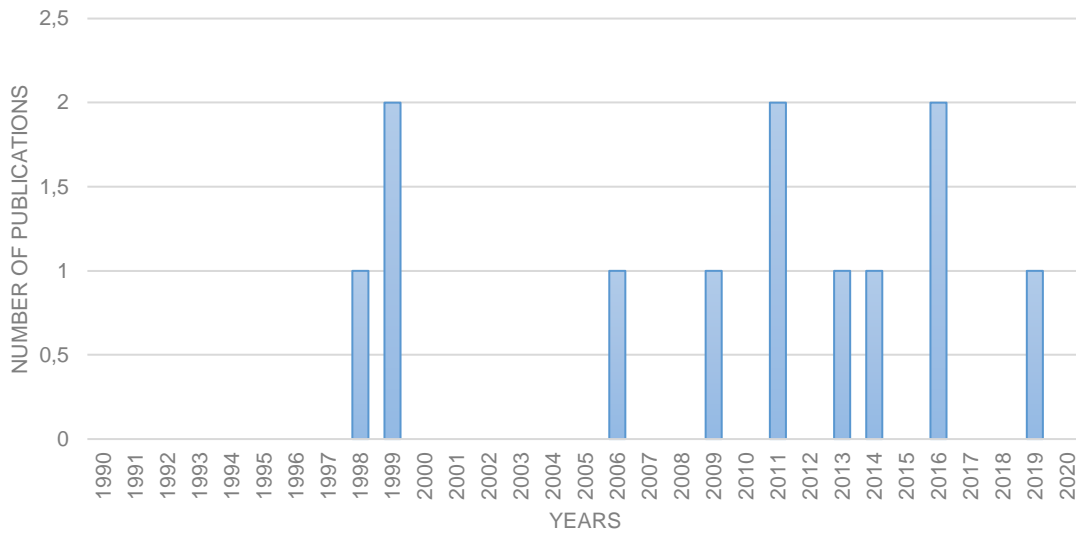


Figure 5 Article Publications

Moreover, figure 5 shows that the most popular research designs within the time frame of 1998 and 2019 are case studies. Out of all articles, 83% or 10 articles, were case studies. This shows that more than 3 out of 4 articles used scientific theories to either develop their own and test them or test an existing theory on a case. The remaining 17% or 2 articles, followed a systematic literature review approach, which compiled and evaluated different models. Both literature reviews used product development models developed by May-Plumlee & Little (1998), Wu & Wu (2011), and Wickett et al. (1999) (Lanarolle et al., 2016; Wu & Wu, 2011). The overlap in models, indicates a high level of relevance of these three models. Therefore, this implies that all articles are of high relevance for this research.

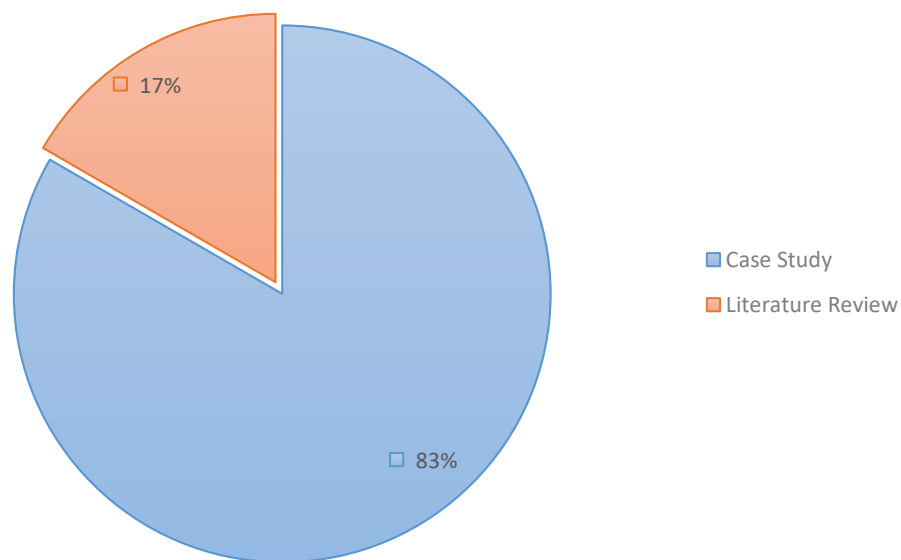


Figure 6 Research Strategy

4.1.2. Content Analysis

To analyze the content a systematic, three-step analysis was applied to evaluate which models should be focused on in the synthesis. Table 11 shows an overview of all models found within the articles. First, the time span of publication of the models is displayed; second, the number of times specific author's models were referred to is calculated; and third, the number of steps attributed to product design in a model are assessed. The content analysis serves as a base to which models will be used in the data synthesis.

Table 11 Total Models found in Articles

ARTICLE AUTHORS	TITLE	MODELS
LABAT & SOKOLOWSKI (1999)	A Three-Stage Design Process Applied to an Industry-University Textile Product Design Project	<ol style="list-style-type: none"> 1. DeJonge (1984) 2. Watkins (1988) 3. Hanks et al. (1977) 4. Kallal & Lamb (1994) 5. LaBat & Sokolowski (1999)
GOWOREK (2009)	An investigation into product development processes for UK fashion retailers	<ol style="list-style-type: none"> 1. Goworek et al. (2007)
SARI & ASAD (2019)	New product development processes in the fashion industry Evidence from Indonesian Islamic fashion companies	<ol style="list-style-type: none"> 1. Sari & Asad (2019)
LANAROLLE ET AL. (2016)	Apparel product development: An overview of existing models	<ol style="list-style-type: none"> 1. Lamb & Kallal (1992) 2. LaBat & Sokolowski (1999) 3. Bailey (1998) 4. Regan et al. (1998) 5. Gaskill (1992) 6. Wickett et al. (1999) 7. Sinha (2001) 8. Han et al. (2012) 9. Chan et al. (2002) 10. Pitimaneeyakul et al. (2004) 11. Ariyatum & Holland (2005) 12. May-Plumlee & Little (1998) 13. May-Plumlee & Little (2006) 14. Wu & Wu (2011) 15. Gam et al. (2009) 16. Morris (2011)
WICKETT ET AL. (1999)	Apparel Retail Product Development: Model Testing and Expansion	<ol style="list-style-type: none"> 1. Wickett et al (1999)
POWELL & CASSILL (2006)	New textile product development: Processes, practices, and products	<ol style="list-style-type: none"> 1. Urban & Hauser (1993) 2. Ulrich & Eppinger (2004)

		<ol style="list-style-type: none"> 3. Crawford & Di Benedetto (2003) 4. Cooper (2001) 5. Bruce & Biemans (1995) 6. Trott (2002)
MAY-PLUMLEE & LITTLE (1998)	No-interval coherently phased product development model for apparel	<ol style="list-style-type: none"> 1. May-Plumlee & Little (1998)
KOCHBA ET AL. (2014)	Product development process in small and medium clothing companies: focus on relations with suppliers, retailers and final client	<ol style="list-style-type: none"> 1. Silva (2011) 2. Kachba et al. (2014)
BANDINELLI ET AL. (2013)	New Product Development in the Fashion Industry: An Empirical Investigation of Italian Firms	<ol style="list-style-type: none"> 1. Bandinelli (2011) 2. Bruce et al. (2004)
WU & WU (2011)	Redesigning the Apparel Product Development Process Based on the No-Interval Coherently Phased Product Development Model	<ol style="list-style-type: none"> 1. Wickett et al. (1999) 2. Kuntz (2005) 3. May-Plumlee & Little (1998) 4. Wu & Wu (2011)
MORETTI & BRAGHINI (2016)	Reference Model For Apparel Product Development	<ol style="list-style-type: none"> 1. Moretti & Braghini (2016) 2. Rozenfeld et al. (2006) 3. Lamb & Kallal (1992) 4. May-Plumlee & Little (1992) 5. Gaskill (1992) 6. Rench (2002) 7. Montemezzo (2003) 8. Pitimaneeyakul et al. (2004)
KAULING & BERNARDES (2011)	Study On The Introduction Of Design Management In The Product Development Process Of Brazilian Clothing Companies	<ol style="list-style-type: none"> 1. Bruce et al. (1999)

Step 1

Within the articles 36 unique models could be found. Figure 6 illustrates that most models were developed between 1998 and 2011. This ranges from two models in 2001 to four models in 2011. In comparison to early or later years, the graph shows that this time period (1998-2011) is most significant to findings in product design in product development in the textile and fashion industry. Therefore, only models that were developed in this time frame will be considered.

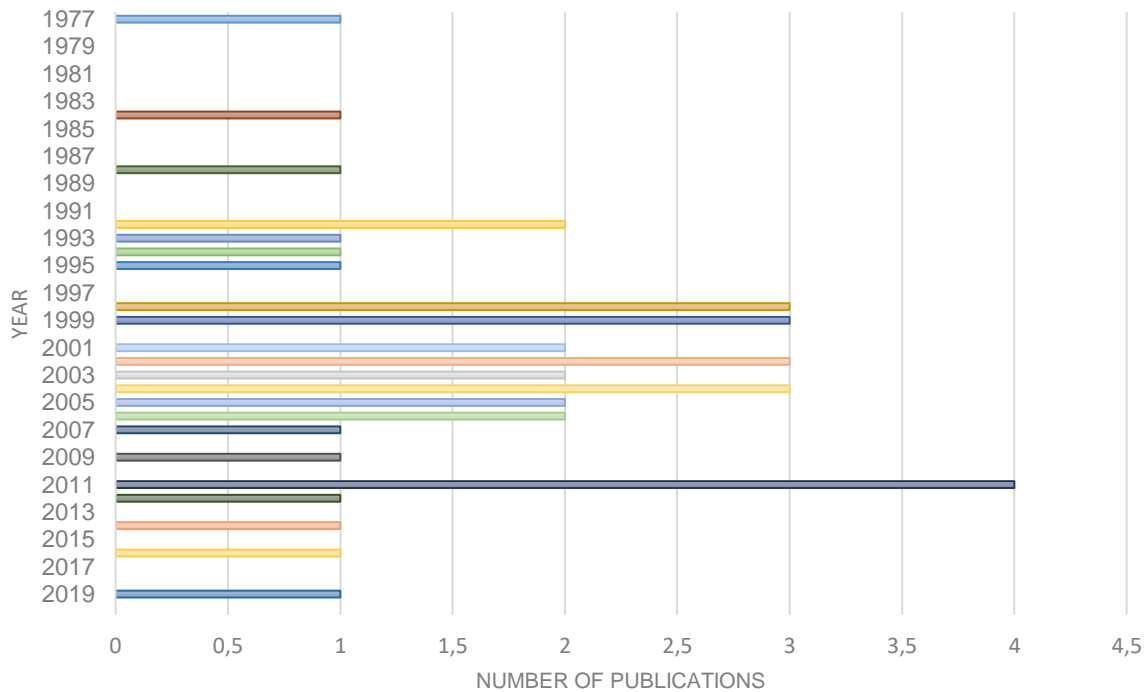


Figure 7 Product Design/ Development Model Publications

Step 2

Figure 7 shows the frequency of authors that were mentioned in the articles. While 66% were only mentioned once, 7 authors were mentioned at least twice. The figure shows that May-Plumlee & Little (1998) lead the ranking with four mentions (8%), followed by Wickett et al. (1999) with 3 mentions (6%) and Lamb & Kallal (1992), LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004), Wu & Wu (2011), and Gaskill (1992) with each two mentions (2%). The high frequency of mentions/ references indicates the popularity and importance of the contributions these product development models have had in the textile and fashion industry, theoretically and practically. When analyzing these findings in combination with the findings from figure 6 ('Published Models'), it can be said that the most relevant product development models are those that were published between 1998 and 2011 and that are mentioned most. Therefore, out of the 7 models that were mentioned most, 5 remain: LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004), Wu & Wu (2011), Wickett et al. (1999) and May-Plumlee & Little (1998). While models by Lamb & Kallal (1992) and Gaskill (1992) do not fall within this criterion and are thus not included in the synthesis, it is important to mention that their models served as a base for LaBat & Sokolowski (1999) and Wickett et al. (1999), respectively.

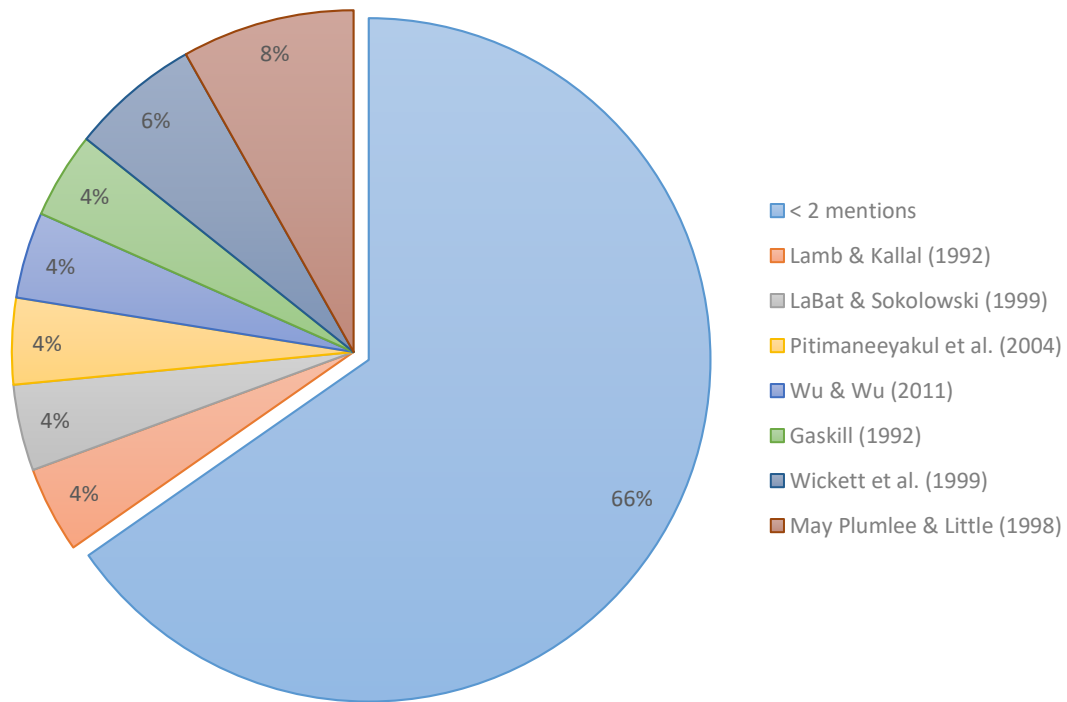


Figure 8 Author Mentions in Articles

Step 3

In the last step, those product development steps which are attributed to product design are emphasized. A high number of steps attributed to product design in relation to the total number of PD steps indicates a high relevance of those PD models for this thesis, since the focus is on design in PD. All information from models in table 10 is included figure 8 ('PD processes and design steps'). However, duplicates as well as those that did not have an explanation (only mentioned) were removed. In addition, models by Wickett et al. (1999) and Gaskill (1992) were explained differently and showed different steps in different articles. Therefore, only the original models by Wickett et al. (1999) and Gaskill (1992) were considered in graph 3 ('PD processes and design steps'). Calculations show that the average number of steps in the product development process is Ø6 and the mean for steps attributed to product design is Ø1. This shows that on average 17% of all processes affect product design. Out of all articles determined relevant in step 2 (LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004), Wu & Wu (2011), Wickett et al. (1999) and May-Plumlee & Little (1998)), all have at least 17% of total steps attributed to product design.

