Can the fashion industry calculate its way to sustainability?

(YES IT CAN)

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The potential of LCA
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Environmental and social problems of the fashion industry

Apparel has a long and complicated life cycle consisting of many phases including material production and extraction, fiber and yarn manufacturing, textile manufacturing, assembly, packaging, transportation and distribution, consumer use, recycling and ultimate disposal (Anika Kozlowski, 2012). The negative impact on the planet related to different stages in the life cycle of clothing involves complex environmental issues such as water degradation, climate change, and the depletion of resources (Fletcher, 2008). Annually produced are 2 billion pairs of jeans consuming each 7000 liters of water. As for a basic T-shirt, the water consumption is around 2700 liters which are equal to the amount a single person drinks in about 900 days. During the dyeing process, 1.7 million tons of chemical are used some of them affecting our planet permanently like Pharmaceutical Fine Chemicals (PFCs) (Chung, 2016). In the production stage, social issues such as worker rights, poor working conditions, long hours, low wages, and child labor are still problems of concern. The majority of fashion products are manufactured in developing countries that do not apply binding rules and regulation towards these issues (Anika Kozlowski, 2012). The majority of all apparel and textile waste ends up in incineration or landfill opposed to either being reused or recycled (Allwood, 2006) (Madsen, 2007). Every stage of a garment’s life cycle relates to different sustainable challenges and the impact of the life cycle as a whole threatens our environment and its resources. (Business of Fashion, 2015).

Today research indicates the unsustainable nature of the fashion industry; however, until ten years ago the facts remained untold. In 2006 the report Well Dressed (Allwood, 2006) by researchers at Cambridge University analyzed the fashion industry in a holistic approach and indicated possible scenarios taken into account social, environmental, and economic consequences (Van Der Velden, 2016). Around the same time, the fashion industry started to take different initiatives to decrease the environmental impact and improve the social norms in the production chain. Many commercial brands publish annual reports on their sustainable strategy and progress such as Nike and H&M (Nike, 2015) (H&M, 2015). As for H&M, their annual Conscious Action Sustainability report covers a broad range of strategic activities. The company shows their serious ambitions to be on the forefront of the sustainable fashion movement by proudly showing off their achievements of the past years. The report however also indicates that H&M has not created radical positive change since the company is still thriving on high volumes and low prices, and is not showing signs of aiming for a different route in the future according to Guardian (Siegle, 2013).

Collectively brands, retailers, manufacturers, governments, NGOs, and academic institutions formed an alliance to improve sustainable production standards by measuring environmental and social impact through a standardized tool called the Higg Index. The Sustainable Apparel Coalition aims to address the urgent, systemic challenges that require joint and global collaboration (Sustainable Apparel Coalition, 2017). 175 companies are currently members of the SAC which account for more than 40% of the total global turnover of the apparel industry; however, the real positive impact the coalition has is still under discussion as members are not obligated to make their data publicly available. The Guardian reports that the Sustainable Apparel Coalition has yet to prove itself as some brands have been slow in collecting the required data and implementing the Higg Index tools confirming even more so that the industry has not yet made significant sustainable progress (Gunther, 2016).
Quantitative data can drive sustainable development

Rick Ridgeway, Patagonia executive, states that providing useful data to decision makers in the apparel value chain is going to result in better decisions (Gunther, 2016). Product designers and developers’ choices can affect more than 80% of the environmental impact created by a product according to Jason Kibbey, CEO at the Sustainable Apparel Coalition. Empowering industry professionals with credible data to make better choices in the early stages of the product development can benefit the people and communities where goods are made, consumers, and the environment as a whole (Sustainable Apparel Coalition, 2016). According to Natascha van der Velden, the author of the Ph.D. thesis Making Fashion Sustainable, The Role of the Designer fashion professionals are not able to find the right data to justify their decisions regarding production and material processes (Van Der Velden, 2016). The lack of data to make efficient, sustainable strategies to reduce the environmental impact and improve social conditions throughout the production chain is one of the major issues the fashion industry is facing.

The most commonly used method to generate quantitative data on the environmental impact of products and processes is LCA (Life Cycle Assessment). This evaluative tool analyses the environmental impact of a product or process throughout its lifespan to indicate which stage of the lifecycle is accountable for the most impact. LCA can also be used to compare two goods or services on an individual lifespan to show which has the least negative environmental impact (Rijksinstituut voor Volksgezondheid en Milieu, 2017). Scientists and the International Organization for Standardization agree upon the principles and framework for LCA (ISO, 2016). Although its use has been increasing over the past ten years, the fashion industry does not use LCA methodologies as a standard practice. The use of LCAs for textile products and processes is more commonly seen in academic literature than as an active reality in the industry by businesses (Anika Kozlowski, 2012). For the fashion industry to research the environmental impact of its products, several simplified commercial tools have been developed many based on LCA methodology or data. Some examples of these tools are: The Higg Index by the Sustainable Apparel Coalition, Making app by Nike, Environmental Benchmark for Fibers by Made-By, and the Ecotool by Modint (The Sustainable Apparel Coalition, 2007; NIKE UNVEILS NEW APP TO HELP DESIGNERS INVENT BETTER, 2013; Made-By, 2017; Modint, 2017). These tools play an important role in measuring the impact of apparel products. Critical research is yet to investigate the value and success of these simplified commercial tools. Even though recent developments and studies have focused on the integration of LCA methodology, the fashion industry is lacking a strong vision on how to measure the environmental impact of its products to make effective, sustainable strategies. Therefore the fashion industry is in need of advice on how to use LCA to create sustainable apparel products and supply chains.
The result of this research is an article to be published on an online news platform, such as Fashion United or Business of Fashion, focused on the entire fashion industry to reach a broad audience which may or may not be interested in sustainability. The article advises the fashion industry on how to use LCA to create more sustainable apparel products and supply chains and stresses the potential of integrating LCA. In this information taken into account are different stakeholders such as different sized companies. The aim of this product is that the fashion industry will use LCA methodology to make justified decisions about apparel products and realize sustainable supply chains.

1.2 AIM

Main question: What is the practical relevance of Life Cycle Assessment (LCA) methodology in the transition towards a sustainable fashion industry?