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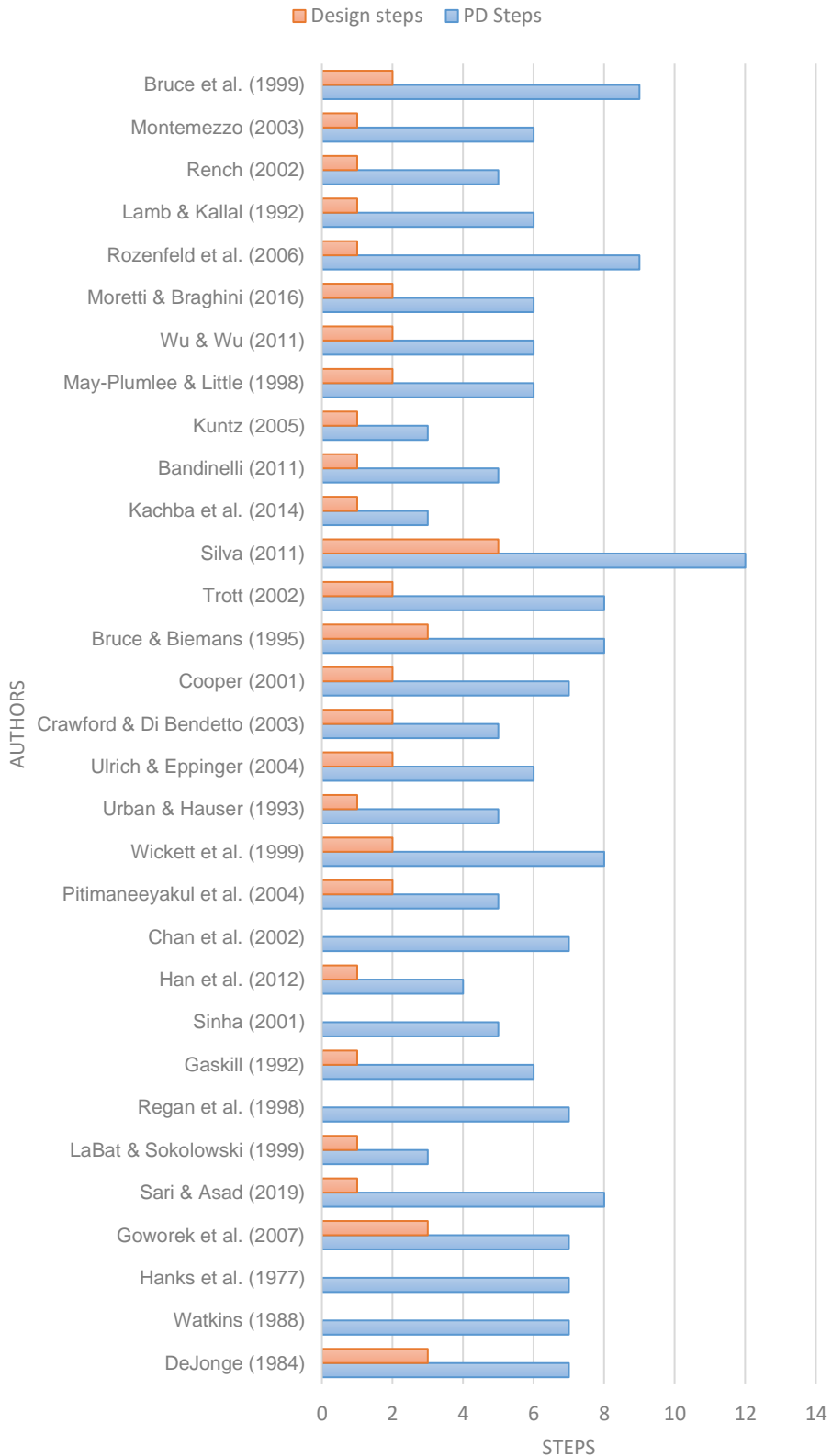


Figure 9 PD Process and Design Steps

All three steps show that the chosen five models are most relevant in serving as a base for synthesis and further critical reflection. Although other models might be relevant as well, the chosen five models by LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004), Wu & Wu

(2011), Wickett et al. (1999) and May-Plumlee & Little (1998) are most applicable to the research in this thesis.

4.2. Data Synthesis

In the data synthesis, the product development models, and product design is described. Furthermore, similarities, differences and the product design stage is described in detail.

4.2.1. Model Description

The data analysis shows that five models have been assessed as highly relevant for this research. Therefore, the synthesis will focus mostly on collating data from these product development models. Moreover, within the product development models, focus will be on product design. Each model will be explained in detail, followed by a comparison of similarities and differences. Based on the synthesis, a final model will be created which allows for further critical reflection on product design. Figure 9 shows an overview of the five models.

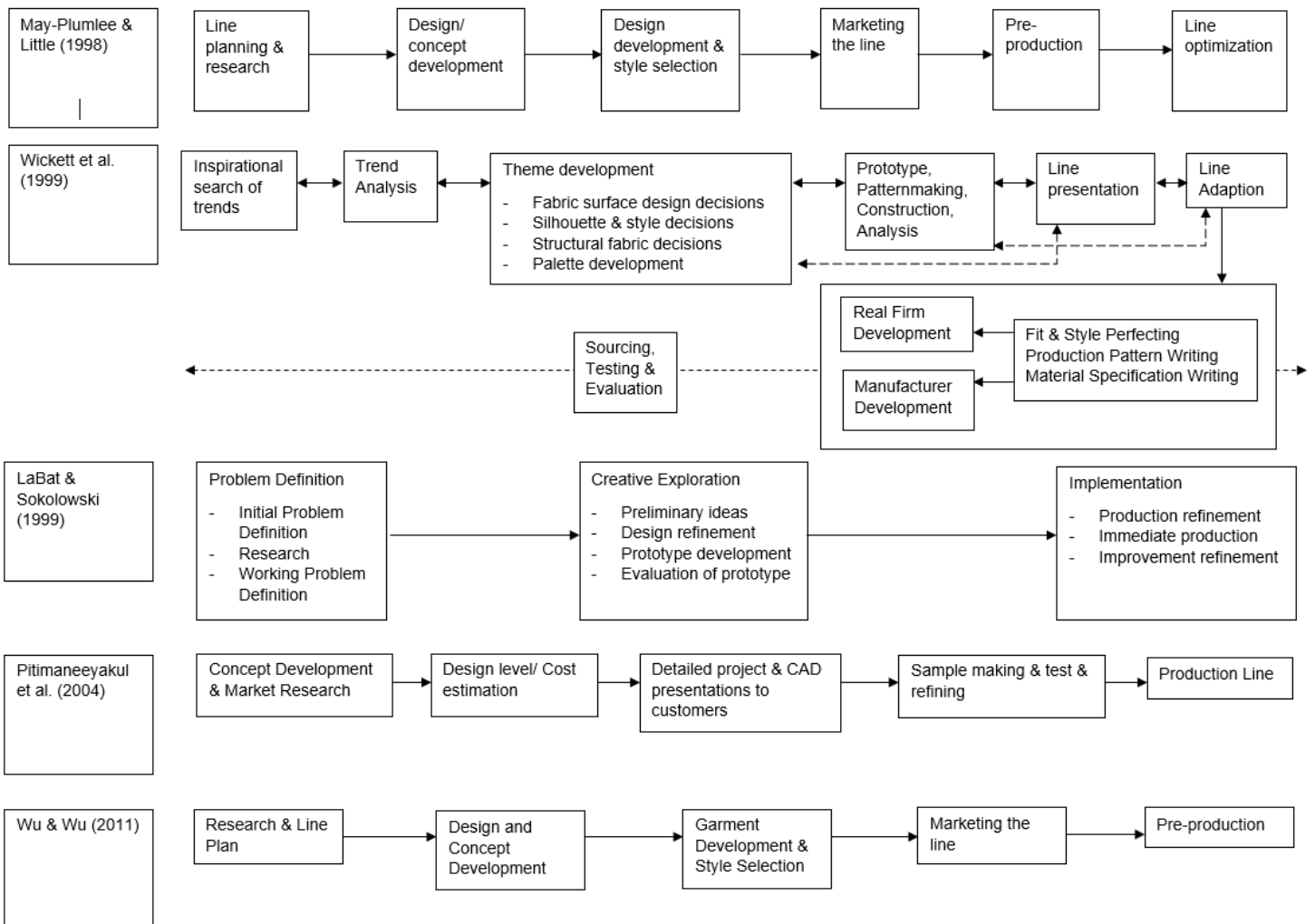


Figure 10 Overview of 5 models based on May-Plumlee & Little, 1998; Wickett et al., 1999; LaBat & Sokolowski, 1999; Pitimaneeyakul et al., 2004; Wu & Wu, 2011

May-Plumlee & Little's 'No-interval coherently phased product development model' from 1998 is based on the works of Burns and Bryant (1997), Glock and Kunz (1995), Kunz (1993), Littrell (1997), and Magg (1997). May-Plumlee & Little find that an apparel product development process must be able to develop product lines and individual products, develop seasonal lines and multiples season per year, and develop new products, take-offs, and modify existing products (May-Plumlee, 1998; Moretti & Braghini, 2016). This can only be accomplished when coordinating the four key functional areas: marketing, merchandising, design and development, and production. The model/ process has overlapping stages and fuzzy gates which enables products within a product line to either advance or be recycled to other development stages (May-Plumlee & Little, 1998; Lanarolle et al., 2016). The process is subject to limitations like vendor reliability, raw material availability, target retail price point, and consumer wants and feedback. Two of the six phases are attributed to product design, as explained below.

The first phase of the 6-step model, line planning and research, is triggered by an "impetus for initiating development of apparel lines" and is concerned with establishing research parameters that guide the development process (May-Plumlee & Little, 1998). Each department formulates goals such as a marketing plan, financial goals, line plan, and the creative direction of the line.

Phase two, design and concept development, initiates the design of specific products. Based on the concept, color stories and concepts for product groups are defined which are then translated into design specifications and sketches. At this product design stage, decisions regarding aesthetic design elements are already made (concept, colors). In Phase 3, design development and style selection, more decisions regarding product design are made. Materials are chosen, ordered, and tested by the Raw Material Development department to construct a prototype. Patterns and fit standards are also developed and reviewed by merchandising, marketing and product development. By the end of the stage, styles and colors are set (May-Plumlee & Little, 1998; Lanarolle et al., 2016).

In phase 4, marketing the line, the line is marketed to retail channels and the line may be modified based on buyer responses. In phase 5, pre-production, the prototypes and sample sizes are translated into the complete size range. Quality, production and process standards are also set, which may affect which styles/ colors or sizes are dropped or added. The Product Development department and the Production, Planning and Control department are involved in this step. In phase 6, line optimization, the product line is improved according to changes in

sales by the Merchandising department (May-Plumlee & Little, 1998; Wu & Wu, 2011). In total, in the two design phases, decisions regarding aesthetic design elements, amongst others are made (color, material, style, fit).

The 'Revised Apparel Retail Product Development Model' by Wickett et al. (1999) is based on Gaskill's model of 1992 (Wickett et al., 1999; Lanarolle et al., 2016; Wu & Wu, 2011). The first step of the 8-step model begins with an inspirational search of trends. Wickett et al. (1999) find that inspiration is triggered by various sources such as travel, media, competition, etc. This is followed by an in-depth trend analysis in step 2.

In step 3 a theme direction is set. The theme has major impact on design as decisions regarding the color palette, the fabric surface design, structural fabric, the fit, and style decisions are made. This stage affects the aesthetic design elements vastly as decisions regarding fabrics, colors, fabric construction and fit are made. The color palette refers to deciding on core color, secondary color, and accent colors for the entire line. The fabric surface design refers to the in- or exclusions of plaids and prints in the initial product line. The structural fabric design is concerned with the fiber content and the structure of the fabric. Criteria for selection of the structural fabric are performance, quality, appearance, draping ability, weight, and hand. The fit and style are designed based on merchandise categories and are then refined into final groupings. Wickett et al. (1999), in a study of the product development process of 21 specialty stores, found that as many as 400 styles can be designed out of which only 25 finals are selected.

Step 4 is concerned with prototyping, patternmaking, construction and analysis. All decisions that have been made in the previous step are turned into a garment sample: the prototype. Changes to those aesthetic design elements decided in stage 3 can be made if the sample is not sufficient, leading to backward development. However, Wickett et al. (1999) find that this step can be skipped if companies use sketches, computer renderings and magazine tears in step 3 instead of making the prototype sample. This would then directly lead to line presentation (stage 5). In step 5, the ideas for the seasons line are presented and evaluated for final adoption. However, this step can also be skipped if line ideas are narrowed down through the product development process, eliminating the need for line presentation. In step 6, a chosen line is then adopted. After line adoption in step 6, the post-adoption expansion is started in step 7. This concerns fit and style perfecting to assess aesthetic appearance and comfort. Once fit and style are set, production patterns are made either inhouse or by a contracted manufacturer. Meanwhile garment and material specifications are written to ensure exact production of final products. In step 7 design elements are tested based on their fit and style. The steps in the post

adoption expansion occur simultaneously and in sequence. They might overlap e.g. when production patterns are constructed and when specifications are being written. Throughout the entire process, step 8 takes place. This is referred to as sourcing and testing and evaluation. It starts during trend analysis and ends in the stages of post adoption (Wickett et al., 1999). The process typically moves forward until the post-adoption stage but can move backward if changes must be made prior to line-adoption. (Wickett et al., 1999; Lanarolle et al., 2016). In total, in the design phase (theme direction), decisions regarding aesthetic design elements, amongst others are made (color, material (fabric and construction), style, fit).

LaBat and Sokolowski's (1999) 'Three-stage design process' model is based on clothing design models by DeJonge (1984), Watkins (1988), Hanks et al. (1977) and Kallal & Lamb (1994) as well as design models for industrial products, engineering etc. It is specified that the designer must ensure the design criteria match the 'functional, aesthetic, and economic (FAE)' needs of the consumer (Lanarolle et al., 2016). The model includes 3 stages with a total of 10 sub-steps (Lanarolle et al, 2016).

Stage 1 of the process is 'Problem Definition & Research'. It encompasses the (a) initial problem definition, (b) research, and (c) working problem definition. The target customer presents the initial problem and the company identifies the customer's needs (new product/ product improvement/ line expansion). As research continues the problem is redefined multiple times and should reflect the consumer's demands more.

In stage 2, 'Creative exploration', preliminary ideas are presented, and the design is refined. This includes aesthetic design elements and production constraints. In a study conducted by LaBat and Sokolowski (1999) an athletic shoe ankle, the design and the materials were analyzed. Based on the design criteria and the production constraints, prototypes are developed. The prototype is then tested and evaluated by the designer and by an industry client/ target customer.

In the last stage, 'Implementation', the company focuses on marketing, sales and the use of the product by the target customers. Production criteria are refined to match the expectations of the consumers (cost, time, methods, sales potential). Two types of changes can be made in the last phase; changes that can be incorporate into to current methods and budgets or drastic changes that involves returning to earlier stages (LaBat & Sokolowski, 1999). It can be said that in the design phase (Creative Exploration), decisions about aesthetic design elements, amongst others are made (color, material, style, fit).

The knitwear product development model by Pitimaneeyakul et al., (2004) examines the product development process by US sweater companies. It is made up of 5 stages and focuses on incorporating customer's FAE needs (Lanarolle et al., 2016). Step 1 is concept development and market research. Step 2 refers to the design level which includes aesthetic design elements and cost estimations. Pitimaneeyakul et al. (2004) include the customer's functional and aesthetic needs in this step. Moreover, quality assurance and pre-costing is discussed in this step. Step 3 looks at the detailed project and presents a computer-aided (CAD) printout to customers. In step 4 samples are made, tested and refined, affecting aesthetic design elements if changes need to be made. In step 5, the production line is completed, and production starts (Lanarolle et al., 2016; Moretti & Braghini, 2016). In total, in the design phase (design level), decisions regarding aesthetic design elements, amongst others are made (color, material, style, fit).

Wu & Wu's (2011) 'Redesigned No-interval coherently phased product development model' is based on May-Plumlee & Little's model from 1998. It is based on a study of Chinese apparel companies and indicates how responsibilities should be distributed amongst different divisions at each stage (Wu & Wu, 2011; Lanarolle et al., 2016). Moreover, it identifies major decision points in the process. 5 phases are identified before production starts.

In phase 1, 'research and line plan', the marketing department is concerned with decisions making regarding the market, sales and consumer research. The merchandising and product development teams engage in trend research. By the end of the phase, the merchandising team produces a plan for the upcoming line.

In phase 2, 'design and concept development', the product development team develops a concept and the design and produces a preliminary line. In this phase decision for aesthetic design elements are made because design includes color, material, fit and style. In phase 3, 'garment development and style selection', the product development team is responsible for raw material development as well as prototype patternmaking and evaluation. The merchandising team decides on the final adoption of styles in the line. This phase also affects aesthetic design elements as the concept is narrowed down, the designs reviewed, and materials tested.

In phase 4, 'marketing the line', the product development team is responsible for sales and sample development. Moreover, the product development team in cooperation with the marketing team handles retail orders. By the end of step 4 the line should be modified according to consumer demand and design capabilities. In step 5, 'pre-production', the product

development team creates product patterns. The merchandising and the production team are responsible for line optimization and produce the final line which is then sent over to production. This affects product attributes also as the line might add or drop styles and parameters for production are set and fit and style are evaluated (Wu & Wu, 2011). In total, in the two design phases (design and concept development & garment development and style selection), decisions regarding aesthetic design elements, amongst others are made (color, material, style, fit).

4.2.2. Similarities and Differences of Product Design

Figure 10 shows a synthesized model of the five chosen models by May-Plumlee & Little (1998), Wickett et al. (1999), LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004), and Wu & Wu (2011). The highlighted step shows that this phase affects product design, steps with full lines show overlapping steps of all models, and the steps with the striped lines show different, additional steps. The striped lines steps were included because the models from which this information was taken, although not the entirety of models but still the majority of relevant models, include these steps. The synthesis, especially those steps linked to design, will serve as base for further critical reflection with regard to sustainability. The synthesis also partly includes the similarities and differences of the entire models in order to find out where product design decisions are taken. This is important because it determines which stages can be attributed to product design. Furthermore, according to Shafiq (2020) the entire product development process must be regarded in order to understand what role product design plays within it because the design must be matched with capabilities of further steps within product development in order to be successfully executed (Shafiq, 2020).

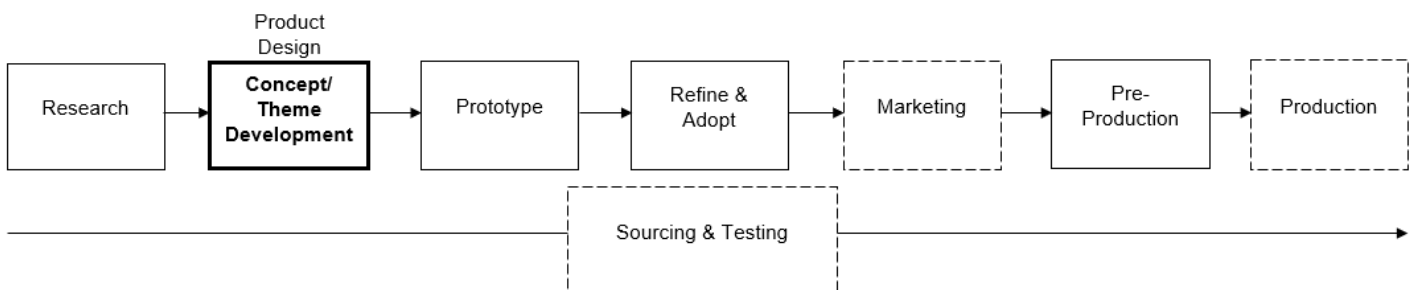


Figure 11 Synthesis of PD models based on May-Plumlee & Little, 1998; Wickett et al., 1999; LaBat & Sokolowski, 1999; Pitimaneeyakul et al., 2004; Wu & Wu, 2011

Moreover, immediately following step 1 at least one step is dedicated to defining a concept and developing preliminary ideas about the major theme the product line will revolve around. This already majorly affects the product design because the chosen theme will already narrow e.g.

the material and color spectrum down. All authors agree that decisions regarding materials, colors, patterns, sizes, style, silhouette, structure, and fabric fall under aesthetic design element decisions in product design. Within the same phase or directly afterwards, the concept is translated into design specifications. Either within this step or subsequently, all models emphasize the importance of a prototype sample. The prototype can be described as a physical version of the design characteristics of a product. The realization of the design gives more insight into what part of the design is sufficient and what needs to be changed. Therefore, aesthetic design elements can be subject to change at this stage. The changes can be made in the refining and adopting stage, which all models include (May-Plumlee & Little, 1998; Wickett et al., 1999; LaBat & Sokolowski, 1999; Pitimaneeyakul et al., 2004; Wu & Wu, 2011). Moreover, most (4 out of 5 models, excluding Pitimaneeyakul et al., 2004) discuss pre-production requirements or line refinements before production. This has an effect on the aesthetic design elements, as they can be subject to change. In pre-production complete size ranges, patterns for fit and style for aesthetics and comfort, qualities, production and process standards are set, which may affect which styles/ colors or sizes are dropped or added. Moreover, garment and material specifications are written for the production of final products. After pre-production most authors (4 out of 5, excluding Wickett et al., 1999) agree that the line is tested once again, followed by production for some model (May-Plumlee & Little, 1998; Wickett et al., 1999; LaBat & Sokolowski, 1999; Wu & Wu, 2011). Overall, similarities are vast as models overlap in the following phases: research, theme/ concept development, prototyping, refining and adopting.

Although most differences occur after line adoption, some occur before line adoption. Unlike the other 4 models, Pitimaneeyakul et al.'s (2004) model recommends computer-aided design (CAD) printouts instead of physical prototypes. Moreover, Pitimaneeyakul et al. (2004) and LaBat & Sokolowski (1999) are the only authors that explicitly include the opinions of targeted consumers or industry clients by showing them the CAD printouts or physical prototypes. However, main differences occur after line adoption. While 3 out of 5 models start the pre-production phase after prototyping, May-Plumlee & Little (1999) and Wu & Wu (2011) include marketing after prototyping. Marketing is entirely disregarded by those 3 out of 5 who continue with pre-production as a part of the product development process. This is followed by pre-production in both aforementioned models. Furthermore, 3 out of 5 models include production in the product development process. LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004), and Wu & Wu (2011) explicitly mention production in product development, whereas the other models do not evaluate production as part of product development. Moreover, Wickett et al.

(1999) specify the need for sourcing, testing and evaluating, which is disregarded by others. In their model sourcing starts during trend analysis and ends in post adoption or pre-production. Additionally, they also mention that the product development can go backwards and forwards depending on the necessary changes, whilst all other models indicate that the process only moves forward. Overall, differences mainly occur in the later stages of product development and are rather additional steps than differences in content. The following additional steps were found marketing, production, sourcing, and testing and evaluation. In addition, only some authors value clients' opinions in the product development process.

Product design within the product development process, is the focus of the 'Concept/ Theme Development' step. All authors agree that within this design stage, decisions regarding aesthetic design elements are first made. While product design also includes the prototype and garment specifications, aesthetic design elements are set first. The e.g. styles can be added or dropped later on, but the early design phase sets the conditions for the aesthetic design elements. Therefore, decisions that are made later on in the design or development phase are guided by the design concept and hence, the aesthetic design elements. (May-Plumlee & Little, 1998; Wickett et al., 1999; LaBat & Sokolowski, 1999; Pitimaneeyakul et al., 2004; Wu & Wu, 2011). In synthesis, the design phase starts by initiating the design of specific products. A design level which includes aesthetic design elements and cost estimations is set according to the customer's functional and aesthetic needs. This includes the color palette, the fabric surface design, structural fabric, the fit, and style decisions and functional elements, such as performance. The color palette refers to deciding on core colors, secondary colors, and accent colors for the entire line. The fabric surface design refers to the in- or exclusions of plaids and prints in the initial product line. The structural fabric design is concerned with the fiber content and the structure of the fabric. Criteria for selection of the structural fabric are performance, quality, appearance, draping ability, weight, and hand. The fit and style are designed based on merchandise categories and are then refined into final groupings. This stage affects the aesthetic design elements vastly as decisions regarding fabrics, colors, fabric construction and fit are made. Next, the design is refined. This affects aesthetic design elements and production constraints. The prototype is then constructed, tested and evaluated by the designer and by an industry client/ target customer. For example, raw material and prototype patternmaking are evaluated. The merchandising team decides on the final adoption of styles in the line. This also affects aesthetic design elements as the concept is narrowed down, the designs reviewed, and materials tested. However, this is done within the scope of the established aesthetic design elements

(May-Plumlee & Little, 1998; Pitimaneeyakul et al., 2004; Wickett et al., 1999; LaBat & Sokolowski, 1999; Wu & Wu, 2011).

4.3. Interview Findings

This section compiles data from the interviews of two experts. Originally, the interviews would have been focused on the applicability of theoretical solutions in practice, however, due to the current Covid-19 crisis, the industry expert (Company Unland Ltd.) was not available for interviewing. This would also have increased validity of answers as the interview questions would have been exactly the same for all participants. Nevertheless, interviews with a sustainability expert and an industry expert were conducted, catering to the areas of expertise of the individual interviewees and thus, increasing validity of answers. The data is used to validate and further critically evaluate and discuss the theoretical framework/ results of the analysis (figure 14). This triangulates the findings, as explained in the 'Methodology', as more information is gathered from various sides about the topic of aesthetic design elements in product design. The interview is based on the analysis. During the interviews, the same first question was asked to both interviews for higher reliability and validity. However, afterwards, different questions to each interviewee were asked based on their expertise. Larsson's questions were focused on the UN Sustainable Development Goals, whereas Shafiq's questions were focused on applicability and considerations.

Q1: Looking at the sustainable suggestions that are proposed in the theoretical framework (figure 14), do you know any other suggestions that could be added within the chosen Ted's 10?

Both interviewees agreed with the initial suggestions under the Ted's 10 (Larsson, 2020; Shafiq, 2020). However, Larsson (202) recommended to look into process and product chemicals under Ted's 10 #3 'Design to reduce chemicals'. Process and product chemicals refer to the treatment, such as the gluing of the warp in the weaving machine, but also in the fiber and yarn spinning stage. Moreover, many types of chemicals are used to prepare the fabric for the dyeing process (Larsson, 2020). He also identifies a challenge in the dyeing process that concerns the re-dyeing and thus the re-preparing of the fabric if the "dyeing process is not up to the quality" (Larsson, 2020). Furthermore, Shafiq (2020) suggested considering mono color in addition to mono materiality under Ted's 10 #2 'Design for Cyclability'. Using a mono color, no color or minimum colors can add to recyclability. When aiming for recyclability, a product should be designed in order to be easily disassembled, and easily sorted. Sorting by color simplifies the process, thus adding into to recyclability of the product (Shafiq, 2020). Shafiq (2020) also

discusses several suggestions under this question. Looking at the coloring process (dyeing), he evaluates the applicability of natural dyes. For a minimal scale of production, natural dyeing could be a solution, but for mass or medium scale production natural dyes are not a solution. This is due to color inaccuracy, which leads to waste. However, if you (e.g. the buyer) are flexible with that, then it could be a solution. He further stresses that the best product is the one, which respects the production limitations and capabilities. Often, changes have to be made in preproduction to match the production requirements reflected in the tech pack. So, in the development process and in low scale, natural dyes might work but in large scale production the color rejection will be too high, making the process even less sustainable due to the rejections (Shafiq, 2020). Additionally, Shafiq (2020) suggests looking into the fabric formation processes, e.g. knitting and weaving. Knitting and weaving have a different water and energy consumption and waste emanation. Lastly, Shafiq (2020) finds that unisex and unisize clothing can cover more body types so this also fits to Ted's 10 #8 'Design to reduce the need to consume' because it leads to a slight extension of the product's life. Using the answers provided by the interviewees to this question, the suggestions under the Ted's 10 were further developed and expanded.

Table 12 Interview Questions Comparison

Larsson (2020)	Shafiq (2020)
Q2: How do the suggestions from the Ted's 10 relate to the UN SDGs?	Q2: What do you think is the most realistic for a company to focus on looking at the strategies or the suggestions that we've made?
Q3: Are other SDGs also affected by the Ted's 10? Are the chosen SDGs the most relevant to the Ted's 10 in your opinion?	Q3: Do you have any suggestions on what can be improved in the research?
Q4: Why do you think the combination of Ted's 10 with the UN SDGs are relevant?	
Q5: Do you see any challenges or implications regarding the fit between the Ted's 10 and the UN SDGs?	

The interview questions directed towards Larsson, focused on the UN SDGs. Larsson (2020), identified, in the second question, that the Ted's 10 for this thesis relate to several UN goals. The UN SDGs can be divided into three categories: high impact, medium impact, and low impact. According to him, "there will be more goals that are related to the [...] Ted's 10, but perhaps not at high significance" (Larsson, 2020). In answer to the third question, he mentioned

that in his research he uses UN SDGs 6, 8, 12, 13, 15, 17, and 9. His research focuses on environmental sustainability, but he argues that “It’s 2020. We can’t talk about sustainability without including any social aspects” (Larsson, 2020). For question four, he states the combination of the Ted’s 10 with the UN SDGs is highly relevant in practice. Companies that use the Ted’s 10 methodology in their design and product development process are able to understand which of the UN SDGs they are contributing to (Larsson, 2020). When asked about the implications and challenges of the fit between the Ted’s 10 and the UN SDGs (Q5), Larsson (2020) highlights that the Ted’s 10 are weak on the social side because the Ted’s 10 are more related to the environmental factors. Moreover, the Ted’s 10 do not aim at fulfilling the SDGs. It depends on the commitment of the designer/ company to implement the Ted’ 10 methodology. However, the implementation of the Ted’s 10 would most likely positively affect some SDGs (Larsson, 2020).

The interview questions direct towards Shafiq, focused mainly on the applicability and considerations of the Ted’s 10 propositions. When asked about the applicability in real-life (Q2), Shafiq considered the capabilities and interests of the company, the production, and the supplier. He argues that from a company’s perspective, the main focus is gain. While it is possible to include all sustainability aspects on a single product, the commercialization and mass production is very expensive. Companies have a set budget to buy for the product, which can be extended but which also has limits. According to Shafiq (2020), social sustainability aspects can be better developed but environmental sustainability is challenging. The product attributes, which are similar to the aesthetic design elements, such as material, are added during product development. Most companies are already working on fabric materials, whereas the color choice is very personal. In addition, the dyeing process is already very toxic, so from the supplier’s perspective, the color choice does not make a big difference. Moreover, looking at material choices again, alternative materials that are more sustainable, are not readily available in the market. In comparison to the common materials, like cotton and polyester, they are also expensive. For small quantities, the price for the alternative materials even increases. He argues that everything that comes from the upstream supply chain, from the supplier, is very expensive (Shafiq, 2020). According to Shafiq (2020), it “is just like the [shopping] basket, you just add on the value and then you have to pay”. Furthermore, the styling in different markets also makes a difference. The Swedish style is rather minimalistic compared to the U.S. design, where products are mostly fashion products. Therefore, he concludes that discarded textile products from the Swedish market can be more easily disassembled and reused (Shafiq, 2020). In answer to the last question (Q3), aiming at finding more perspectives to write about in the thesis, Shafiq

(2020) suggested to narrow down the market to a specific niche market and narrow down the product type. His argument behind that is that each product has a different “routing”/ process. For example, a knitted product and a denim product have a completely different process. He mentions, that designer try to fix this ‘process’ problem by having a different sequence of steps or skipping process steps. Lastly, he suggests including the environmental sustainability perspective from the Ted’s 10 of textile substrates. These are the fiber substrate, yarn substrate, fabric substrate, and garment substrate (Shafiq, 2020).

5. Analysis

The analysis is divided into two parts: the product design analysis and the Ted's 10 analysis. In the first part of the analysis, the UN Sustainable Development Goals will be used to identify how aesthetic design elements in product design compare to the environmental sustainability of the UN SDGs. By considering the UN SDGs, phases in the product development process involved with product design, which do not contribute to the goals become apparent. On the basis of uncovering a lack of environmental sustainability pertaining to the UN goals, opportunities for improvement can be identified. Therefore, the second step in the analysis is based on using applicable Ted's 10 goals (see 'Frame of Reference') to develop a theoretical framework (figure 14) concentrated on product design in product development and on fulfilling the set UN goals. The following figure (figure 11) explains the structure of the analysis. Sub-research question 2 will be answered in step 1: How do aesthetic product design elements in product design lack compared to the environmental sustainability as defined by the UN Sustainable Development Goals? Sub-research question 3 will be answered in step 2: How can aesthetic product design elements in product design become more environmentally sustainable using the Ted's 10 goals? Both questions will be discussed further in the discussion section.

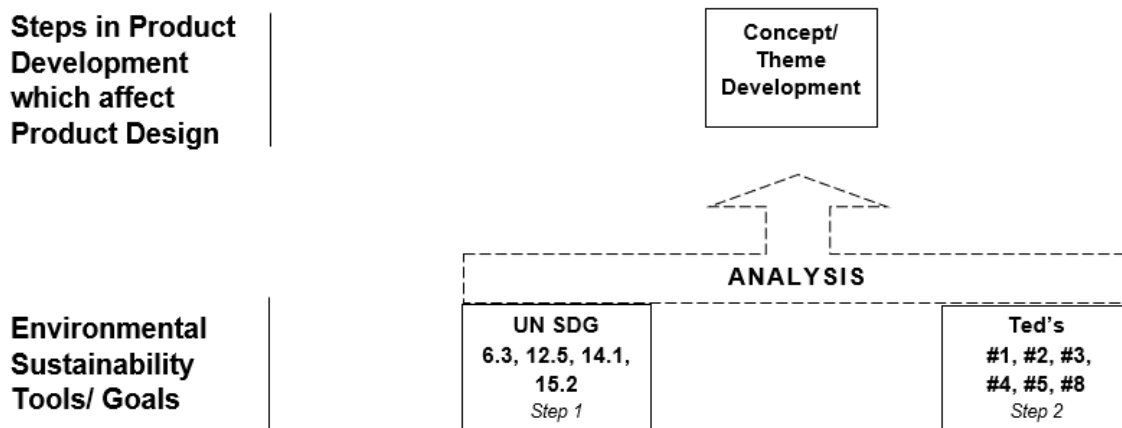


Figure 12 Analysis Structure (own figure)

5.1. Product Design Analysis based on UN SDGs

The analysis is based on the synthesized product design stage, 'Concept/ Theme Development' (figure 10) from the systematic literature review. As the purpose of this thesis is to develop a theoretical framework for sustainable product design which affects the sustainability of

aesthetic design elements of the final product, the synthesis of product design must first be analyzed based on environmental sustainability. The UN Sustainable Development Goals from the 'Frame of Reference' will serve as a guideline to how aesthetic design elements in product design compare to the UN SDGs and what they lack. Only the step identified as having an impact on aesthetic design elements is regarded.

Based on the findings (4), it was found that within the 'Concept/ Theme Development' step of product development, decisions regarding the aesthetic design elements were made. As explained in this section, the design level (in accordance with the consumer's identified needs) determines the design of the (final) product. According to May-Plumlee & Little (1998), Pitimaneeyakul et al. (2004), Wickett et al. (1999), LaBat & Sokolowski (1999), Wu & Wu (2011), within the design level decisions regarding the color palette, fabric surface design, structural fabric, fit, and style are made. The color palette includes core, secondary, and accent colors, fabric surface design is concerned with the in- or exclusion of plaids/ prints, the structural fabric refers to fiber content/, appearance, and draping ability, and the fit and style are chosen based on merchandise categories. Afterwards, the styles are refined, made into prototypes, and reviewed and tested (May-Plumlee & Little, 1998; Pitimaneeyakul et al., 2004; Wickett et al., 1999; LaBat & Sokolowski, 1999; Wu & Wu, 2011).

UN SDGs 6.3, 12.5, 14.1, and 15.2 can be applied as a guideline to environmental sustainability in product design as the final product should be in line with them and they have the potential to affect decisions regarding product design (see 'Frame of Reference'; May-Plumlee & Little, 1998; Pitimaneeyakul et al., 2004; Wickett et al., 1999; LaBat & Sokolowski, 1999; Wu & Wu, 2011). Table 13 shows how the aesthetic design elements in product design compare to the UN SDGs. A lack of clear guidelines within the practice of product design is found, which hinders aesthetic design elements from reaching several UN SDGs.