Sub-questions:
1. How is LCA methodology currently used to improve sustainability in the fashion industry?
2. What are the limitations and benefits of LCA methodology used in the fashion industry?
3. What is the potential positive and negative impact of implementing an LCA-based methodology in the fashion industry?
1.4 Methodology

The methodology used in this research is a multiple case study of six different LCA Methodological approaches and tools. The LCA methods selected are Full LCA studies commissioned by the scientific community, Full LCA studies commissioned by the fashion industry, Modint Ecotool, The Higg Index (SAC), MADE-BY benchmarking tools, and EIM software (Jeanologia). These LCA methods represent the different ways LCA is currently used within the fashion industry. In chapter 2.2 the selection process of the LCA methods is explained. The literature consists of scientific research on one of the selected LCA methods. Examples of this research are the Ph.D. thesis Making Fashion Sustainable, The Role of the Designer by Natascha van der Velden (2016) and the article THE MODINT ECOTOOL: A VERSATILE LCA TOOL FOR THE TEXTILE INDUSTRY” by Marijn M. Bijleveld and Geert C. Bergsma (2012). Used also is commercial information published at company websites or journals to promote one of the selected LCA methods. An example of such literature is the report Ten Ways the Higg Index Creates Business Value by the SAC (2015a). This information is critically assessed and never used solely to form conclusions. The leading primary research methods used are semi-structured interviews, focus group discussion, and a sustainable fashion conference visit. Fifteen semi-structured interviews were held with experts on one or more selected LCA methods as well as users of one or multiple selected LCA methods. The interviews are semi-structured to have an in-depth conversation with the respondent on a particular topic. A focused group discussion held with four design and management students from the Amsterdam Fashion Institute on the subject of integrating LCA in the fashion education system generated to verify findings from earlier research. The group discussion was held with students who are not aware of the potential of LCA which is why this focus group provided information on a perspective of a non-expert. Also, a visit to the fashion conference Kingpins Transformers gives insight into expert opinions on sustainable fashion. Kingpins Transformers is a sustainable conference hosted during Amsterdam Denim days on the 21st of April 2017. During the meeting, 12 professionals working on sustainable projects within the denim industry gave each a ten-minute presentation about their work and all later interacted in a group discussion. This group discussion provided valuable information as many experts on the subject interacted with each other and provided insight information not found in the literature.

1.5 Structure

Followed by the introduction chapter three chapters according to the sub-questions present the results of the research followed by a conclusion on how the goals are met. The second chapter identifies the different LCA methods. An analysis is given on how these methods are currently used within the fashion industry. In the third chapter, an analysis of the limitations and benefits of the identified LCA methods is given taking into account different stakeholders such as differently sized companies and individuals with various specializations. In the fourth chapter, the potential negative and positive impact of implementing LCA data and methods are analyzed. Here, the benefits and limitations are taken into account. Afterward, an answer will be provided regarding the main research question. The final chapter discusses the restriction of the research as well as the suggestions for future studies.
LCA is not integrated into the fashion industry as common practice despite recent developments. To enhance environmental impact research regarding textile products the scientific methodology to perform LCA research is improving which leads to the increase in available LCA data. The quality of the research will increase once more LCA data will become available. Due to the small increase in available LCA data and the improvement of the methodology consultancy companies have been able to develop commercial tools that simplify LCA methodology or data. Research needs to analyze how these recent developments have influenced the fashion industry.

To assess the practical relevance of LCA methodology in the transition towards a sustainable fashion industry, the theoretical importance of LCA needs to be discussed. The theoretical importance of LCA provides information about the function and process of LCA. How these methods are used is analyzed to understand the practical significance of LCA. Different ways the industry integrated LCA methodology, including the simplified commercial tools, are identified and analyzed. Based upon the identified methods a selection is chosen to specify the research scope. For each defined method an analysis is made regarding the stakeholders that use and create these methods followed by how each method has been used to improve sustainability challenges. This chapter is finalized with a conclusion regarding the first sub-question: how is LCA methodology currently used to improve sustainability in the fashion industry?

2.2 WHAT IS THE THEORETICAL RELEVANCE OF LCA METHODOLOGY?

Life cycle assessment (LCA) is a quantitative scientific tool that assesses the environmental impact of a particular product or process throughout its lifespan. LCA can be used to assess a single product or make comparisons between multiple products. The goal of LCA is to make informed product development decisions that lead to the production of the least burdensome product. The term ‘life cycle’ refers to a holistic assessment that includes raw material production, manufacturing, distribution, use, and disposal as well as all the intervening transportation steps. LCA studies comply with the ISO 14040 and 14044 standards.

The ISO standards give guidelines regarding the outline of an LCA study which includes four phases:

a) Goal and scope definition phase
   The scope includes the system boundary and level of detail of the study. The goal of an LCA depends on the subject and the intended use of the research. Therefore the depth and the breadth of an LCA study can differ depending on the goal.

b) Inventory analysis phase
   The life cycle inventory analysis phase (LCI phase) is a list of input/output data. It involves the collection of the data required to meet the goals of the research.

c) Impact assessment phase
   The life cycle impact assessment phase (LCIA) is meant to better understand the environmental significance of the LCI results by grouping and quantifying them into a limited number of impact categories.

d) Interpretation phase
   Life cycle interpretation is meant to summarize and discuss the results of an LCI or an LCIA to be used for recommendations and decision-making (ISO, 2016).
LCA studies can be used to identify opportunities for improvement of the environmental performance of products at different stages of the life cycle. Decision-makers of all kind are therefore given tools to set strategic priorities regarding product or process (re)design (Cotton Incorporated, 2017). LCA results can also be used for marketing purposes as implementing ecolabelling or making environmental claims.

The life cycle perspective of LCA methodology is suitable in avoiding problems shifting from one phase of the life cycle to another. Even though LCA models aim for a holistic assessment, it’s hard to include every applicable input. Results of LCA studies can vary enormously depending on where the LCA model outlines the beginning and end of the product’s life cycle. Also, the complexity of some factors is making quantification difficult. For example, to define parameters for measuring impacts on biodiversity, human health, and land use is challenging (California Climate and Agriculture Network (CalCAN), 2015). Transparency of the underlying assumptions, data sets, and boundaries is highly relevant to the credibility of LCA results. The quality of an LCA study requires a peer view before it can be published in a scientific journal. The peer review process calls for an independent expert to verify the results of the survey. Also, a sensitivity analysis can be held to test the robustness of the LCA results (Earth Shift Global, 2017).