UN SDG 6.3 refers to improving the water quality by reducing pollution through dumping hazardous chemicals. However, by not restricting color standards in the product design, the water quality is often compromised. Each season has a different color palette, which demands different types of colorants to add color to a fabric (Kaldolph & Langford, 2013, p.445). Depending on the type of material (fiber content) used, a matching dye or printing dye is needed to bind the color to the fabric (fabric surface design). For example, disperse dyes can only be used on synthetic materials, while reactive dyes can only be used on natural or cellulosic materials (Kaldolph & Langford, 2013, p.453). The dyeing and printing process has significant impacts on the environment because the discharge of dyes releases polluting chemicals into

water systems, such as colors, salts, acids, and heavy metals (Kaldolph & Langford, 2013, p.472). Moreover, the type of material (fiber content and construction) used also affects the use of chemicals in the production process. The production of synthetic fibers and the cultivation of natural fibers release chemicals in water and air (McCourt, 2020.).

UN SDG 12.5 refers to reducing waste generation through prevention, reduction, recycling, and reuse by 2030. By not restricting decisions regarding the material, style, the color, and the fit products can potentially be discarded early (short life) and not recycled properly, while this goal focuses on circular business models. This affects the materials and colorants (fabric surface design and structural fabric, colors) used to be bio-based and recyclable to be able to recycle waste. Moreover, the style, the color and the fit must be appealing and valuable to the consumer to extend the products lifecycle and thus prevent disposal (fit and style) (UN Sustainable Development Goals, 2020.).

UN SDG 14.1 refers to preventing and reducing marine pollution form land-based activities. By not restricting decisions regarding the material, the color, the style and the fit, products can be discarded early while being non-degradable and releasing wastewater in production. This affects the materials and colors, which should be biodegradable to prevent marine pollution. Usually colorants and their wastewater are not biodegradable (Kadolph & Langford, 2013, p. 473). Furthermore, synthetic materials, such as polyester are also not biodegradable and their production emits emissions into air and water (heavy metal cobalt, manganese salts, etc.) The biodegradability of natural fibers is also compromised if using non-degradable dyes. Moreover, the commonly used cultivation technique of natural fibers, such as cotton, also uses toxic chemicals (fertilizers, pesticides, etc.) which can pollute water bodies (McCourt, 2020). In addition, the style and fit of the products also affect marine pollution as the style and the fit can become less appealing to customers and be subject to disposal.

UN SDG 15.2 refers to promoting the implementation of sustainable management of all forests, halt deforestation and increase forestation by 2020. This target affects decision-making about materials, as e.g. cellulosic fibers are sourced from forests. The target states to use reduced-impact harvesting techniques and receive forest management certifications as well as certifications of forest products. Therefore, when deciding to use cellulosic fibers such as lyocell, which is made from eucalyptus wood, companies must pay attention to certification, which disclose the raw material sources from sustainably harvested forests (McCourt, 2020).

Table 13 Lack of Aesthetic Design Elements in Product Design in Comparison with the UN SDGs

SDG	UN SDG Target	Considerations/ Lack in the practice of product design
<i>#6 Clean Water Sanitation</i>	6.3 improve water quality by reducing pollution through dumping hazardous chemicals	- no clear guide to restrict chemicals from dyeing (colors, fabric surface design) - no clear guide to restrict type of fibers used (synthetic/ cellulose/ natural fibers) (structural fabric)
<i>#12 Responsible Consumption and Production</i>	12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse	- no clear guide to restrict waste emanating from dyeing, processing (fabric surface design, structural fabric) - no clear guide to restrict design decisions that prevent disposal (style, color and fit)
<i>#14 Life below Water</i>	14.1 by 2025 prevent and reduce marine pollution from land-based activities	- no clear guide that restricts design to prevent disposal (style, color and fit) - no clear guide to restrict waste emanating from dyeing, processing (fabric surface design, structural fabrics)
<i>#15 Life on Land</i>	15.2 by 2020 promote implementation of sustainable management of all forests, halt deforestation, increase forestation	- no clear guide that restricts sustainable harvesting of manmade cellulosic fibers (structural fabric)

By comparing decision-making in all steps to the UN SDGs, it becomes evident that all decisions regarding aesthetic product design elements (style, color, material, fit) are very general and thus, cannot be seen as specifically unsustainable practices but rather as a lack of following environmentally sustainable guidelines. Therefore, the lack of environmentally sustainable guidelines leaves options that can have negative environmental impact. However, product design also includes decisions that are somewhat in alignment with the UN SDGs but only in the later stages of product design, which do not have great effect of the aesthetic design elements. In the prototype stage Wickett et al. (1999) propose to skip the making of the prototype by using sketches, computer renderings, and magazine tears instead of constructing a prototype. Moreover, LaBat & Sokolowski (1999) also suggest using computer-aided sketches and present those to target customers. By skipping this step or digitalizing it, less waste is generated. Moreover, by including the consumer's opinion, designs can be tailored more to customer's needs and wants, thus potentially increasing the product's life. This is in accordance

with UN SDG 12.5 and UN SDG 14.1. In addition, in the refine & adopt stage, Wickett et al. (1999) also propose to skip this step by narrowing the concept down before and thus, eliminating the need for prototype evaluation. Pitimaneeyakul et al. (2004) also suggest involving the customer in this stage. This is in alignment with UN SDG 12.5 and UN SDG 14.1 as less waste is generated by eliminating a step and the product is designed to appeal more to consumer hence, potentially extending the product's life. As the focus within product design is on aesthetic design elements, other steps will be disregarded in further analysis but are worth mentioning here. It is also important to mention that while governmental laws and regulations regarding environmental restrictions for business activities exist and are legally binding, there is still a large negative impact on the environment due to the textile and fashion industry even with these regulations. The EU legislation addresses the use of chemicals, called REACH (Registration, Evaluation, Authorization and Restriction of Chemical Substances), the Biocides regulation (use of pesticides and bacteria), and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora; use of any parts of animals and plants which are endangered) (What requirements must apparel comply with to be allowed on the European market? | CBI - Centre for the Promotion of Imports from developing countries, 2020; European Commission, 2013). Furthermore, the use of POPs (Persistent organic pollutants) is restricted by the Stockholm Convention for example for waterproofing and textile finishes (What requirements must apparel comply with to be allowed on the European market? | CBI - Centre for the Promotion of Imports from developing countries, 2020). Anything beyond these regulations falls within the 'grey-zone' in which textile and fashion companies comply with regulations but have the option to make an additional effort (UN SDGs) for environmental sustainability, as the UN SDGs are not legally binding (The Sustainable Development Agenda, 2020)

5.2. Ted's 10 Analysis

On the basis of identified environmental sustainability gaps in accordance to the UN SDGs in step 1 of the analysis, six Ted's 10 goals (see 'Frame of Reference') will be applied in an attempt to render the aesthetic product design elements in the product design process more environmentally sustainable. As mentioned in the 'Frame of Reference' the Ted's 10 are strategies especially tailored to designers to design the final product "better" in light of environmental and social sustainability. The application of the Ted's 10 goals will give insight into how those goals can potentially improve the environmental sustainability position/overcome the lack thereof in product design that target aesthetic design elements. In the

discussion, the newly developed propositions will be evaluated based on how they contribute to reaching the said UN SDGs. Hence, this gives insight into how product design, with focus on aesthetic design elements, can become more environmentally sustainable as per the UN SDGs.

5.2.1. Ted's 10 #1

Ted's 10 #1 refers to 'Design to minimize waste' pre- and post-consumer. This entails reducing waste in the textile industry, recycling and producing products that do not work and that consumers do not buy. Examples of designs that minimize waste are recycling, design for long-life, and design which "enhances aesthetic value" ('Ted's 10', 2020). All four aesthetic design elements (material, color, design, fit) can potentially add waste pre- and post- consumer, as analyzed in 5.1.2, in product design. 'Waste' can come from various pre- consumer sources, such as chemicals from fiber production and coloring process (will be analyzed in detail in 5.2.3. – Ted's #3), and post-consumer sources, such as disposal. Therefore, 'design to minimize waste' must be incorporated in product design.

Managing textile waste is becoming increasingly difficult due to rising volumes. As predicted by the Boston Consulting Group and Global Fashion Agenda (2017), 92 million tons of textile waste were discarded in 2015 and it is predicted to increase by 50% in 2030. That is equivalent to 23kg per capita and year in Germany. A way to reduce these number is by designing for reuse, repair, recycling, long-life, and durability. Three strategies exist in handling waste management efficiently: reuse of products, repairing and reconditioning, and recycling. Reuse involves the collection and resale of products. Repair and reconditioning strategies have the opportunity to use second-clothing or fabrics as a source of materials to construct new designs. Techniques such as restyling, reshaping, embellishing, overprinting can give a new life to materials and divert them from ending up as waste. Furthermore, they also affect the style and the fit of the final product. Another strategy is recycling. This can be done mechanically or chemically. Natural fibers are recycled chemically and then blended with longer virgin fibers. Synthetic polymers are melted and processes like virgin fibers. The recycling of polyester is growing in popularity as statistics suggest than more than 50% of staple polyester fiber in the EU comes from recycled materials (Fletcher, 2014, pp.118-123). Nevertheless, products must be recyclable (see Ted's #2 – cyclability). In addition, durable products allow for a longer product lifecycle. It not only refers to the materials used but also to the style and fit. Focusing on the physical robustness of the product, the material should keep its shape, and not use prints or patterns that wear off. Design characteristics like quality and timelessness are proven to

extend a product's lifecycle. Examples are versatile, unisex, unisize designs that affect the fit of a product and can be shared with multiple people and sizes (Fletcher, 2014, pp.193-196).

5.2.2. Ted's 10 #2

Ted's 10 #2 refers to 'Design for cyclability'. This includes designing a product that can be recycled or upcycled. Sustainable practices are using a mono-material, design for easy disassembly in a closed-loop system and using re-usable and non-invasive designs ('Ted's 10', 2020). The cyclability of a product can be affected by the choice made in all aesthetic design elements, as analyzed in 5.1.2, thus affecting product design.

Design for recycling (DFR) and Design for disassembly (DFD) are initiatives that explore how products must be designed to be disassembled and recyclable. Checklists offer designers the possibility to promote reuse already in the designing phase. Textile products should avoid the use of fiber blends as this slows down sorting operations and leads to reduced material quality (downcycling). In addition, it is found that the color also influences the recyclability (Fletcher, 2014, p.124-125; Shafiq, 2020). According to Shafiq (2020) the principle of mono-color in product design should be considered, as this simplifies the sorting process. Figure 12 shows the checklist for DFR, which designers should keep in mind to allow cyclability of materials.

DFR CHECKLIST

1. White textiles (easy re-dyeing)
2. Natural fibers (easier to process mechanically and more versatile)
3. Quality (long staple fibers can be processed in faster machines)
4. Pure (not blended fibers require more processing) mono-material

Figure 13 DFR Checklist based on Fletcher (2014) p. 124

However, the disassembly of complex textile products, can only be possible through developments in innovations such as laser and water-jet technologies, which enable cutting, etching and bonding to sew fabric together without a thread that simplifies disassembly later on (Fletcher, 2014, p. 124-125). Moreover Fletcher (2014) proposes modular design, in which parts of garments can easily be disassembled (see Ted's #4).

5.2.3. Ted's 10 #3

Ted's 10 #3 refers to 'Design to reduce chemical impacts'. The release of chemicals can be affected by the type of material, material construction and colorants chosen ('Ted's 10', 2020). Therefore, choices in aesthetic design elements (materials and colors) influence the sustainability of the product in product design.

Considering the material of a product, choices between natural and manufactured fibers can be made. Natural fibers are plant and animal fibers, while manufactured fibers can be derived from natural polymers (vegetable and animal) and synthetic polymers. While all fibers have a chemical impact, differences can be vast. Alternatives exist to lessen the impact of chemicals on the environment. Table 14 shows the most common types of fibers, their chemical impact, from processing and coloring, sustainability implications and alternatives for designers (discussed in 5.2.4)

Table 14 Chemical Impact of Fibers and Sustainability based on McCourt (2020)

<i>Fiber Origin</i>	<i>Fiber</i>	<i>Chemical Impact (1) processing, (2) coloring</i>	<i>Sustainability Implications/ Alternatives</i>
<i>Natural Fibers</i>	Alpaca	1 – 2 – dyeing: untreated dye water must be treated before release	Use alpaca as alternative to wool, cashmere, silk, synthetics; promote natural color fiber (biodegradable); use OEKO-TEK certified fiber
	Cotton	1 – 2 - dyeing: untreated dye water must be treated before release	Source organic cotton (less water contamination & Co2 emissions from synthetic fertilizers and pesticides) Integrated pest management cotton (IPM) (less pesticides); Natural colored cotton (naturally pigmented fiber (e.g. purple, brown, green) that eliminates the need for dyeing)
	Bamboo Linen	1 – Retting (dew, water, or chemical) chemical retting emits chemical rich wastewater must be treated before release 2 – natural color must be chlorine bleached for further coloring; wastewater must be treated	Source from organic production certified by IFOAM; use linen that was sourced through dew retting (less wastewater and nutritious to soil); promote natural color fiber (less need for dyeing; biodegradability is not clear); promote use of non-chlorine bleaches (ozone bleaching)
	Recycled Cotton	1 – Garneting (mechanical shredding) 2 – used in existing colors	Use waste from yarn spinners; can only be used in combination with at least 15% virgin fiber
	Wool	1 – instead of mulesing (removing wool in the back of the sheep to attract less flies and maggots) spray-on chemicals can be used, which can contaminate receiving water bodies; pesticides used to control parasites and lice can contaminate water	Use chlorine-free wool (chlorine is not used during the shrink proofing process), promote use of natural color wool (no bleaches/ dyes, biodegradable), OEKO-TED certified wool (no chemicals that pose health risk)

Manufactured Fibers

	<p>systems; scouring (removing grease from fiber) leaves pesticides in wastewater</p> <p>2 - dyeing: untreated dye water must be treated before release</p>	
Silk	<p>1 – high biological load on water if left untreated due to weaving process that removes gum from the weave</p> <p>2 - dyeing: untreated dye water must be treated before release</p>	Use wild or ‘Tussah’ silk (chrysalis is not killed), organic silk (cultivation of organic mulberry bushes)
Polyester & Recycled Polyester	<p>1 – fully chemical, uses petroleum, which releases chemicals into water and air</p> <p>2 - dyeing: untreated dye water must be treated before release</p>	Recycled polyester using chemical recycling (closed-loop system); use polylactide (PLA) instead, which is derived from plant starch and is biodegradable
Acrylic	<p>1 – fibers contain 85% acrylonitrile (chemical can lead to cancer in humans); anti-pilling treatments use chemicals</p> <p>2 - dyeing: untreated dye water must be treated before release</p>	Use OEKO-TEK certified acrylics that do not use chemicals that pose a health risk, use recycled acrylic
Lyocell (from eucalyptus)	<p>1 – solvents are derived from petrochemicals but are recovered and reused</p> <p>2 – good water absorption qualities require less dye and chemical use</p>	Use TENCEL lyocell (recovers 99.8% of solvent in the cellulose process), is biodegradable (depending on coloring and trims)
Modal	<p>1 – nontoxic and 95% solvents are recovered</p> <p>2 – Lenzing Modal Color adds pigments to fiber matrix, eliminating dyeing process</p>	Use Lenzing certified modal, and modal color; not all colors can be dyed with Modal Color, traditional dyeing methods might be used, biodegradability is questionable
Polyamide 6 and 6.6	<p>1 – uses petrochemicals, durable water repellents (DWR) are typically applied for water repellents but compounds release chemicals</p> <p>2 - dyeing: untreated dye water must be treated before release</p>	Non – biodegradable, recycled polyamide (chemical recycling) ensure a closed-loop system, use non-toxic waterproofing methods, OEKO-TEK certified do not use chemicals that pose a health risk
Viscose made from wood	<p>1 – viscose process is chemically intensive and emits wastewater</p> <p>2 – bleach is used</p>	Use raw materials from responsibly sources forests (Certifications), use Lenzing Viscose (carbon neutral), use lyocell instead, OEKO-TEK certified for less chemical use

Moreover, the fabric construction also affects the release of chemicals. Different types of lubricants are used in the weaving and knitting process. In the weaving process, a sizing agent is applied to the warp thread to strengthen and protect it during the process. Typically,

pentachlorophenol (PCP) is used as a sizing preservative. It is then washed in the de- sizing process which requires water, which then contains the sizing chemicals (Fletcher, 2014, p.58). Fletcher (2014) proposes to move to polyvinyl alcohol (PVP), which reduces pollution as 94% can be reclaimed and reused, it is more affordable and uses natural starches. In the knitting process, oils are usually used, which also produce wastewater (Fletcher, 2014, p.58). Fletcher (2014) suggests the designers to choose suppliers who use biodegradable/ water-soluble lubricants (Fletcher, 2014, p.59).