2.3 What are the different LCA methods used in the fashion industry?

LCA is used by researchers or consultants who are trained to perform LCA studies. When full LCA studies are conducted in the context of the fashion industry, they are commissioned by either the scientific community or the fashion industry. Complete LCA studies commissioned by the fashion industry can be executed differently compared to LCA studies by independent researchers, and therefore differences in results can exist (Understanding Science, 2017) (Stuart, 2014). For the fashion industry to conduct research regarding the environmental impact of textile products without the help of LCA experts, several commercial tools have been developed that simplify LCA methodology or data (Van Der Velden, 2016). In practice, many different tools exist designed to guide sustainable development using LCA data or methodology to quantify environmental impact issues. The tools are developed by consultancies who offer a service that fulfills the needs of their customers. Therefore, tools differentiate regarding end user, sector focus, interface, calculation or information based, and the level of incorporation of the classical LCA approach. The identified tools currently used by the fashion industry are listed below. This list may not be complete but is meant to give a good indication of the tools most commonly used.

- Modint Ecotool (Modint, 2017a)
- Higg Index by the SAC (Sustainable Apparel Coalition, 2016h)
- MADE-BY Benchmarks (Made-By, 2017a)
- The Nike Making App (NIKE UNVEILS NEW APP TO HELP DESIGNERS INVENT BETTER, 2013)
- EIM software by Jeanologia (Jeanologia, 2017)
- Environmental Textile Calculator by Brown & Wilmanns Environmental LLC (Brown & Wilmanns Environmental LLC, 2017)
- Instant LCA Textile by RDC Environment (rdc environment, 2017)
- EcoMetrics by Colour Connections (Colour Connections, 2017)
The following LCA methods are selected to be analyzed in this study:

- Full LCA studies commissioned by the scientific community
- Full LCA studies commissioned by the fashion industry
- Modint Ecotool
- The Higg Index (SAC)
- MADE-BY benchmarking tools
- EIM software (Jeanologia)

In the fashion industry, two different approaches towards the usage of LCA exist: one being full LCA studies and second being simplified commercial LCA tools. Complete LCA studies in the context of the apparel industry are either commissioned by the scientific community or by the industry, which is why they are analyzed separately in this research. Many commercial tools exist that simplify LCA for the industry to perform research without the help of an LCA expert. For this study, four tools are selected that differ regarding end user, sector focus, interface, calculation, or information based, and the level of incorporation of the classical LCA approach to providing a holistic analysis. The Modint Ecotool was chosen because it’s a commercial tool that functions most similar to a full LCA study. On the other hand, the Higg Index supported by the SAC network shows potential for uptake by the industry. Its aim to target the whole fashion industry with a global collaborative approach shows possible potential. The MADE-BY benchmarking tools are the only tools completely available to the public which makes that these simplified tools have a high potential reach within the industry. The benchmarking tools also translate LCA data which makes their approach different from the calculation based tools. Because the EIM software is specially developed for the textile finishing industry, this tool is very specialized. The EIM tool was chosen because of its development was indicated in close relation to the industry. In combination, the six selected methods will provide a holistic perspective on how LCA is used currently in the fashion industry. In figure 1 the usage of different LCA methods is visualized.

Figure 1. Visualization research scope
2.4 HOW ARE THE IDENTIFIED METHODS CURRENTLY USED WITHIN THE CONTEXT OF THE FASHION INDUSTRY?

**Full LCA studies commissioned by the scientific community**

Independent researchers can perform full LCA studies as well as develop new methodological approaches to perform full LCA studies on textile products. They are guided by research institutes such as universities. Organizations supporting environmental research, such as the Swedish Foundation for Strategic Environmental Research (Mistra), play a significant role in the development of LCA studies (N. van der Velden, personal communication, February 17, 2017). LCA data is used fundamentally in new research by academia or by consultants to create simplified tools (Vogtländer, 2013). Overall, the quality and the extent of LCA research is increasing resulting in more data on which environmental strategies can be based (Schatsky, 2011). Scientific LCA data is rarely used directly by the fashion industry without the help of a consultant. This data generated through scientific research is precious as it supports the development of further research and development.

Academic literature on textile LCA studies consists mostly of case studies on products or processes as well as research regarding improvements for LCA methodology specifically for textiles. The Ph.D. thesis Making Fashion Sustainable, The Role of Designers by Natascha van der Velden (2016) is an important recent source that includes a series of articles on textiles and LCA. Another important source of LCA studies in the context of fashion is the Handbook of Life Cycle Assessments (LCA) for Textiles which consists of appropriate methodological approaches as well as case study examples (Muthu, 2015). These sources provide valuable data to researchers and consultants.
Most of the time LCA research on textile products is executed by consultancy companies or independent research institutes because most fashion companies do not have internal LCA experts. These external LCA experts interpret the related ISO standards in their way to supply the industry with the right data to achieve a specific goal. The fashion industry communicates these results in reports, and through marketing activities, they reach the public (Vogtländer, 2013). Fashion companies can hire LCA experts to perform a full LCA with a specific goal in mind such as to prove the relevance of new technology. The LCA experts can either work for a consultancy firm or operate independently (T. Spathas, personal communication, February 14, 2017).

In very rare cases companies may choose to recruit LCA experts. Michael Brown, an environmental consultant who collaborated with Nike on the development of MSI (Material Sustainability Index), states that Nike hired experts to be part of the company to develop the MSI further and perform internal LCA research (M. Brown, personal communication, April 5, 2017).

Brands have used full LCA studies on core products to determine sustainable product strategies. For example, Levi Strauss & Co. conducted an LCA on the entire life cycle of three LS&Co. products: a pair of Levi’s® 501® jeans, a pair of Levi’s® Women’s Jeans, and a pair of Dockers® Signature Khakis. Through the research LS&Co. determined the main impact stages in the product lifecycle, which guided their sustainable strategy. The LCA resulted into programs that reduced the water, energy, and chemical use in their production stage as well as programs that focused on reducing the impact generated in the product use stage by educating the consumer about product care. In the case of LS&Co. the LCA was performed to create awareness regarding the impact of different categories taking into account the whole life cycle (Vishvajith, 2017).

In some cases, full LCA studies are commissioned by organizations other than brands to support research beneficial towards the industry as a whole. The non-profit consultancy Circular economy commissioned three case studies regarding the sustainability of recycled materials in collaboration with master student Theodoros Spathas (Chalmers University of Technology). Together with three industry partners G-star Raw, ReBlend, and ReShare cases of recycling presented with LCA results stress the potential for high-value recycling of various materials. In the case of Circular Economy, the LCA served to confirm the sustainable potential of a technical process (Circular Economy, 2017). This result can support the uptake of high-value recycling techniques which is beneficial for the industry as a whole as well as Circular Economy as an organization.
The Modint Ecotool was developed in collaboration between CE Delft (construction, data supply), NL Agency (funds), Modint (sector organization, owner), Alcon consultancy (data supply) and eight manufacturers in the textile industry (data supply, user feedback). The first version was launched in 2011 in the Netherlands (Bijleveld, 2012). Modint currently owns the tools, and in collaboration with CE Delft continuously improves it.

The Modint Ecotool is an Excel-based tool that simplifies the processes of conducting an LCA. The tool is developed in a way that it is a complete assessment that is based on scientific and/or in-depth data (M. Bijleveld, personal communication, March 6, 2017). This tool takes into account the complete life cycle of a product which can be customized by the user by the inclusion of personal data. The tool also offers the possibility to work with standard textiles in case fashion brands are not able to access data regarding the fabric production stage. Processes such as recycling and industrial dry cleaning are also included in the tool (Modint, 2017a). Results are shown for the following impact categories; greenhouse gas emissions, primary energy demand, water requirements, land use and use of chemicals.

The tool is mostly suitable for performing quick-scan comparative LCA which allows the user to compare LCA results in a short amount of time. The tool, however, can, in theory, be used to calculate a carbon footprint according to PAS 2050 by including personal in-depth inventory data. (Bijleveld, 2012). The Ecotool was initially designed for textile manufacturing companies. Recent updates include the option to select predefined fabrics since fashion brands usually do not have data regarding the material production process.

The Modint Ecotool is currently used by Modint members who are mostly located in the Netherlands. Members include both apparel manufacturers and brands such as TenCate who are paying Modint to have access to the tool (M. Bijleveld, personal communication, March 6, 2017). Educational institution Saxion in the Netherlands incorporated the Modint Ecotool into its study program for the Bachelor Fashion & Textile Technologies. Students are introduced with the possibility of using tools to calculate the environmental impact of products and are asked to make justified product development decisions taking into account environmental aspects (G. Bouwhuis, personal communication, April 11, 2017).

The Modint Ecotool educates users about environmental impact research which is necessary for putting results into perspective. For example, because the results are shown in GHG emissions users need to understand what the negative consequences of GHG emissions are in a global context. Educating industry professionals about environmental problems will help sustainable practices to increase. Because the Modint Ecotool requires the user to gather detailed supply chain data it increases transparency of the total supply chain. TenCate, one of the users of the Ecotool, is focusing increasingly on making the CSR policy more measurable and visible. In 2012 the product Ecotool was used to calculate the CO2 footprint of four product categories (Royal Ten Cate, 2011b). In 2015 energy efficiency targets have been set to 2% a year in the Netherlands (Royal Ten Cate, 2015a).
In 2009 Walmart and Patagonia came together with the idea to create a collaboration platform that would transform the industry. The SAC (Sustainable Apparel Coalition) is an alliance between different members of the fashion industry to enable sustainable production. In 2016 the SAC consisted of 175 members who account for more than 40% of the total turnover of the global fashion industry.

The SAC believes that sustainable development requires a global united approach which is why they created a tool that guides sustainable development and is suitable for the whole industry.

In 2011 the first version of the Higg Index was launched to empower brands, retailers, and facilities of all sizes. The Higg Index consists of multiple self-assessment tools designed for different end users, such as fashion brands, designers, and factories. The SAC developed a methodology for verifying self-assessment scores of facilities through SAC approved verifiers. The tools are easy-to-access online and can be used for internal communication and strategy development, but also scores are anonymized and translated into a benchmark that compares industry results (Sustainable Apparel Coalition, 2017). The benchmark results are not available to the public and can be used only for internal development.

Included in the Higg Index are the brand, facility, and products modules. The brand and facility tools both focus on social and environmental sustainability. Contained in the environmental module is the importance of environmental management systems (EMS) to generate data on water, energy, and chemical usages (Sustainable Apparel Coalition, 2017). The product modules consist of three different Higg Product Tools: the MSI Contributor, the Higg MSI (Material Sustainability Index) and the Higg DDM (Design & Development Module) (Sustainable Apparel Coalition, 2017). The DDM focuses on analyzing products with a life cycle approach, and the MSI incorporates LCA data on materials.

All SAC members commit to using, revising, and improving the Higg Index together. The different tools are developed by SAC’s members, stakeholders, and experts (Sustainable Apparel Coalition, 2017). An Excel version of the brand and facility tool and an online copy of the MSI is available to the public however the complete versions of all tools are only available for SAC members.

The current members of the SAC are mostly large industry stakeholders such as PVH and Lenzing (Sustainable Apparel Coalition, 2017). However, in 2016, a pilot project was initiated in collaboration with the IDH (the Sustainable Trade Initiative) to engage European small and medium-sized enterprises (SME) to work with the Higg Index (Sustainable Apparel Coalition, 2017). MUD Jeans is one of the participants of this pilot project and states that the Higg Index has opened their eyes to new areas of development. Because their supply chain is relatively small and their previous experience with gathering data implementing the Higg Index was not a struggle according to co-owner Dion Vijgeboom (D. Vijgeboom, personal communication, April 11, 2017). In many other cases, full implementation of the Higg Index requires extensive time and expertise that most small businesses do not have (Stuart, 2014). The module structure of the Higg Index assumes that product, brand, and supplier facility already exist meaning that start-up companies cannot implement the Higg Index at all.

Until now about 6000 suppliers have provided data on their performance. The report The Ways the Higg Index Creates Business Value by the SAC (2015) shows that most members are focused on increased efficiency. Colleen View of Timberland states that the due to the “one-stop-shop” approach for tools, expertise, and other resources the company was able to eliminate 46,000 US dollars in costs. In the case of ANN INC. the Higg Facility module helped to find over 200,000 US dollars in potential energy savings at one of its leading suppliers and therefore also strengthened the position and the relationship with the vendor (Sustainable Apparel Coalition, 2015). The Guardian reports that most members have been slow to implement the Higg Index and that there is no evidence that the members are reducing their impact.

Until data regarding the progress of the SAC members becomes public, its value will be limited. Linda Greer, a senior scientist at the Natural Resources Defense Council, states in the article by the Guardian that too many companies are not implementing all the Higg tools and are very slow to collect the required data (Gunther, 2016).