Decisions regarding the fabric and thus, the fiber need to be made. However, trade-offs exist. While natural fibers can be biodegradable, depending on the coloration, the coloring and the cultivation is the main factor for the release of chemicals into the atmosphere. Synthetic fibers are not biodegradable, and they also have a vast chemical impact. However, cellulose fibers have an advantage, as the solvent used to turn pulp into fiber is often recovered and reused. Nevertheless, alternatives to natural and manufactured fibers in terms of chemical impact exist. Designers are recommended to choose a material derived from more sustainable fiber in order to render the product more sustainable.

In terms of coloring, designers must pay attention to bleaching, dyeing, and finishing. Natural fibers have an off-white color which requires bleaching. Synthetic fibers are also bleached as this “enhances color brilliance after dyeing” (Fletcher, 2014 p. 61). By combining scouring (purification of natural fibers) and bleaching, chemicals, energy and water can be saved. Moreover, companies must check whether wastewater was treated prior to discharge. The dyeing process is resource intensive as it uses water, energy, and chemicals and produces large amounts of effluent that is highly polluting. An alternative for cellulosic fibers is pad-batch dyeing, which saves energy, water, dyes, chemicals, labor and floor space. Furthermore, natural dyes, made from plants, shells, etc. are an alternative to generic reactive dyes. However, they can only be applied to natural fibers and need fixing agents (mordants) in order to stick to the fiber. Moreover, they are subject to color variations and need more time to achieve good color. In addition to looking for natural dyes, companies should check whether suppliers have water- and energy efficiency measures in place, reuse dye liquors, and treat wastewater prior to discharge. The fabric should be finished using formaldehyde-free or poor and easy-care finishing agents (Fletcher, 2014, pp. 61 – 68).

The Higg Index, developed by the Sustainable Apparel Coalition, is a tool that allows companies, organizations and institutions to assess their or their apparel, footwear, or textile product's sustainability throughout each stage of its journey. It measures the impact on the

environment, such as water use, wastewater effluence, chemicals, etc. Based on several factors, a total score is calculated (Sustainable Apparel Coalition, 2020). This can be a valuable tool for designers to make decisions regarding fabric material, material compositions, coloring, printing, and finishing.

It may be difficult to source a material from a sustainable source which has been treated 'sustainably' and trade-offs may have to be made in product design, specifically in the theme/concept stage. The Higg-Index might be a valuable source to evaluate a material, or a fabric composition's environmental impact (Sustainable Apparel Coalition, 2020)

5.2.4. Ted's 10 #4

Ted's 10 #4 refers to 'Design to reduce energy and water use'. This affects the production and use phase in the product lifecycle. The color, material, style and fit have a great impact on energy and water use.

In reference to table 13 above, the water and energy use and impact in the pre-consumer phase can be seen. Recycled fibers usually use less energy and water than the production of virgin fibers. In addition, some manufactured cellulosic fibers offer the benefit of using less water and energy. For example, in Lenzing modal dyeing process, up to 80% less energy and 76% of water can be saved. However, the viscose process requires "copious" amounts of water at high temperatures, which is a water and energy intensive process (McCourt, 2020). Regarding fabric construction, seamless knitting or whole-garment knitting save 30-40% of total time and thus energy during the knitting process (Fletcher, 2014, p.59). Additionally, the cut fabric waste (Fletcher, 2014, p.59). By applying Higg-Index more in-depth information can be gathered to evaluate trade-offs.

Especially in the use phase, large amounts of water and energy contribute to the environmental impact of products. By changing the composition of garments low-impact laundering is promoted. Cotton is usually washed at warmer temperatures than synthetics, which favors the use of synthetics in product development. By using synthetic fibers in different fabric construction methods, performance characteristics such as resistance to creasing and water absorption have an effect on laundering behavior (Fletcher, 2014, pp.99 – 100). Moreover, synthetics are more lightweight and thus consume less energy and water during laundering (Fletcher, 2014, pp. 179-180). The fiber of the garment also plays a role. Alpaca fiber is water-dirt – and stain- repellent and absorbs odors to reduce smells and avoid lots of washing. Lyocell also absorbs and redirects moisture, which results in fewer washes (McCourt, 2020). The fabric

construction also plays a vital role. For example, construction such as innovative hexagonal, waffle or honeycomb construction “enclose the maximum amount of space with minimum amount of materials. Therefore, these construction types store more body warmth, are light, and direct water away (Fletcher, 2014, pp. 179-180). Moreover, modular design can reduce the amount of laundry by “making the parts of garments that get soiled most quickly detachable” (Fletcher, 2014, p. 100). Furthermore, design for low or no launder/ wash can reduce the frequency of laundering by consumers. Examples includes wipe-clean surfaces, or pre-stained garments which give the design a unique and intended look (Fletcher, 2014, pp. 102 – 103).

5.2.5. Ted's 10 #8

Ted's 10 # 8 refers to ‘Design to reduce the need to consume’. Long-lasting, adaptable products support this goal as they can be used multiple times. By applying this target, decisions about material, style, fit and color can be specified. Strategies such as emotionally durable design, and slow design are part of this.

According to Chapman, products are discarded faster when they lack a meaning. He proposes that by attaching an emotional meaning between a person and object, dependence on consumption can be disrupted (as cited in Fletcher, 2014 p. 197). It is proposed that in order to enable the consumer to build an emotional bond with the product, the following approaches can be applied (figure 13).

Approaches to Extending Product-User Relations

1. High quality, good-design, reliable, upgradable, maintainable products
2. Cooperatively designing and producing products together with users
3. Creating personal narratives through customization, personalization
4. Retention of aesthetics through personalization and ageing with dignity
5. Sharing products

Figure 14 Approaches to Extending Product-User Relations based on Fuad-Luke (as cited in Fletcher, 2014, p. 197)

The approaches affect the material to be of high quality (e.g. less pilling), and the style, fit, and color to be designed with consumers. However, Chapman realizes that while a design can potentially trigger an emotional response from the design, one cannot influence the perception and response of the consumer as each user is unique. Slow fashion is another strategy which focuses on reducing consumption. It involves long lead times, small production scales and design classics (Fletcher, 2014, pp.196 – 206). While it might be difficult to foresee what design consumers prefer, LaBat & Sokolowski (1999), Pitimaneeyakul et al. (2004) suggest, similarly

to Fletcher (2014), that a specific target consumer should be involved in the product development process in order to find out what a ‘good’ design entails for the target group.

5.3. Theoretical Framework

Based on the above suggested propositions for sustainable aesthetic product design elements in product design, a theoretical framework was established. This framework shows a ‘sustainable’ guideline within product design that summarizes suggestions guided by the Ted’s 10. It is based on overcoming the lack of sustainable guidelines, as identified in comparison to the UN SDGs (5.1).

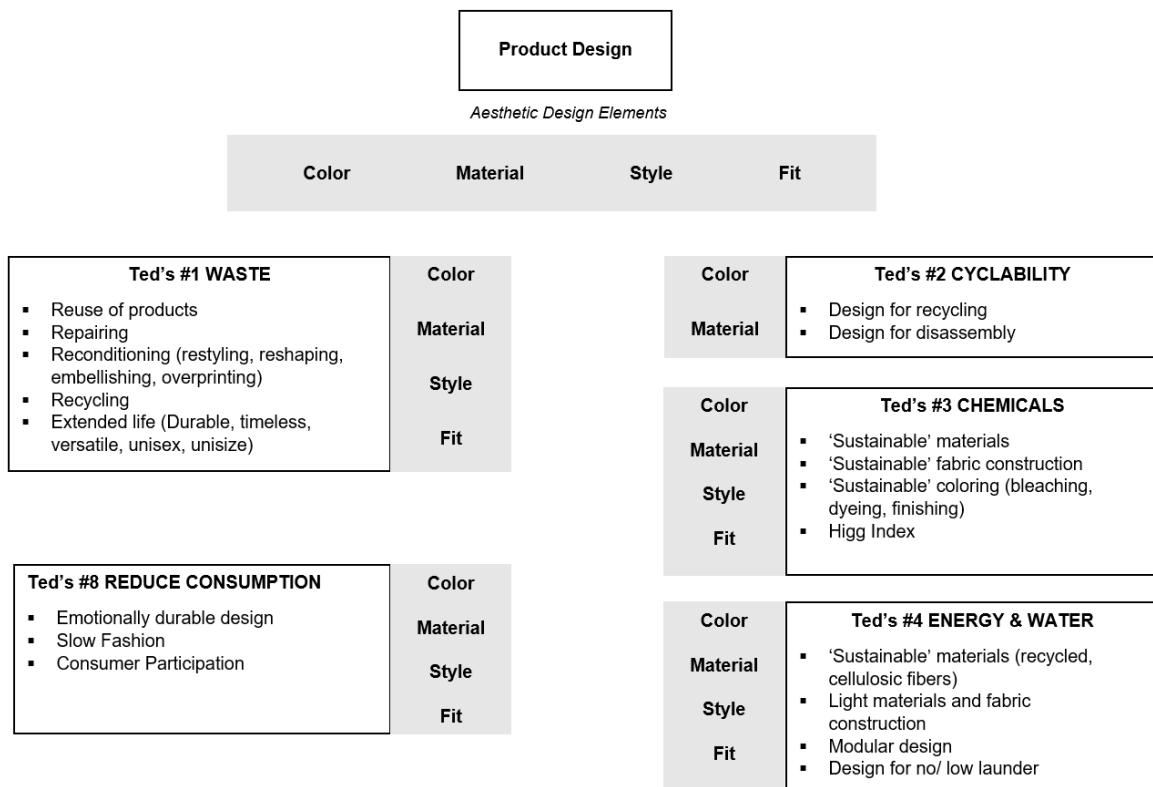


Figure 15 Sustainable Theoretical Framework (own figure)

Environmentally sustainable suggestions about product design that affect the aesthetic design elements were made. The aesthetic design elements are material, color, style, and fit. As evaluated in the ‘Frame of Reference’, the chosen Ted’s 10 influence the aesthetic design elements. Sustainable propositions from the analysis in regard to the aesthetic design elements are reflected in this theoretical framework.

According to Larsson (2020), the Ted’s 10 strategies, focused on textile design, are highly relevant design methodologies from the design perspective. By evaluating how the Ted’s 10 contribute to the UN SDGs, companies know exactly, which of the UN SDGs they cover when

adapting a Ted's strategy. However, a limitation is that the Ted's 10 are mostly developed on the environmental sustainability side and not much on the social sustainability side. Furthermore, the UN SDG's are not focused on the textile industry explicitly, so a common ground has to be found upon which the design methodologies can be incorporated with the UN SDGs. Therefore, not all targets within the goals can be applied to the Ted's 10 (Larsson, 2020). In addition to the UN SDGs deemed relevant by the researcher, Larsson validates the importance of the chosen UN SDGs for the thesis but also recommends UN SDGs 8, 9, 13, 15, and 17 which are discussed in the Textile Fashion 2030 platform, where the interviewee is a member (Larsson, 2020). However, upon closer examination of these goals, it was found that the goals are partly applicable to environmental sustainability but do not set a guideline for aesthetic design elements in product design. Hence, the UN SDGs are limited to SDG 6.3, 12.5, 14.1, 15.2.

Table 15 shows how the environmental Ted's 10, targeting product design, can contribute to the fulfilment of the UN SDGs. Explanations for the allocation of the UN SDGs to the Ted's 10 are discussed.

Table 15 Combination of UN SDGs & Ted's 10

Ted's 10	UN SDGs
<i>#1 Design to minimize waste</i>	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse Life below Water - 14.1 by 2025 prevent and reduce marine pollution from land-based activities Clean Water Sanitation - 6.3 improve water quality by reducing pollution through dumping hazardous chemicals
<i>#2 Design for cyclability</i>	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse Life below Water - 14.1 by 2025 prevent and reduce marine pollution from land-based activities
<i>#3 Design to reduce chemical impacts</i>	Clean Water Sanitation - 6.3 improve water quality by reducing pollution through dumping hazardous chemicals Life on Land - 15.2 by 2020 promote implementation of sustainable management of all forests, halt deforestation, increase forestation
<i>#4 Design to reduce energy and water use</i>	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse
<i>#8 Design to reduce the need to consume</i>	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse Life on Land

Ted's #1 focuses on waste minimization and thus, supports the realization of UN target 12.5, 14.1, and 6.3. Target 12.5 aims at reducing waste by preventing, reducing, recycling, and reusing. Target 14.1 aims at preventing and reducing marine pollution from land-based activities. Target 6.3 aims at improving the water quality by reducing pollution through chemicals. In the analysis, under Ted's #1, suggestions regarding reuse, repair, recondition, recycle are made. Furthermore, it is discussed what to consider in the aesthetic design elements that extends the product's life (style, fit, material: durability, timelessness, etc.). In addition, the waste generated by materials and color are also mentioned but explained in detail in other Ted's strategies. Therefore, Ted's #1 supports target 12.5 as reuse, repair, reconditioning, and recycling reduce waste reduction. Moreover, through waste reduction, pollution from land-based activities can be reduced through less waste from material processing and coloring waste and less product waste from discarded products (extended product life) which enters water bodies. Hence, Ted's #1 also supports the realization of target 14.1. Furthermore, a by-product of material processing and colorations is wastewater, which entails hazardous chemicals (explained in detail in Ted's #3). Different strategies that support target 6.3., from choosing the type of fiber to the type of coloration that reduce the need and thus the contamination of water with chemicals, are proposed.

Ted's #2 focuses on designing for cyclability. Target 12.5 and 14.1 are applicable. In the analysis, under Ted's #2, suggestions regarding recyclability and disassembly are made. Design for recyclability affects the color and material to be of light colors, and natural, high quality, non-blend fibers and fabrics. In design for disassembly, different technologies are suggested that eliminate the use of trims and simplify disassembly of products. By designing products that simplify the disassembly of final product at the end of their use and designing them in such way that materials can be recycled, target 12.5 is supported. Furthermore, through the prevention of pollution, materials are prevented of entering the marine ecosystem, supporting target 14.1.

Ted's #3 focuses on designing to reduce chemical impact. Target 6.3 is applicable here, since it also focuses on chemical pollution of water. In the analysis, under Ted's #3, different types of commonly used materials and coloring are assessed. For each fiber, an alternative which is more environmentally friendly in terms of chemical pollution is given. For example, it is analyzed that manufactured cellulosic fibers, such as lyocell, generate less wastewater than the production of synthetic fibers and less chemicals than the cultivation of cotton. Moreover, different types of techniques for coloring are discussed. The results can be validated and applied

by designer using the Higg Index as a guide, which scores each material on an environmental impact scale. These strategies support the UN target 6.3, which is focused on reducing the chemical impact on water.

Ted's #4 focuses on reducing energy and water. Target 12.5 is applicable because waste can be generated in the form of energy and water. In the analysis, under Ted's #4, 'sustainable' materials, design for no/low laundry, modular design are discussed. The production of different materials also varies in the use water and energy in fiber processing. For example, the production of Lenzing lyocell, recovers 95% of the solution and reuses it, which saves water. Moreover, Design for no/ low laundry targets the design of the garment which can save water and energy in the use phase. Using fibers which are self-cleaning, such as alpaca, is also mentioned. Modular design allows the consumer to detach dirty parts of the product and wash them. These strategies support the UN target 12.5.

Ted's #8 focuses on reducing the need to consume. Target 12.5, and 15.2 are applicable because by preventing waste through the form of recycling products' lives can be extended, and consumption slowed down. Emotionally durable design, slow fashion, and consumer participation are strategies that can prolong a product's life. Designer can, to some extent, design products that allow the consumer to form an emotional bond with the product and thus, reduce their need to discard more and consume more. Moreover, slow fashion, being the exact opposite of fast fashion, can increase the consumers perception of quality and thus reduce waste and allow the consumer to enjoy the product for longer. Also, by including the consumer in the process, products that are more tailored to the consumers' needs can be designed. Therefore, these strategies can be used to prolong a product's life and hence, in turn reduce the need to consume.

Although, the Ted's 10 strategies can benefit companies in their goal to be in line with several UN sustainable goals, there are several implications as defined by the expert interviewees in their fields of expertise (UN DSG, product development). While Larsson (, 2002) argues that the Ted's 10 can pose a valuable methodology for companies to achieve environmental sustainability (as defined by the UN SDGs), he also mentions that there are other sustainable development goals that the Ted's 10 do not cover, since they are focused on product design. Therefore, some SDGs are directly and strongly linked with the Ted's 10, but many have a mid- or low impact on other UN SDGs. Moreover, he states that the Ted's 10 are "weak" on the social sustainability side and social sustainability must be considered when talking about sustainability nowadays (Larsson, 2020). According to Shafiq (2020) the level of

implementation of the proposed design strategies have several implications regarding capabilities, scale, and product types. First, he argues that product design cannot be evaluated as a stand-alone. All stages in the product development process affect each other. Therefore, all capabilities must be matched. According to him, the best product (design) is the one that matches with the production capabilities. The tech-pack in the pre-production phase reflects what *can* be done. Furthermore, the level of implementation of the theoretical suggestions depend heavily of the scale of the product. In small scale production, there are more possibilities to include sustainable practices. However, in large scale production this become challenging due to the large quantity, higher cost and the problem of 'sustainable' material availability. Furthermore, the use of natural dyes is more feasible small scale as the product design of different products may vary because outcomes are generally not uniform, and the problem of uniformity would be more difficult to control large scale. Lastly, depending on the product type, the design process and capabilities differ. For example, the design of a denim product has many restrictions and thus, a different design process (Shafiq, 2020). While both experts see various challenges regarding decision-making concerning aesthetic design elements and their sustainability in the final product, both agree that the Ted's 10 could give designer and textile and fashion companies a clearer guide to different environmental sustainability strategies to be implemented.