One of the companies who recently implemented the Higg facility module is PVH owner of large fashion brands such as Tommy Hilfiger and Calvin Klein. Georgiana Ungureanu who works on implementing the Higg facility tool for PVH states that she hopes that applying the Higg facility tool will further develop the sustainability level throughout the full supply chain. Because many suppliers are already familiar with the Higg Index implementing the facility tool over their entire supply chain as not caused large problems so far (G. Ungureanu, personal communication, April 11, 2017).
The originally Dutch non-profit consultancy organization MADE-BY who also currently holds offices in the United Kingdom and Germany developed two publicly available benchmarking tools: the Environmental Benchmark for Fibers and the Wet Processing Benchmark. MADE-BY has worked with more than 100 apparel brands and retailers to guide their sustainable progress and discovered the need for a simple tool that translates LCA data on two high impactful stages: fiber production and finishing (Schijvens Corporate Fashion, 2017).

The Environmental Benchmark for Fibers was first launched in 2009 to classify on the impact of commonly used fibers in the apparel industry. The tool was designed to create awareness and guide sustainable material strategies. More than 150 references including LCAs, material safety data sheets, and additional literature were used to create the tool. Expert judgments have been used when necessary in addition to the literature data.

The scope of the tool includes the production process of natural fibers and man-made fibers from the origin of the raw material to fibers ready to be spun. The tool does not contain the stages of fabric production, use phase, end of life, nor material performance, durability, and quality. The exclusion of these steps is due to the lack of publically available data, a significant amount of different textile processing techniques as well as the considerable variability and dependencies. The unit of comparison is 1kg of fiber ready to be spun.

The environmental performance of the selected fibers is assessed on six parameters: greenhouse gas (GHG) emissions, human toxicity, ecotoxicity, energy, water, and land use. MADE-BY has decided to define the weight per parameter. The first three parameters are weighted all 20%, and the last three are weighted all 13.3%. The overall weighted score per fiber is assigned to the 5 classes within the benchmark: Class A – Class E. The best scoring fibers are located in class A, and the worst scoring fibers in class D. Class E is the category of ‘Unclassified’ fibers; for those which have not yet been included in the tool because of the lack of available credible data (MADE-BY, 2013b).

For the Wet Processing Benchmark, no LCA data but data from factories around the world analyzing the efficiency regarding water use, energy consumption, and potential chemical or safety hazards of standard wet processing techniques was used. This tool aims to help the industry understand efficiency industry averages and compare personal performance. The tool has four sections focusing on: dying, finishing, printing, and pre-treatment. The data used is based on water and energy consumption measurements from actual factories. This benchmark focuses on water and energy use, with selected chemical hazard information. Parameters such as effluent impact, fastness/other quality implications, cost, lead time, order size, etc. are not included in the scope (MADE-BY, 2014c).

MADE-BY developed the environmental benchmark for fibers in collaboration with environmental research company Brown & Wilmanns Environmental LLC. The Wet processing benchmark was developed in cooperation with Sustainable Solutions. In both cases, the consultancy partners were responsible for the data supply, and MADE-BY for the design requirements of the industry (MADE-BY, 2013b) (MADE-BY, 2014c).

Because the tools are publicly available, the tools are not limited towards specific industry members. However, the members of MADE-BY are more aware of the existence of the tool. Because the tools are publicly available, they have been widely used throughout the industry by companies such as G-Star RAW and H&M (H. Fell, personal communication, March 14, 2017).

The benchmarking tools can give fashion professionals more insight into the sustainability of different fibers and wet processing techniques. For fashion brands who do not have a sustainable strategy in place, the tools can serve to create awareness about sustainable materials and wet processes. Once a fashion brand has developed a sustainable approach the tools can help to set strategic goals. For Schijvens Corporate Fashion, the Environmental Benchmark for Fibers has helped them to establish strategic materials goals which include their goal to sustainably source materials as 75% of their total material usage by 2020 (Schijvens Corporate Fashion, 2017).
Jeanologia, a Spanish producer of sustainable finishing machines and sustainable consultant, created a tool to measure the environmental impact of the textile finishing process in 2012 (B. García, personal communication, March 20, 2017).

The EIM software is an easy to use tool that through benchmarking scores the environmental impact of the finishing process on four categories: water consumption, energy consumption, a chemical product used, and worker health (Figure 6). Each category has a benchmark of green (low impact), orange (medium impact), and red (high impact). EIM take into consideration the hazards level to the environment of the chemicals used. This way more harmful chemical no matter the quantity of the product leads to a worse result. Most measurement tools only look at the total amount of chemicals used; however, Jeanologia punishes the use of more pollutant chemicals (Jeanologia, 2017).

The tool is not based on LCA data but requires personalized data on the finishing process to assess this information in the benchmarking scores. Jeanologia developed the EIM software specifically for the textile finishing industry. The benchmarking system was developed in-house through the brought experience of the company. The software can be purchased from Jeanologia by all interested companies. The software can be used by laundry facilities and the results of the EIM can be shared with their customers (fashion brands). Jeanologia improves the software by constant feedback from its customers (B. García, personal communication, March 20, 2017).

The results of the EIM software can be used to develop more conscious fashion items which can be communicated to the end consumer which gives the product an extra benefit. Fashion designers and buyers normally do not have technical knowledge regarding the finishing process. The EIM tool can create awareness amongst designers and buyers about technically sustainable laundry processes and allows them to discuss the results of the EIM scores.

The EIM tool can, therefore, increase the interaction between brands and laundry facilities.

In general, laundries do not always understand the value of the EIM software because it takes time to changes the way of working which has been dominant for decades. The EIM software is slowly changing the dominant unsustainable way of working common in the textile finishing industry. At the 2017 Kingpins Transformers Conference in Amsterdam, Enrique Silla, CEO at Jeanologia, argued that 25% of all the jeans currently produced are measured by the EIM software (Enrique Silla, Kingpins Transformers conference, 21-4-2017).

For Jeanologia the EIM software has guided the development of sustainable laundry techniques and has helped to promote sustainable solutions. Brands have taken an interest in the tool and are pushing their suppliers to improve their environmental impact using the EIM tool (B. García, personal communication, March 20, 2017). The EIM has been used to measure the impact of the H&M denim collection. Jeanologia supported the creation of Conscious Denim standards for creating the conscious denim collection (Textiles Update, 2014). In the case of Kings of Indigo, a small Amsterdam-based denim brand, the EIM software was not operating successfully in the laundry facility they work with. Maria Gunnarsson, product developer at Kings of Indigo, states that because of technical difficulties the facility was no able to implement the EIM successfully, and therefore Kings of Indigo stopped its personal internal use of the tool (M. Gunnarsson, personal communication, March 9, 2017).
LCA is used within the fashion industry in many different forms. Because LCA is a scientific tool the scientific community plays a significant role in both the development and the usage. Many consultancies have developed commercial tools based on scientific LCA methodology or data for their members. For example, the Modint Ecotool is used by Modint members who are mostly Dutch apparel and home textile companies. In the case of the Higg Index, the SAC members are mostly large apparel and footwear brands and manufacturers. On the other hand, Jeanologia sells the EIM software to its clients who are brands and manufacturers specialized in denim. Because the MADE-BY benchmarking tools are publicly available, these tools are also used by non-MADE-BY members such as fashion institutes. Within the fashion industry, many different stakeholders including fashion brands, facilities, and designers use these simplified LCA tools directly and are guided by consultants who translate research into practice. Each selected LCA method is used by different stakeholders as they are developed for specific customers (Figure 2).

<table>
<thead>
<tr>
<th>Users of LCA methods</th>
<th>Designer/Product Developer</th>
<th>Buyer</th>
<th>Marketing manager</th>
<th>CSR manager</th>
<th>Manufacturer</th>
<th>Student</th>
<th>Researcher</th>
<th>Consultant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full LCA studies commissioned by the scientific community</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Full LCA studies commissioned by the fashion industry</td>
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<tr>
<td>Modint Ecotool</td>
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<tr>
<td>Higg Index (SAC)</td>
<td></td>
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<td>x</td>
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<tr>
<td>Benchmark for fibers and wet processing (MADE-BY)</td>
<td></td>
<td></td>
<td>x</td>
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<tr>
<td>EIM (Jeanologia)</td>
<td>x</td>
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<td>x</td>
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</tbody>
</table>

Figure 2. Users of LCA methods

The positive, sustainable impact these tools have initiated so far shows great potential. On the supply side of the industry, the usage of LCA methods by the early adapters has increased, awareness, transparency, efficiency, knowledge, and innovation. Overall LCA methods are currently creating awareness within the fashion industry regarding environmental problems related to high impactful processes and materials. The usage of LCA tools has created more insight into the full supply chain of fashion companies and supported transparency. Better resource management and conscious development decisions have increased the efficiency of suppliers and brands. At the same time, increasing communication within the supply chain has led to the overall improvement of technical knowledge regarding production processes and materials. The development of sustainable innovation has been supported by the quantitative data that proves their viability.

On the demand side of the industry, LCA has stimulated sustainable consumption behavior. The results of full LCA studies and the EIM software are used to be communicated to the consumer through marketing initiatives. By sharing LCA results, sustainable consumption can be stimulated which increases the impact of these methods. The Higg Index, MADE-BY benchmarking tools, and Modint Ecotool are currently focusing on internal sustainable product and supply chain development giving industry professionals the tools to improve their sustainable business practices.
Because each LCA method is designed and used differently, the total impact created by each tool also differs (Figure 3). All tools are used globally except for the Modint Ecotool, which is used mainly in the Netherlands. The global reach indicates the potential total impact each tool has in the industry. The members of the SAC account for more 40% of the entire industry which makes that the Higg Index has an extensive reach to improve sustainability challenges.

Furthermore, LCA methods have different levels of complexity. Each method is designed with a particular user in mind which determines the level of complexity the tool should include. More complex studies which are unique to a product or situation may be more impactful. For example, full LCA studies are conducted by experts who can perform more detailed research which gives more quality insight into a product or situation. The commercial LCA tools are all aiming for simplicity and user friendliness while at the same time producing high-quality results. The Modint Ecotool requires the user to fill in detailed product data. This is feasible for Modint members because most of them are textile manufacturers but may not be for fashion brands who do not have detailed information on their supply chain. For tools such as the benchmarks by MADE-BY fashion, companies do not have to fill in the information themselves which makes this tool very user-friendly. However, the results presented within the benchmark are generalized and not specific to a company or situation. Therefore, the impact of LCA methods is strongly dependent on the details of the user, the global reach, and the goal in mind.

Figure 3. LCA tools matrix
There are many different ways LCA methodology is currently used within the fashion industry. Each identified approach towards LCA methodology is designed to support sustainable decision making for various end users. For all the different approaches towards LCA exist, therefore, different limitations and benefits to the users.

To assess the practical relevance of LCA methodology in the transition towards a sustainable fashion industry an analysis of the limitations and benefits of the identified LCA methods used in the fashion industry is made. Through the identification of the limitations experienced by the user of the methods, an assessment can be made regarding why the impact and uptake of the methods are currently limited. The benefits to the users of the different methods identified will provide information that can be used to increase the uptake of LCA by the industry. In conclusion together the limitations and benefits experienced by the users show the relevance of the LCA methods for future sustainable development and indicate information that can promote their uptake. In this chapter the following question is answered: What are the limitations and benefits of LCA methodology used in the fashion industry?

3.2 Benefits

LCA research provides the user with many benefits as indicating improvement areas, increasing efficiency, and comparing industry performance. These benefits provide insights to promote their uptake and strengthen the business case of integrating LCA.

Indicating improvement areas

Companies can become more aware of supply chain challenges because an LCA analysis requires the user to collect extensive supply chain data. More data on the supply chain enables businesses to use this information for indicating which process steps need improvement. The interaction between supply chain partners will also increase the quality of the data and strengthen relationships. LCA research helps quantify and understand which areas in a product lifecycle require improvement. Once a company has identified impact hotspots actions can be taken to make enhancements. You can’t manage what you don’t measure is a management adage which describes this perfectly.