The chosen UN SDG targets must be regarded from the perspective of product design in textile or fashion companies. Although there are many possibilities to e.g. achieve water quality by reducing chemical pollution (UN SDG 6.3), the possibilities regarding aesthetic design elements are more limited, as targets are seen out of the perspective of product design. Therefore, it can be said that the Ted's 10 do not fully support the realization of the chosen UN SDGs, but rather propose suggestions about the aesthetic design elements, which enable the practice product design to be more in line with the UN SDGs than before. In comparison with product design as found in literature, the new framework restricts decisions regarding the aesthetic design attributes while the practice of product design from literature did not exhibit many sustainable guidelines. Although there might be several implications regarding the heavy environmental focus of the Ted's 10 and the implementation thereof, as discussed by the expert interviewees, the sustainable framework proposes several general strategies that can further be tailored to a specific textile or fashion product or company.

6. Discussion/ Conclusion

In the discussion section, sub-research questions as well as the main research question are answered. As the sub-research questions build on each other, they are answered sequentially. By answering all three sub-questions, the main research question can be answered, and the research concluded.

How can the aesthetic design elements in product design, as part of the product development process, in the fashion and textile industry be improved considering environmental sustainability using the Ted's 10 methodology and the UN Sustainable Development Goals as a guide?

Sub-research questions

1. What does current product design in product development models in the fashion and textile industry entail?
2. How do aesthetic product design elements in product design compare to environmental sustainability as defined by the UN Sustainable Development Goals?
3. How can aesthetic product design elements in the product development process become more environmentally sustainable using the Ted's 10 goals?

6.1. Sub Research Question 1

What does current product design in product development models in the fashion and textile industry entail?

Product development is a process which entails product design (Ashby & Johnson, 2010). Therefore, in addition to product design, product development models were also searched for in the systematic literature review. Within 12 articles, 36 unique models were found. Of those 36 unique models, May-Plumlee & Little (1998), Wickett et al., (1999), LaBat & Sokolowski (1999), Pitimaneeyakul et al (2004) and Wu & Wu (2011) provided the development/design models that are most relevant for this research. This was determined based on a data analysis that took into account whether the publication year of a model is within the relevant time frame (1998-2011), the number of times a specific model was referenced, and its association with product design. The synthesis of these five models revealed that the product design stage starts early on in the process of product development. Moreover, all authors identified that decisions regarding aesthetic design elements of the product's design are made in a phase called the 'Concept/ Theme Development'. Within this step, it was found that a design level is set

according to consumer's identified needs. The design level includes decisions regarding the color palette (core, secondary, accent colors), the fabric surface design (e.g. plaid/print), the structural fabric (fiber content/ construction, appearance, draping), and the fit and style (designed based on merchandise categories). This overlaps highly with the identifies aesthetic design elements in the 'Frame of Reference' (style, color, material, fit). After making decisions regarding the concept, these are refined, turned into a prototype, and reviewed/tested (May-Plumlee & Little, 1998; Wickett et al., 1999; LaBat & Sokolowski, 1999; Pitimaneeyakul et al., 2004; Wu & Wu, 2011).

6.2. Sub Research Question 2

How do aesthetic product design elements in product design compare to environmental sustainability as defined by the UN Sustainable Development Goals?

In comparison to the UN Sustainable Development Goals, it can be said that all decisions regarding aesthetic product design elements (style, color, material, fit) are general and can, hence, not be seen as specifically unsustainable but rather as a lack of following environmentally sustainable guidelines. Compared to UN SDG target 6.3, there is no clear guide to restrict chemicals from the dyeing process, (colors, fabric surface design) and no clear guide to restrict the type of fibers used (synthetic/ cellulose/ natural fibers) (structural fabric). Compared to UN SDG target 12.5, there is no clear guide to restrict waste emanating from dyeing/ processing (fabric surface design, structural fabric), and no clear guide to restrict design decisions that prevent disposal (style, color and fit). Compared to UN SDG target 14.1, no clear guide that restricts design decisions to prevent disposal (style, color and fit), and no clear guide to restrict waste emanating from dyeing/ processing (fabric surface design, structural fabrics) is in place. In comparison with UN SDG target 15.2, there is no clear guide that restricts sustainable harvesting of manmade cellulosic fibers (structural fabric). This lack of environmentally sustainable guidelines in place leaves options that can have negative environmental impact. While the authors of the models also include propositions that are somewhat in alignment with the UN SDGs, they only affect the later stages of product design, such as prototyping, which exceed the scope of this thesis.

6.3. Sub Research Question 3

How can aesthetic product design elements in the product development process become more environmentally sustainable using the Ted's 10 goals?

Each Ted's 10 design methodology shows different opportunities for designers in companies to render product design more sustainable. In specific, the chosen Ted's 10 goals are able to

provide a guideline/ tool for decision-making concerning the four aesthetic design elements: material, color, style, and fit.

Ted's 10 #1 focuses on reducing waste. Propositions to reduce waste are (1) the reuse of products, (2) repairing, (3) reconditioning (restyling, reshaping, embellishing, overprinting), (4) recycling, (5) and extending life (durable, timeless, versatile, unisex, unisize). The propositions target the pre consumer phase, the use phase, and the post-consumer phase. These propositions affect decisions regarding the material, the color, the style and fit of the final product, as analyzed in 5.3.

Ted's 10 #2 concerns cyclability. Design for recycling and disassembly are suggested that affect the post-consumer phase. These also affect the choice of material, color, style and fit, as analyzed in 5.2.

Ted's 10 #3 focuses on reducing chemicals. It is recommended to source more sustainable materials (fiber and construction) and more sustainable types of coloring pre consumer. The Higg Index is pointed to for a detailed assessment of different types of fibers and fiber compositions. The goal to reduce chemical impact, affects which the type of material and color should be chosen.

Ted's 10 #4 is about reducing energy and water use. Suggestion regarding this design strategy are the use of more sustainable materials (recycled, manmade cellulosic fibers), lightweight materials and fabric construction, modular design and design for no/ low launder that reduce the use of energy and water in the pre consumer phase and during the use phase. These recommendations affect the type of materials, coloring, style and fit of products.

Ted's 10 #8 refers to reducing the need to consume. Recommendations include emotionally durable design, slow fashion and consumer participation to prevent disposal and thus reduce need to consume. This type of design impact decision making regarding the materials, color, style and fit.

By incorporating suitable sustainable propositions, depending on the type of textile/ fashion product, the product design of this product can become more sustainable and reduce the environmental impact it would have had without the application of the Ted's 10. Figure 14 in section 5.3 shows the theoretical framework that has potential to improve the sustainability of the final product.

6.4. Main Research Question

How can the aesthetic design elements in product design, as part of the product development process, in the fashion and textile industry be improved considering environmental

sustainability using the Ted's 10 methodology and the UN Sustainable Development Goals as a guide?

The theoretical framework developed in the analysis (5.3) was critically analyzed using the chosen UN SDGs. Table 16 summarizes how the Ted's 10 contribute to more environmental decision making regarding the aesthetic design elements and how this supports the fulfillment of the UN SDGs.

Table 16 Impact of Ted's 10 on Aesthetic Design Elements and Contribution to UN SDGs

Ted's 10	Aesthetic Design Elements	UN SDGs
<i>#1 Design to minimize waste</i>	material, color, style, fit	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse Life below Water - 14.1 by 2025 prevent and reduce marine pollution from land-based activities Clean Water Sanitation - 6.3 improve water quality by reducing pollution through dumping hazardous chemicals
<i>#2 Design for cyclability</i>	material, color, style, fit	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse Life below Water - 14.1 by 2025 prevent and reduce marine pollution from land-based activities
<i>#3 Design to reduce chemical impacts</i>	material, color	Clean Water Sanitation - 6.3 improve water quality by reducing pollution through dumping hazardous chemicals 15.2 by 2020 promote implementation of sustainable management of all forests, halt deforestation, increase forestation
<i>#4 Design to reduce energy and water use</i>	material, color, style, fit	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse
<i>#8 Design to reduce the need to consume</i>	material, color, style, fit	Responsible Consumption and Production - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse Life on Land

In conclusion, it can be said that the impact that the Ted's 10 have on the aesthetic design elements do not fully support the realization of the chosen UN SDGs, but rather propose suggestions about the aesthetic design elements, which enable the practice of product design to be more in line with the UN SDGs than before. In comparison with product design as found in literature, the new framework restricts decisions regarding the aesthetic design attributes while the practice of product design from literature did not exhibit many sustainable guidelines. As was analyzed by the interviewees in section 5.3, the theoretical framework has several implications. The product design must always be a match with production capabilities, the scale of production affects which sustainable practices can be adopted and the type of product greatly affects its environmental sustainability. Moreover, the decisions that are made about the aesthetic design elements not only affect the chosen UN SDGs. They have the possibility of also reaching other targets to some extent but indirectly. Although there might be several implications regarding the heavy environmental focus of the Ted's 10 and the implementation thereof, as discussed by the expert interviewees, the sustainable framework proposes several general strategies for the aesthetic design elements that can further be tailored to a specific textile or fashion product or company.

6.5. Limitations and Future Research Direction

The objective of the thesis is to develop a theoretical framework which focuses on environmentally sustainable product design of aesthetic design elements. In a systematic review, data about product design and development was found, analyzed, and synthesized. Using the UN SDGs, the practice of product design was explored and analyzed. Next, by applying the Ted's 10 goals, propositions were formed to improve the environmental impact of aesthetic design elements in product design. The propositions are reflected in a theoretical framework, which was analyzed by two expert interviews and compared to the UN SDGs. Throughout this process, several limitations as well as possibilities for future research directions were encountered, which are discussed in this section.

Limitations regarding the methodological approach, and content were found. Firstly, in connection to the methodology, the reliability of the interviews is somewhat compromised. Initially, a third industry expert interview was planned but unfortunately, cancelled. Due to the cancellation of the interview, the implications in practice are to some extent given through the interview with industry- knowledge from Shafiq (2020) but could have been more consistent with a third interview.

Second, the interviews are, to some extent, subject to interviewee and interviewer bias. The questions for the interview were previously chosen by the interviewer and are thus, influenced by what the interviewer thinks most important to ask. However, questions were kept as objective as possible without any premise, and the research process was explained thoroughly before the start of the interview. In addition, the interviewees chosen also displayed bias to some extent due to their different backgrounds. However, by specifically asking questions targeted at their area of expertise, the interviewer tried to extract information of high validity (Salazar, 1990). Furthermore, the interview with Shafiq (2020) was conducted before an impactful change in course of the thesis. Previously, the focus was on the process of product development and product attributes. However, the interview data is still largely applicable because product attributes were previously defined as similar to the aesthetic design elements. Additionally, only minor changes to the theoretical framework were made after the change in course.

Third, the data collection method of the systematic literature review also has several limitations. First, the systematic review is known to lead to “bureaucratization of the review process” because it is more concerned with the technicality than analytical interpretation (Bryman, 2012; p.108). This can be seen looking at the data analysis of the systematic review findings. The researcher chose the inclusion and exclusion criteria, data extraction and analysis criteria based on the researcher’s thought relevance. However, the process was accurately documented to ensure high replicability and thus, reliability.

Fourth, in connection to the content, this thesis has a limitation due to a general focus. While the focus is on aesthetic design elements, only general and main aesthetic design elements are targeted that are common in all textile and/or fashion products. Garment accessories and trims are disregarded because the objective of the thesis is kept general. However, this affects the applicability of the theoretical framework to specific products.

Fifth, the theoretical framework only aims at improving environmental sustainability in the early stage of product design. However, as identified by the authors in the systematic literature review, product design also includes other steps, such as prototyping. While decisions regarding aesthetic design elements are made in the beginning to set the direction, they have to be matched with the capabilities of further steps. Otherwise, ‘sustainable’ products cannot be produced. Nevertheless, narrowing down more sustainable options to choose from in product design may help in steering further steps into the direction of sustainability.

Sixth, not all UN SDGs and Ted's 10 were focused on. Some may add value, but the most clearly applicable ones were used due to general focus. In connection to a specific product, other Ted's 10 or UN SDGs might be included.

Lastly, the thesis focuses on environmental sustainability only. However, today sustainability must also be regarded from a social side (Larsson, 2020). While social sustainability is highly relevant, the focus of this thesis is on aesthetic design elements in product design, which focus mainly of environmental sustainability, as they constitute 80% of the final product's environmental impact (Curwen et al., 2012). In addition, extending the scope of this thesis would exceed the project's capabilities.

The future research directions are partly linked to the limitations of the thesis. As mentioned in the 'Frame of Reference' design elements can either be aesthetic and functional. This thesis focused on aesthetic design elements, such as material, color, style, and fit. However, aiming at functional design elements, such as the performance and quality, could also pose a worthwhile research. In combination with this, research could be further extended to the inclusion of Ted's 10 #9 'Design to Dematerialize and Develop Systems & Service'. For example, under Ted's #9, renting systems are proposed, which require durable and functional materials for renting periods ('Ted's 10: 9, 2020). Moreover, the process of product design could also be analyzed using the Ted's 10. This would reduce the environmental impact of the design process. Suggestions such as 3D prototyping or 3D modelling could be proposed, which reduce the waste from sampling (McQuillan, 2019). Next, by targeting a specific textile or garment market the propositions could be adjusted for this market. For example, Shafiq (2020) experienced that the overall design of garments is more minimalistic in Scandinavia than it is in the United States. Therefore, more specific suggestions for different markets can be made. Lastly, the theoretical framework could be applied to a specific type of product or product group. As Shafiq identified during the interview, each product follows a different type of design and development process. Therefore, close attention to the product's requirements needs to paid in order to make appropriate aesthetic design element decisions and narrow down the theoretical framework for one specific textile or fashion product.

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8. Appendices

8.1. Appendix A

Complete List of Ted's 10 Goals

NUMBER	TED'S 10 GOALS
1	Design to minimize waste
2	Design for cyclability
3	Design to reduce chemical impacts
4	Design to reduce energy and water use
5	Design that explores clean/ better technologies
6	Design that takes models from nature & history
7	Design for ethical production
8	Design to reduce the need to consume
9	Design to dematerialize and develop systems & services
10	Design activism

8.2. Appendix B

UN Sustainable Development Goals for the Environment and their Targets

NUMBER	SUSTAINABLE DEVELOPMENT GOALS	TARGETS
6	Clean Water Sanitation	<ul style="list-style-type: none"> - 6.1 universal access to safe and affordable drinking water - 6.2 access to adequate sanitation and hygiene - 6.3 improve water quality by reducing pollution through dumping and hazardous chemicals - 6.4 increase water-use efficiency - 6.5 implement water resource management at all levels - 6.6 protect and restore water-related ecosystems
7	Affordable and Clean Energy	<ul style="list-style-type: none"> - 7.1 universal access to affordable, reliable energy services - 7.2 increase share of renewable energy - 7.3 double rate of improvement in energy efficiency
12	Responsible Consumption and Production	<ul style="list-style-type: none"> - 12.1 Implement 10-year framework of sustainable consumption for countries - 12.2 by 2030 access to safe, affordable housing - 12.3 by 2030 halve per capita food waste - 12.4 by 2020 environmentally sound management of chemicals - 12.5 by 2030 reduce waste generation through prevention, reduction, recycling, reuse - 12.6 encourage companies to adopt sustainable practices - 12.7 promote public procurement practices - 12.8 ensure that people have information for sustainable development
13	Climate Action	<ul style="list-style-type: none"> - 13.1 strengthen resilience to climate-related hazards - 13.2 integrate climate change measure into national policies - 13.3 improve education, awareness-raising in humans and institutions
14	Life below Water	<ul style="list-style-type: none"> - 14.1 by 2025 prevent and reduce marine pollution from land-based activities - 14.2 by 2020 manage and protect marine and coastal ecosystems - 14.3 minimize and address impacts of ocean acidification - 14.4 by 2020 regulate harvesting, overfishing, illegal and unreported fishing practices - 14.5 by 2020 conserve at least 10% of coastal and marine areas - 14.6 by 2020 prohibit certain fishery subsidiaries which contribute to overfishing, etc. - 14.7 by 2030 increase economic benefits to small island developing states

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- 15.1 by 2020 ensure conservation, restoration of terrestrial and inland freshwater ecosystems
- 15.2 by 2020 promote implementation of sustainable management of all forests, halt deforestation, increase afforestation
- 15.3 by 2030 combat desertification, restore degraded land and soil
- 15.4 by 2030 ensure conservation of mountain ecosystems
- 15.5 take action to reduce degradation of natural habitats and protect extinction of threatened species
- 15.6 promote fair sharing of benefits arising from utilization of genetic resources
- 15.7 take action to end poaching and trafficking of protected species
- 15.8 by 2020 introduce measures to reduce the impact of invasive alien species on land and water
- 15.9 by 2020 integrate ecosystems and biodiversity values into national and local planning

8.3. Appendix C

Interview Transcript Larsson (2020)

Interview Transcript Jonas Larsson

00:00:09

Interviewer: Looking at the sustainable suggestions that I proposed in the theoretical framework, do you know of any other suggestions that could be added within the Ted's 10, or in the five of the Ted's 10 that I chose?

00:00:46

Interviewee: Maybe looking at the chemicals, you could have not only coloration, but also other process and product chemicals. So, treatment but also other chemicals in there that are used in the manufacturing process.