LCA studies allow for informed product development decisions in materials, design, and processes. A full LCA study enables a company to identify the phases with the greatest impacts accurately. These quantitative data can be used for sustainable product strategies and supply chain development. Users of the Modint Ecotool can make quick scan comparisons between products and are therefore able to design products with the least amount of impact. [M. Bijleveld, personal communication, March 6, 2017]. The MADE-BY benchmarking tools do not allow the user to calculate the impact of a particular product, but give insight into LCA results of different fibers and wet processing which allows companies to develop a sustainable material strategy without researching the impact themselves. Improvement areas will be indicated when a company analyzes its fiber and finishing techniques used and compares it to the benchmarks. The brand and facility modules in the Higg Index focus on pointing business development opportunities. For example, in the case of MUD Jeans, the companies used the Higg Index to find out that their internal social policies require improvement [D. Vijgeboom, personal communication, April 11, 2017].
Increased efficiency

LCA research can increase efficiency and improve resource management. Improvements regarding increased efficiency can reduce current production costs. Identifications of resource, energy, and water savings can be made with LCA research which leads to optimization of the company and reduces costs (Sustainable Apparel Coalition, 2015a). Maaike van Middendorp who works as a buying intern for the Dutch Ministry of Defense states that by working with the Modint Ecotool, she has become aware of the large impact generated by transportation. When buying decisions are based on the geographical location, transportation impacts can be minimized, and costs can be reduced (M. van Middendorp, personal communication, April 18, 2017). When an LCA study is performed with a simplified tool, the user can save resources compared to the usage of external LCA experts or sophisticated supply chain measurement instruments. Using simplified LCA tools can also eliminate the costs of a strategic consultant which is indicated to be between $25,000 - $50,000 (Sustainable Apparel Coalition, 2015a). The Higg Index can eliminate the need for such advanced product and supply chain analysis tools which can cost up to hundreds of thousands of dollar annually to develop and maintain by providing a one stop simplified tool (Sustainable Apparel Coalition, 2015a). However, once companies have already implemented such systems, it is not likely that they will be replaced entirely. In the case of PVH, the Higg Index operates next to the internal system (G. Ungureanu, personal communication, March 22, 2017). Using multiple systems is more resource intensive. However, the overall quality of the results will be higher due to the extra information streams.

Comparing industry performances

Communication of LCA results can increase awareness about sustainability at both the industry and the consumer. Some LCA methods allow the user to share the results with the end consumer or other companies. The communication towards the industry and consumers can strengthen the position of the company and supports industry development by the supply of relevant data (Vishvajith, 2017). The end consumer is empowered to make better purchasing decisions when more quality data is made available to them. Communicating about LCA will portray a positive image to the outside world and can stimulate sales. By being able to compare and benchmark industry results the user is offered insight into new business development opportunities and motivation. The MADE-BY benchmarking tools are available for free to the general public. This permits the industry as a whole to use it and to communicate about it with every partner or consumer. For the Higg Index, the opportunity to benchmark scores of manufacturers enables more sustainable sourcing and is awarding sustainable production for those who can work with the tool. Fashion brands can compare their results unanimously to the rest of the industry which will motive companies to achieve better results and level their performance (Sustainable Apparel Coalition, 2015a). Full LCA results can be shared both with the industry and the end consumer to support industry-wide sustainable business practices and consumption.
3.3 LIMITATIONS

The LCA currently methods used in the fashion industry have many limitations such as the lack of accuracy and the high resource intensiveness which are strongly interconnected. By understanding the limitations of LCA tools, the users can make well-informed decisions about the integration of LCA for individual businesses or processes.

Lack of accuracy

For users of all LCA methods, the lack of robust results limits the value of the research and its direct impact as decisions can be made that are not generating the demanded results. The accuracy of the results is dependent on the quality of the data input for the study. For scientists, there are many limitations to working with high-quality data. For example, there is no open life cycle inventory (LCI) databases to build future scientific research on. Checking the underlying datasets is difficult because researchers create their own dataset by combining information from different and sometimes very old or confidential sources. Recent developments such as improvements in energy consumption make old LCA data not valuable for contemporary research (Vogtländer, 2013). At the 2017 Kingpins Transformers Conference in Amsterdam, Brent Crossland, head of Fiber Development for Seeds at Bayer CropScience, argued that data on the water usage of cotton is outdated. According to the data of Bayer, some of the cotton now has a water efficiency of 98% (Brent Crossland, Kingpins Transformers conference, 21-4-2017). Another factor limiting the input of quality data for future research is the low-level transparency in the fashion supply chain. A strong sense of competitiveness and confidentiality specific to the fashion industry are making the supply chain less transparent (Frischknecht, 2004). For example in the textile laundry industry companies are hesitant to share information about their recipes used which is limiting the availability of the data (B. García, personal communication, March 20, 2017). On the other hand, the complexity of the fashion supply chain due to the remarkable geographical diversity and the number of processes steps is a problem in collecting the required quality data.

Full LCA studies provide more accurate results than research conducted using simplified LCA tools. However, the accuracy of the results derived from both studies done by simplified LCA tools and full LCAs is questionable. Gerrit Bouwhuis who is a researcher and teacher at Saxion University of Applied Sciences explains that the results of LCA research may vary by a factor of ten depending on the selected method (G. Bouwhuis, personal communication, April 11, 2017). In the case of the research project Circle Textiles by Circular Economy and ReBlend, the results also differed from previous data. Anita de Wit co-founder of ReBlend states that the yarn producer Recover performed previous LCA research which indicated a water saving of 90% for the particular yarn used. In the study conducted by Circular Economy, the results show potential water saving of 62% (A. de Wit, personal communication, April 18, 2017). Even though in both cases the results prove a significant amount of potential water saving
Conducting LCA research through any method requires resource investments which can be a limitation to the user. Performing LCA research is resource intensive due to the complexity of the process and the required accuracy of the results. Independent researchers aim to produce very high-quality studies that can be published in scientific journals. To do so, the research needs to be checked during an intensive peer review. This intensive peer review process makes scientific LCA studies extra time and resource intensive (N. van der Velden, personal communication, February 17, 2017). For companies to perform a full LCA, a fashion company needs to hire an LCA expert. The SAC indicates that hiring an LCA expert to carry out a single LCA studies costs between 10,000 and 40,000 US dollars (Sustainable Apparel Coalition, 2015a). Companies such as large apparel brands and manufacturers can make such investments however smaller companies with a limited budget are therefore not able to perform full LCA studies without the help of external investors. The characteristics of the fashion industry are also making LCA research more resource intensive. Fashion products, in general, have a short lifespan. Therefore, the investment of a full LCA study is only profitable on a core product that is developed in high quantities and sold for a long time. Fashion professionals need to be trained to perform LCA research using commercial tools correctly. This training again also requires time investment in addition to the purchasing costs of the device. In the case of the Dutch Ministry of Defense, they recruited Maaike van Middendorp a third-year Bachelor Fashion and Textile Technologies student to work out how to use the Modint Ecotool. She states that learning to work with the tool requires time which most companies do not have as the general employees are occupied with their daily tasks (M. van Middendorp, personal communication, April 18, 2017). The resource intensiveness of implementing and executing LCA research is limiting the uptake by the fashion industry. However, a collaboration between stakeholders