00:01:32

Interviewer: Do you mean like processes like printing, for example?

00:01:36

Interviewee: That too. But you have, for example, chemicals that you use in processes. Glue, for example, for gluing the warp in the weaving machine. You have to glue that before you weave. There are tons of chemicals in in the dyeing process that you use to prepare the fabric for dye. A lot of times the dyeing process is not up to the quality, so you have to re-dye. And then you need to prepare it again. So, tons of different process chemicals that can be hazardous.

00:02:48

Interviewer: So, do you mean to also think about not only the fabric stage, but also fiber and yarn spinning.

00:02:58

Interviewee: Yes.

00:03:06

Interviewer: OK. The next question is: because I'm analyzing this based on the UN Sustainable Development Goals, some of them, could you maybe discuss the suggestions that I have there from the TEDS 10 and how they relate to the U.N. goals?

00:03:44

Interviewee: They relate to several of the UN goals.

00:03:56

Interviewer: I will show you the ones that I chose. So here we have the Ted's 10. This is how I allocated the Ted's 10 to the U.N. SDGs. Four of them were chosen, the 12.5, 14.1, 6.3, and 15.2.

00:05:04

Interviewee: We have done similar analysis of their global goals or the SDGs. What you can do and what we've done is that we have divided it in three categories where we have sort of the direct impact, indirect impact. In three levels, high impact and low impact and then medium impact somewhere in between. There will there will be more goals that are related to this to the Ted's 10, but perhaps not at high significance. The once you have identified are perhaps the most significant ones. But I'm sure there are more goals that are relevant for the Ted's 10 but not as significant.

00:06:12

Interviewer: Do you think I should divide it into the three categories?

00:06:13

Interviewee: You can divide it divided into three or four levels. Perhaps where level one is highly significant and then level four is a sort of "could be relevant"?

00:06:30

Interviewer: I have previously looked at the product design stage and also I've done the analysis with the U.N. SDGs, but only with the ones that I thought were relevant in terms of design and environmental sustainability. So maybe I could also add that there. OK. I mean, do you know which other ones (SDGs) I could also or which other ones that the Ted's 10 also affect?

00:07:45

Interviewee: No, I don't. No, especially not on a Friday afternoon.

00:08:00

Interviewer: Okay, I understand. Looking at the ones that I have here, do you think they are the most relevant?

00:08:23

Interviewee: The ones that we use for Textile Fashion 2030 platform are goal number 6, 8, 12, 13, 15, 17, maybe 9 as well. Yeah, 9 as well. So clean water, decent work and economic growth, industry, innovation, infrastructure, responsible consumption and production, climate action, life on land and partnership for the Goals. These are the ones that we have.

00:09:17

Interviewer: Ok, and there you also focus on environmental sustainability?

00:09:21

Interviewee: Yeah, and we also have goal 8 there because we needed to have that. The argumentation behind that is that it's 2020. We can't talk about sustainability without including any social aspects. So, that was the background to that.

00:09:47

Interviewer: Can I find this paper somewhere?

00:09:56

Interviewee: You can have a look at Textile Fashion 2030. But I don't know whether we are all that explicit about it.

00:10:06

Interviewer: Did you use the Ted's 10 there as well?

00:10:13

Interviewee: No, we started from a report from the Swedish EPA and we translated that into the SDGs.

00:10:23

Interviewer: OK, and last time you said it's relevant to look at the Ted's 10 in combination with the U.N. SDGs. Could you explain why you thought so?

00:10:39

Interviewee: Because it's relevant. Because if a company uses the Ted's 10 in their design and product development process and if there is a comparison with the SDGs, then the company would understand which of the SDGs they're contributing to.

00:11:02

Interviewer: So mainly in practice it would be relevant?

00:11:12

Interviewee: Yes.

00:11:18

Interviewer: OK. From the information that I have provided you with so far, do you see any implications how the Ted's 10 could not fit to the UN SDGs?

00:11:32

Interviewee: I am not sure.

00:11:50

Interviewer: Or do you see any challenges for the Ted's 10 that are related to the SDGs?

00:12:05

Interviewee: The SDG's are maybe weak on the social side.

00:12:11

Interviewer: Do you mean the SDGs or the Ted's 10?

00:12:14

Interviewee: No, the Ted's 10. We know that they're not so developed on the social side. But I think it is a tool for environmental design, right? Textile environment design. So that explains it.

00:12:37

Interviewer: Yes, but they also have some social factors.

00:12:41

Interviewee: They do, yes.

00:12:43

Interviewer: But mainly it's environmental factors. If you compare it to the U.N. SDGs, I found a lot of them had to do with the social factors.

00:12:54

Interviewee: Yeah, I would say about half or so.

00:13:21

Interviewer: I have one more question. Do the Ted's 10 sufficiently fulfill the U.N. SDGs?

00:13:38

Interviewee: Well, the short answer is no, but also they don't aim at fulfilling the SDGs. For sure they contribute to the environmental SDGs.

00:13:58

Interviewer: Also looking at the environmental SDGs, do you think that they (Ted's 10) fulfill them?

00:14:17

Interviewee: If somebody uses their patterns to design a collection, they would probably cover several of their environmental SDGs. But that depends on how committed they are in using the Ted's 10. Because the Ted's 10 are not specific on the environment, on biodiversity and life below water

and life on land. But if you use the methodology in the Ted's 10, you would, hopefully anyway, have a good impact on those SDGs.

00:15:05

Interviewer: And by methodology, what do you mean by that?

00:15:10

Interviewee: The Ted's 10 as a design methodology.

00:15:21

Interviewer: OK. I think that's it. The main goal of the interview was to use the interview as triangulation to validate what I have done so far and what can be done. Thank you for your time.

00:16:04

Interviewee: Yes, have a nice evening.

Interview Transcript Shafiq (2020)

Interview Transcript Ahsan Shafiq

00:00:01

Interviewer: OK, I'll tell you about my thesis first and then what I was hoping from the interview and the questions. So, I will do the thesis out about product development. I already did a systematic review about the models and product development that exist. And based on five of those models, I synthesized the process into one model. But I was focusing on those steps where decisions regarding the product attributes are made and for the product attributes. I'm looking at the fabric material, the color, the design, the silhouette and the sizes, and I am also looking at how those decisions regarding the product attributes and the steps can be made more environmentally sustainable. So, I compared those steps against the UN Sustainable Development Goals. And I found that in each step, actually, there was no guideline for sustainability, and it was kept quite general. So, I decided to apply some of the Ted's 10 goals that were linked to environmental sustainability to find out how I can turn that into a guide in the product development process to make the process regarding the product attributes more environmentally sustainable. So, I researched some ideas for each of the Teds 10 goals that I chose. My goal is to propose a more specific model that is more environmentally sustainable. So, from the expert interview, I hope that I can use the interview as a source of triangulation. So, I will evaluate and validate the proposition that I've made and discuss them with you. Basically, to find out how realistic they are and if you have any other suggestions in terms of environmentally sustainability that can be added from the Ted's 10 goals, also looking at pre and post-consumer and also the use phase. So maybe I can share my screen with you first, This is kind of a work in progress model. So up here I have the four steps that I chose from the model that affect the product attributes. And this one, I have kind of a dotted line here because I found that actually you can skip this step if you use 3D prototyping, but I will talk about it later. And here I listed which of the attributes are affected in each of the steps.

00:03:25

Interviewee: Before we start, your product attributes are more generic products in textile application, or are they also specific? Because when we talk about the product attributes and sustainability for the impact on the environment, are you also looking a specific end use? Because the products, people can change from one product to another product based on the end use and actually the purpose of the product. Is it somehow more specific about the purpose of any specific product or product group or is it a more generic product attribute? Because if that is more generic, then it's more of your social and also from your resource efficiency, you can talk about very much in

general. But if you are working on a specific product or the end use, then you can further add more into the fabrics, sellers to make those choices, which is actually quite specific.

00:04:26

Interviewer: Yes, so this is in general. I do not have any product in mind. So, the Ted's 10 goals that I found were appropriate, because they are focusing on environmental sustainability, are 1, 2, 3, 4, 5, 8. So design to reduce waste, recyclability, chemicals, energy and water, clean and better technologies and reduce the need to consume. And under each of those goals, I describe what kind of strategies you can apply to reach that goal. For example, under Ted's 10 you could apply and reuse, repair and recycle. Looking at the fabric, using fabric that has already been used or that has been recycled. So, that links to the fabric material and to the design that is durable, timeless, and that's a high-quality design.

00:05:40

Interviewee: So durable, timeless high-quality design - It is the design that these product attributes can go with and with the fabric material because it's one of the components of the design. It's durability, timelessness. That's actually comes with the durability of the material. So, the fabric material itself is one of the components then you're leading or you're aiming for a timeless or durable design overall.

00:06:15

Interviewer: Okay. Yeah, and under Ted's 2, I found that 3D modeling exists. So that's where you can just draw on each of the parts of the garment, and then it turns it into a prototype.

00:06:38

Interviewee: Have you logged into this CLO3D?

00:06:38

Interviewer: No.

00:06:48

Interviewee: Right now, in the course sustainable business development, it's quite a big course and we found that right now, I think this offer is offering a one-month free trial. So, if you can try and get yourself logged in. I will see if I can send you the details we have. We have already posted a log in. Maybe I can share the same details with you. But it's not really from Högskolan i Borås platform, it's just a normal one-month trial. Maybe you can get into it and get your data out before it shuts down. If you if you want to use it.

00:07:22

Interviewer: Yeah, that would be good. I found it from a source that was from someone who is also from this University. So, I thought maybe it was from the university.

00:07:45

Interviewee: I think we do not have a license for that from the university, it's just a normal membership.

00:07:52

Interviewer: OK, but it would be good to try it out. Under recyclability, I also found design for recyclability him and design for disassembly, so these are strategies that exist.

00:08:10

Interviewee: It's with all of them. I think when we talk about design for recyclability. If we look at your attributes, fabric material again, it's connected to mono materiality. And when we look at, for example, color, we think that if you if you design for a mono color, no color or minimum colors, it actually can add into recyclability. Because you have to recycle something, you have to sort them

first. So, it helps in the disassembly if you use less color somehow, indirectly, when you are designing for recyclability.

00:08:55

Interviewer: OK. So, not only the material, but also if you have mono color?

00:09:02

Interviewee: I think when we talk about design here, you are talking about the style of the garment. Because when we in sustainability, when we talk about design it's everything. When we talk about design in general, we talk about only the styling of the garment. If you remember, we had in the tech pack, what is the styling of the garment, what it looks like? But in sustainability, design is everything. So, material also comes under the design. You cannot separate that. So, what do you really mean about designing here? It's a very generic term, but very wide scope.

00:09:49

Interviewer: The definition that I found for design was the style of the garment.

00:09:57

Interviewee: So, it's the style of the garment, I understand now. So, for example, for design for recyclability also goes with the design because recyclability and disassembly, both are somehow tied. When you have to aim for a recyclability, you have to design a product which can be easy to disassemble. Easy to disassemble and easy to sort. There are two things: you can easily disassemble and then you can easily sort garments, all the parts off the garments. So sorting is to just make it easy. And for that matter, material color and design, all three are quite related to both of them.

00:10:44

Interviewer: Yes, and then about the chemicals I made a list of the fabrics that are most commonly used and found what chemical implications they have and proposed alternative fabrics. And the same goes for the coloration as well. But within coloration, I found that it was proposed that you can use natural dyes, but I also found that those are not really completely sustainable because you have to use a mordant, I think. And that also releases chemicals into the water.

00:11:30

Interviewee: Yeah, I think we're here it's a bit of a difference because when we speak about the research or if we talk about dyeing the fabric which has a very minimal scale of production, then I think natural dyeing would have been one off the solutions that I would suggest. But when we have to talk about commercial or mass volumes or even medium scale of the volumes for the quantity, then natural dyes will not really work in there because then there will be a lot of rejection and problems with the fabric. And that is not a sustainable solution because if you have a rejection, it means that you are leading to waste. So natural dyes have had their own limitations when it comes to the scale of the volume or scale of the quantity for the product. But for the single product development, yes, you can do that. That is not a problem. But when you have to convert that single product development to a production there is a limitation. So, the product attributes are really important and that is what I will force in this conversation that it's always important that you develop a product based on the production capabilities. You do not develop a product on your ambition or your visions. Because then you develop a product on your vision or your ambition for the sustainable development, mostly when you get into the production, you really cannot develop the multiples of them. And this is one of the biggest challenges I have learned from my experience. If you remember, we discuss about, in our lecture that in the in the textile supply chain, in a manufacturing supply chain, the preproduction and production, they are two different things. Mostly in the preproduction, they look into the product attributes to match to the tech packs. Because they have to form the garment out of it. So, they try to follow that. But when they get into the production, their production itself, there's a lot of limitations which actually resists not to adopt those preproduction samples.

And they still have to go into the negotiation about some of the details which in production could not be possibly done. So, this is a difference. I would still say that the best product development is which actually respects, the production limitations. So, natural dyes is one of the things which I still believe that, yes, for the one product, you can do that, or you can do for the smaller quantities. But when it comes to a bigger point, do the production, then it will not really be more sustainable. Then it will start maybe creating problem with the rejection of the product if you're not aiming for color accuracy for example. If, as a buyer, you are flexible with color accuracy, then it's fine. But if you are if you are strict as a normal acceleration, then it will create a lot of rejection.

00:15:01

Interviewer: And then in terms of energy and water, I also looked at the fabrics again, the energy use and the water use. Same for coloration. And I found that there are some types of design. I found two of them, the modular design and the design for no launder to decrease the water use in the use phase. I found it difficult for each of the Ted's 10 to consider each of the three phases pre-consumer, the use phase and post-consumer.

00:15:52

Interviewee: What do you mean by the use phase? You are considering for post-consumer the end of the use?

00:16:09

Interviewer: Yes, that's what I meant.

00:16:15

Interviewee: And what do you mean by Ted's 3 and 4, you mentioned about alternative fabrics here and then alternative coloration? What do you mean by alternative fabrics? When it comes to chemical application and when for example efficiency of the resources, energy and water.

00:16:34

Interviewer: I will show you the table in the document. So here, for example, for cotton, I looked at the alternatives, for example, use organic cotton, and that's what I mean by the alternative fabrics.

00:17:22

Interviewee: OK. So now I understood your here, the whole thing that I was I was a bit confused with the fabric material. Because when we talk about fabric material, we specifically talk about the fabric formation in those processes. we surround ourselves within the knitting weaving, non-wovens, all these things. These are the fabric formation processes. But when you say fabric material it means you are addressing the fiber as a material as it is at the base of the material?

00:17:58

Interviewer: Yes.

00:18:03

Interviewee: Then its fine, then I understand.

00:18:10

Interviewer: Then there it is still missing whether it is woven or knitted for example.

00:18:15

Interviewee: Those are the fabric formation processes. When we name a fabric design for example. You can divide them into two: fabric material, fabric design. Then it makes more sense. Because fabric designs means that you could choose an alternate design and save energy to say chemicals, which is very much less impact, I would say. But still, there are two different aspects to talk about. One is the design, the fabric material. And the other one is a fabric design. These are two different things. If we put them both together, then it makes sense. That fabric materials means the materials used to make the fabric and the fabric design meaning what is the design of the fabric? Is it woven, is

it knitted? We talk about the energy consumption and the water consumption, weaving and knitting has a very different energy and water and consumptions and the wastages also. So that is also something to consider.

00:19:28

Interviewer: Do you know any sources where I can find more information about that? Any books?

00:19:33

Interviewee: About the weaving, knitting or about sustainable development? I can send you some data after the meeting, I will e-mail you. We have I think that we also have in our course, if you remember the TEKO Sustainability kit. They address the fiber separately, and the fabric formation processes separately as well within the sustainable development. I think that Toolkit will be the best one. Or maybe you can also read the Kate Fletcher book, which we had for this sustainability-oriented business model course.

00:20:17

Interviewer: OK, then for the next one, the clean and better technologies, I haven't found that much because I was thinking about the 3D prototyping, but it's similar to the 3D modelling. And then what also came to mind was maybe the QR code, which also adds to the cyclability goal. Maybe you have some suggestions of what strategies or what can be applied to use clean and better technologies?

00:21:08

Interviewee: I think when it comes to energy and water and chemical and when it comes to clean and better technologies, we just discussed about the difference between the knitting and weaving. If you remember, we have seen the big stall machine in the knitting which we also have in the lab. There you just have to have a yarn and then you can make the finished product out of that in a finished form. So that is one of the clean and better technology examples for the fabric formation. And that goes with the fabric material. Plus, I would also say its somehow color because that machine also helps because you can do yarn dyeing. If you have to run that machine, it has the yarn, which is dyed in there. So, I think they both go with that. But again, the styling of the garment is not really so much improved, but then you add 3-D, then I think it has to do something with the design and style of the styling of the garment. I don't know if you can take in the 3-D prototype or so. But I will look into it and write some something more about it with the clean and better technologies. I will if I can find something in the process of product development.

00:22:43

Interviewer: Okay. Thank you. And then lastly, the Ted's 10 'reduce the need to consume', is more about the design, emotionally durable design, slow fashion, but also about the colors and also the sizes. For example, I found that there is design that kind of grows with your age, so you don't have to continue to buy new garments. And also, consumer participation to include the consumer in each of the steps to find out what designs they want so that they don't discard their clothes that they don't want to early. And also, that those clothes are not discarded before they're even sold.

00:23:58

Interviewee: Also, I think from your Ted's 1 you have mentioned about unisex and unisize, that also has something to do with the consumption because those garments, which are the unisex the unisex and uni size, they can cover more of the body types so somehow it reduces the need to consumer more. So instead of when you do change with the body size, the unsex have maybe slightly more life with when we compare it with the only size perspective.

00:24:40

Interviewer: OK, so my first question is, we talked about it already, to go over the suggestions that I made so far and maybe to add some of your ideas. And the second question is: What do you think is the most realistic for a company to focus on looking at the strategies or the suggestions that we've

made? Because I imagine it's quite hard for a company to focus on all of them, especially since you also mentioned that you have to look at the production capabilities to match those. So, what do you think would be most realistic for a company to apply?

00:25:38

Interviewee: I think from the company's perspective, the bottom line is gain when it comes to product development from a single piece perspective. We know that most of these is really applicable, no problem at all. We can have almost all of the sustainable principles to be applied on a single product. That is fine. And that is a bit of the resistance between that. That is maybe a cause for the companies as well, for the low development or less development of sustainability at in comparison to when we look at how much it has already been discussed in the textile and fashion industry. Just because of this production and commercialization aspect. Because when they put the all the principles into the production and big volumes, it is very expensive. It is very costly because it costs them a lot to develop sustainable products. From the One-Piece perspective, it looks cheap because it's a design that you need to develop for one piece, but when you have to buy it and you have to source these products in bigger volumes, then there is the limitation. Every company has a set budget to buy the product and they can extend that but there's some limited to. When it comes to social sustainability, you can develop that. But when it comes to environmental sustainability through the product development, then you have to add those product attributes into the product development. So, you can impact the environment in a positive manner as what your thesis is all about. In that perspective, that is why most of the companies are working on the fabric materials most of the time, because color choices is very much, I would say, the company's personal decision. It may affect the environment, but from the supplier's perspective, it's really not something which makes a bigger a difference because the color choice is based on if we're working with the light colors, or if we're working with the dark colors. The dyeing process itself is so much toxic. So, that is something that we have to take generally. For that matter, maybe we need to optimize the machinery to use less water and also maybe eco-friendly dyes can be used in the product attributes and the product development, which can actually have a positive impact for that. So, I would say that it's again, the material choices that are the most important. And then we are still looking into the different possibilities for prototyping, which we already have, like virtual design. And we are we are working on that as well. But again, a scale of volume is very important because when we do the research and the stall machine, which I have already mentioned before. The stall machine is being into the industry for quite many years now, but still, that cannot facilitate the scale of volume or the big quantities. Because the production of stall is very slow, and it does not cope with fast fashion. So, there is still a problem with this scale of quantity int that case and that is a big resistance for the development of sustainability or sustainable development in other ways.

00:29:13

Interviewer: For example, looking at Zara. What I know is that they have a lot of seasons in their year, so they bring out lots of collections, but all on a rather small scale. Do you think it would be feasible for them to look more into sustainability or is their production still too large?

00:29:39

Interviewee: Now, the problem is that small scale, again, for the Zara, it is maybe possible for them. But from which perspective are we looking? Because sustainable materials or alternate materials. Alternate materials are not readily available in the market, at least from the current state. Even currently, what materials do we have which is the most commonly consumed. We have cotton, we have polyester, we have maybe nylon for the sportswear, we have wool. It's again, you know that it's not so much readily available as compared with the cotton, polyester. Now looking at the alternate materials, when we look into the organic materials, if we look at their recyclable materials, or the recycled materials, these are just because of unavailability in the markets, expensive. When you then

when you have to apply those materials on the minimum quantities, which are just small quantities, it makes their price even more expensive. So, again, that is why most of the fashion brands they are working on the retail solution as for the second-hand and as for the repair solutions as, as for the reuse solutions, because all these solutions are in their own territory where they can have those solutions in their own retail stores. But when it comes to anything from the from the upstream supply chain, which is the supplier side, it's a lot expensive in that way because you have to pay for anything you are aiming for when it comes to product attributes. Product attributes is just like the basket, you just add on the value and then you have to pay for that. And that is really important that how much attributes you are adding, how much value you're adding into the product. That's all the attributes that we have to pay for that. So, again, material choices, design choices, not the color too much, but from your four attributes fabric material, silhouettes, design, they matter a lot when it comes to the product and the sustainable development. I don't know if you you're generally talking about or you are actually doing your thesis for some specific niche market - I don't know, but it's different. When we talk about the styling and silhouettes, those two things are also quite different for different markets? Because the fashion is different in different retail markets or the fashion markets. So, in that case also the design, for example the styling of the garment, if I look at it from the Swedish perspective vs. the US perspective, completely two different stylings. So, this complicates that someone can predicts the sustainable development. The US styling of the garments are highly fashion products. And if we compare them, then the Swedish styling is more minimalistic because then you do not have so much onto the product and that means that it is easily disassembled, and it is easy to reuse. Because it is exactly as if we have less number of seams or the number of pieces on the garment you can reuse that fabric for more applications in number, for example if you need to upcycle or something to make another product out of it. So, you always look. Yesterday, or the day before, we had to supervision of our course, and then students were working on a base material to minimize the waste and they were working with leather products. Now in that case, then you have to work with the waste you're always aiming to find the bigger pieces from the garment or from the products so you can use them outside the upcycling or make new products out of it. So, in that case, the Swedish fashion, which I talked about with having a minimalistic way offers a better disassembly than what maybe for the U.S. products. So, this is maybe also something that you can look into, that which fashion you consider or what benefit style do you consider. I suggested a generic style.

00:04:49

Interviewer: OK. As a last question: do you have any suggestions on maybe what I can improve in the research? You said maybe focus on one market may. Maybe you have any other suggestions or anything to add to the Ted's 10.

00:05:14

Interviewee: I would still I would still think that first thing is to narrow down the market and find out if you can go to some specific niche markets. And also, if you can somehow narrow down the product, which product type. Because then we talk about the products attributes these are very much different because Ted's 10 is just a tool to follow, or to base on. But if I have, for example, a knitted product vs a denim product, these both have a completely different product development routing. Because that is what I always talk about in sustainability, that the design of the product, how you design the product, actually dictates the routing of the product development. And the routing is really important for the impact on the environment. And that is where you can fix the problem, because the designer these days, what they are trying to do is to fix their routing, that which process comes first and which process do we need, or we can have an alternate process or we can completely skip that process out of the product development routing. So, again, I would say that if you somehow can compare two products in your thesis or some products that can make it more

reliable and more authentic because then you can have two different routings of the product development and then you can compare based on Ted's 10. That makes more sense that how you can make more. But if we talk about it in a way, genetic way, then I still believe that we can still touch all the Ted's 10. But on a very surface level, it's not really I don't think that it will make a difference in the end? Well, you have to compare something, I would say.

00:07:21

Interviewer: Or maybe I can use something as an example and use that example throughout all of the Ted's 10. So, because I'm in the last stage now, I don't have time to change the focus. So maybe that could be something.

00:07:35

Interviewee: I didn't know how much you have already dealt with your thesis. What research questions do you have?

00:07:47

Interviewer: My research question is: How can the product development process in the fashion and textile industry be improved theoretically, considering environment sustainability using the UN Sustainable Development Goals as a guide?

00:08:11

Interviewee: But then it's more of like a generic where you can come up with the more theoretical solutions, and then it's really fine because then we can talk about more generic gain from the different solutions we have for the for the material choices. And of course, we already talk about material choices from the perspective of recyclability, disassembly, these are the things we have already discussed about also for the clean and better technology. But you can also talk about not the attributes but textile substrates. I don't know if you can add but we have different textile substrates. Fiber is a substrate and then we have a yarn as a substrate, the fabric as a substrate and then we have a garment as a substrate. Now in that case maybe you can talk about that for each stage or each substrate how do you see the Ted's 10 from that perspective if you want to add something instead of looking in to a specific product if you think that that will be a bigger change in your thesis maybe I would suggest that you can see the product development. Because each product in textile goes through with all these substrates from fiber to yarn, to fabric, to garment. And that is what the product development grouping is. So, these four substrates, you can maybe think about how the environment can be controlled or maybe is having a positive impact on the environment at the fiber stage, at the yarn stage, at the fabric stage, garment stage for the product development. And of course, you can talk about all these 3D prototyping at the garment stage. You can talk about the material choices in the fiber stage. You can talk about something in the yarn and you can also talk about all these Ted's 10, most of these Ted's 10 at the fabric stage. So that can also be one suggestion, I would say.

00:10:23

Interviewer: That's a good suggestion. I will have to do more research about that to find out how much more that would be, because I have to hand it in on Friday, not finally, but almost. That's basically the last stage. And after that, I will just get recommendations from Vijay and the other group. Yes, afterwards I have a week to change that and then I have to submit it again. So now it really depends on how much time I have to add all of the changes, but I will make some research and find out what I can add best.

00:11:15

Interviewee: Now, you do not need to change the overall foundation of course from the research question rather maybe if you can add something more into that. Of course, I understand at this stage

it's difficult to change everything, but I would still think that you can add something on top of your own research.

00:11:40

Interviewer: OK. Well, that was it from me. Thank you for answering the questions and for your feedback. Yeah, maybe you can send me the information about the cleaner, better technologies, if you have some more information. And I will send you the GDP form most likely today. But if not, then tomorrow, because otherwise I can't use the information from the interview.

00:12:16

Interviewer: Okay, goodbye.

8.4. Appendix D

Overview of all articles accepted for review

ARTICLE#	ARTICLE AUTHORS	TITLE
1	LaBat & Sokolowski (1999)	A Three-Stage Design Process Applied to an Industry-University Textile Product Design Project
2	Goworek (2009)	An investigation into product development processes for UK fashion retailers
3	Sari & Asad (2019)	New product development processes in the fashion industry Evidence from Indonesian Islamic fashion companies
4	Lanarolle et al. (2016)	Apparel product development: An overview of existing models
5	Wickett et al. (1999)	Apparel Retail Product Development: Model Testing and Expansion
6	Powell & Cassill (2006)	New textile product development: Processes, practices, and products
7	May-Plumlee & Little	No-interval coherently phased product development model for apparel
8	Kochba et al. (2014)	Product development process in small and medium clothing companies: focus on relations with suppliers, retailers and final client
9	Bandinelli et al. (2013)	New Product Development in the Fashion Industry: An Empirical Investigation of Italian Firms
10	Wu & Wu (2011)	Redesigning the Apparel Product Development Process Based on the No-Interval Coherently Phased Product Development Model
11	Moretti & Braghini (2016)	Reference Model For Apparel Product Development

12	Kauling & Bernardes (2011)	Study On The Introduction Of Design Management In The Product Development Process Of Brazilian Clothing Companies
X	Schlesinger et al. (2019)	Modified product development process for tailored textiles
X	Shi et al. (2016)	Modeling and simulation of fast fashion product development process based on time competition
X	Zhong & Zhao (2011)	Differences of the Chinese and International Fashion Brand Design Management Models based on Product Development Process
X	Shuyu & Piercy, (2008)	New Product Development and Commercialization Process in the SME Fashion Design Houses
X	Ramanan et al. (2003)	Modeling new product development in the textile and apparel industry

8.5. Appendix E

Data Extraction Form

Data Extraction Form												
General Information												
Study Number	1	2	3	4	5	6	7	8	9	10	11	12
Title	An investigation into product development processes for UK fashion retailers	New product development processes in the fashion industry Evidence from Indonesian Islamic fashion companies	Apparel product development: An overview of existing models	Apparel Retail Product Development: Model Testing and Expansion	New textile product development: processes, and products	No-Interval coherently phased product development model for apparel	Product development process in small and medium clothing companies; focus on relations with suppliers, retailers and final client	New Product Development in the Fashion Industry: An Empirical Investigation of Italian Firms	Reshaping the Apparel Product Development Process Based on the No-Interval Coherently Phased Product Development Model	REFERENCE MODEL FOR APPAREL DEVELOPMENT	STUDY ON THE INTRODUCTION OF DESIGN MANAGEMENT IN THE PRODUCT DEVELOPMENT PROCESS OF BRAZILIAN CLOTHING COMPANIES	
Author	Karen L. Labat, Susan L. Sokolowski	Helen Goworek	Rora Pusputa Sari and Nabila Asad	Jennifer Lea Wickert, LuAnn Ricketts Gaskill, Mary Lynn Damhorst	N. B. Powell & N. L. Casill	Traci May-Plumlee, Trevor J. Little	Yslene Rocha Kathua, André Mathias Souza Plath, Marcelo Gomes Githrana Ferreira, Fernando Antonio Forcellini	Romeo Bandinelli, Rinaldo Rinaldi, Monica Rossi, Sergio Terzi	Chun-Sheng Wu 1, Qiao-Isabel Cristina Ying Wu 2	Braghini Junior	Graciela Kauling, Mauricio Bernardes	
Publication year	1999	2009	2019	2016	1999	2006	1998	2014	2013	2011	2016	2011
Type of publication	Article	Article	Article	Article	Article	Article	Article	Article	Article	article	article	article
Publishing Country	U.S.	London	Indonesia	U.S.	U. S.	U.S.	Brazil	Italy	China	Brazil	Brazil	Brazil
Database	Scopus	Scopus	Web of Science	Scopus	Web of Science	Scopus	Scopus	Web of Science	Web of Science	Web of Science	Web of Science	Web of Science
Study Characteristics	qualitative	qualitative	mixed method	qualitative	qualitative	qualitative	qualitative	qualitative	qualitative	qualitative	qualitative	qualitative
Research Strategy	case study	case study	case study	case study	case study	case study	case study	case study	LR	case study	case study	case study
Content	# steps attributed to design 3.0, 0.1,1		1.1.1, x, 0.1, x0, 0, 0.1, x, 2, x, x, x		1.1, 2, 2, 2, 3, 2		2	5,1	1.1, x, 2, 2	2, 1, 2, 2, 1, 1, 1, 2		
# of processes in textile & fashion industry	5	1	1	16	1	6	1	2	1	4	8	1
# of steps in process	7,7,7,6,3		8,5, x, 7,6, x, 5,4, 7, 6, x, 6, x, 5, x, x		8,5, 6, 5, 7, 8, 8		6,12, 3		5,4, 3, 6, 6	6, 9, 6, 6, 4, 5, 6, 5		9
Year of PD process	1984, 1988, 1977,1992,1999	2007	2019	2009,2011	1999	1993, 2004, 2003, 2001, 1995, 2002	1998	2011, 2014, 2011, 2004	1999, 2005, 1998, 2011	2016, 2006, 1992, 1998, 1992, 2002, 2003, 2004		1999
Author of processes	Delonge, Watkins (by Ko Goworek & Carr & Pomero)	Rora Pusputa Sari and Nabila Asad based on Bandinelli et al. (2013), Dissanayake and Sinha (2015), Goworek (2010), Huang et al. (2002), Kircade et al. (2007) / Huang et al. (2002), Dissanayake and Sinha (2015), Kircade et al. (2007) / Huang et al. (2002), D'Avolio et al. (2015), Kircade et al. (2007), Kircade et al. (2007) / Bandinelli et al. (2013), Goworek (2010), Huang et al. (2002), D'Avolio et al. (2015), Kircade et al. (2007) / Huang et al. (2013), Bandinelli et al. (2013), Huang et al. (2002), Kircade et al. (2007) / Huang et al. (2013), Dissanayake and Sinha (2015), Goworek (2010) / Huang et al. (2002)	Jennifer Lea Wickert, LuAnn Ricketts Gaskill, Mary Lynn Damhorst (based on Gaskill 1992)	Urban and Hauser, Ulrich and Little (based on Burns and Eppinger, Crawford and Di Benedetto, Cooper, Bruce and Little, 1997; WaigB, 1997)	Silva, Kathua et al.	Bandinelli R., Terzi	Wickert and Gaskill and Damhorst, Kuntz, May-Plumlee and Little, Wu	Moretti & Braghini, Rosenfeld et al., Lamb and Kallal, May-Plumlee and Little, Gaskill) Rensch, Montemezzo, Pitmanneyakul	Bruce, M., Cooper, R., and Vazquez, D.			

8.6. Appendix F

Interview Guide Expert Interviews

Ahsan Shafiq (2020)

<i>Interview Questions</i>	<i>Possibilities for follow up questions</i>
1. Looking at the chosen Ted's 10 do you know of any other strategies that can contribute to the goal? Pre-consumer, use phase, post-consumer?	- Could you specify which phase these suggestions targets/improves? - Could you please specify?
2. Which of the suggestions are most realistic to focus on in each goal?	- Could you explain if there is a difference among different industries? - Could you please specify?
3. What are the implication in practice?	- Could you elaborate why?

Jonas Larsson (2020)

<i>Interview Questions</i>	<i>Possibilities for follow-up questions</i>
1. What other strategies exist that can contribute to each Ted's 10 goal? Pre-consumer, use phase, post-consumer?	- Could you please specify?
2. Which of the suggestions are most realistic to focus on given current innovations?	- Which SDGs are most relevant in practice?
3. Where do you see implications for sustainability?	
4. Could you evaluate/ discuss the suggestions in light of the chosen UN SDGs? Do they sufficiently fulfill the goals?	- Which of the UN SDGs are most relevant?



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