3.4 CONCLUSION

The available LCA tools are designed for different industry stakeholders that enable the fashion industry to use LCA in various forms. It is important for the fashion industry to understand the benefits and limitations of each tool to select the most appropriate way of incorporating LCA into their practices. LCA is a quantitative tool that can be used to guide sustainable product and supply chain strategies. Because environmental issues are quantified sustainable product strategies can be created, and progress can be measured. Through LCA awareness regarding sustainable issues can be created, transparency of supply chains can be improved, and efficiency can be enhanced. When it comes to performing an LCA on an apparel product are the complexity, and the not transparent nature of the supply chain are key factors. Due to these issues, LCA studies are time and resource intensive and are not always robust which are the main limitations to its users. For LCA to have a high practical relevance in the transition towards a sustainable fashion industry the limitations need to be overcome and the benefits need to recognize.
Recent developments of simplified commercial tools are showing strong potential in integrating LCA methods to support sustainable development. The many benefits and limitations related to each LCA method are important factors which should be considered when investing in LCA research. The potential impact of integrating LCA in the fashion industry indicates the opportunity for investment.

To assess the practical relevance of LCA methodology in the transition towards a sustainable fashion industry, an analysis of the potential positive and negative impact of integrating LCA methods entirely in the fashion industry as a whole is made. As LCA is currently not well integrated into the fashion industry, there is limited evidence on how the identified methods have been used to improve sustainability challenges. Therefore it is important to analyze the potential positive and negative impact of implementing these methods as a common practice taking into account future developments and requirements. This chapter is finalized with a conclusion regarding the first sub-question: What is the potential positive and negative impact of implementing an LCA-based methodology in the fashion industry?

### 4.2 Potential positive impact

Implementing LCA methods as standard practice within the fashion industry has the potential of increasing valuable data, supporting innovation and circularity, and increasing awareness and knowledge regarding environmental issues throughout the industry.

#### Growing relevant data

Integrating LCA throughout the entire fashion industry can increase available high-quality data. Today data is extremely valuable since many companies let big data drive their primary business decision and focus on collecting and storing it. LCA data can be used for sustainable business decisions making. Therefore the collection of LCA data holds opportunities for future economic and sustainable development. Once more high-quality data is accessible LCA research will become of higher quality and will be less resource intensive which will conclude in more justifiable decisions regarding sustainable products and supply chains.

The high-quality data developed through LCA studies commissioned by the scientific community offer opportunities for future development. Governmental organizations supporting and funding scientific research have the possibility of increase the volume of studies and connect science and industry. Natascha van der Velden explains that because the Netherlands has not a large textile manufacturing sector, scientific research in the Netherlands is rarely focused on fashion. In other countries, organizations exist to connect scientific research and the industry to strengthen its position. For example, in Sweden, the Mistra Foundation supports scientific research to enhance the position of large fashion brands and their cellulosic fiber production industry (N. van der Velden, personal communication, February 17, 2017). Organizations supporting and funding scientific research can increase the amount of valuable data. Fashion companies requesting external experts to perform LCA research also hold opportunities to improve accessible data. The collaboration between science and the industry is essential in creating research of high practical relevance. The ISO standards give companies the freedom to choose products that are worth investing resources to conduct a full LCA (Vishvajith, 2017). Products of high volume such as Levi’s 501 are essential products when it comes to reducing the total environmental impact of LS&Lo. The company’s expertise can guide the research into the most optimal way to produce sustainable strategies (Vishvajith, 2017). Michael S. Brown explains that the collaboration with Nike on the MSI has been excellent because the company has a lot of experience within the industry and at the same time the resources to work on such projects (M. Brown, personal communication, April 5, 2017). The collaboration between environmental experts, governments, and the industry is critical in creating relevant and high-quality data on which future development are reliant.
Supporting innovation and circularity

Once LCA research becomes common practice in the fashion industry, innovations that support sustainable progress will be developed and supported. Technical improvements or development of products replacing or altering existing unsustainable ones are important in transforming the industry. LCA research can support sustainable innovations such as 3D printing and alternative cellulosic fibers. Both Theodoros Spathas and Natascha van der Velden indicate that LCA studies can be beneficial with the development of new technologies and materials (T. Spathas, personal communication, February 14, 2017; N. van der Velden, personal communication, February 17, 2017). Early in the development process, it can become apparent if there is real sustainable potential. In the Ph.D. thesis by Natascha van der Velden an article is included on the possibilities of 3D-printing as a viable alternative for contemporary clothing production. The LCA results show that this technology is very promising; however, the study also indicates the limitation such as the relatively long manufacturing process and the implementation of the right business model (Van Der Velden, 2016). Similar scientific research has a very high potential for the development and uptake of sustainable technologies. In the MADE-BY benchmarking tools the inclusions of sustainable alternative fibers such as Monocel® supports the development of innovative fibers. Awareness about new alternative fibers will grow by the inclusion into the tool even though the availability of such fibers remains limited. For Jeanologia the implementation of EIM will lead the development of sustainable alternative finishing processes. Implementing the EIM software will help the company in both the development and the sales of these techniques due to the underlying quantified data that is used to make environmental statements (B. Garcia, personal communication, March 20, 2017).

LCA research can also support circularity. Circularity plays a significant role in the sustainable transformation of the fashion industry as this approach provides a real answer to better resource and waste management. Currently, some tools use a cradle to gate approach which means the end of life and use phase of a garment is not taken into account mainly due to the level of complexity and limited quality data (M. Brown, personal communication, April 5, 2017). However, once the end of life is taking into account recycling, and reuse effects will be considered when researching a product. The possibilities and opportunities of circularity will be verified with quantitative data which will enhance their uptake. For example, included into the Modint Ecotool are the process steps of the use and end of life phase by the inclusion of recycling and professional dry cleaning methods. The Modint Ecotool will, therefore, give a more realistic analysis compared to tools that only use a cradle to gate approach while at the same time promote recycling or reuse opportunities. The Circle Textile project by Circular Economy used LCA as a tool to illustrate the potential of high-value recycling. In this project quantitative data is used to form statements in favor of high-value recycling processes while at the same time the case studies provide a realistic example of how the fashion industry can become more circular. Circularity can be enhanced when all LCA tools include the end of life stage of garments. Therefore, opportunities lie in the development of the LCA methods.
Increasing awareness and knowledge

Results on how LCA is currently used to improve sustainability show that LCA is growing awareness on sustainability challenges and solutions. Once LCA is completely integrated into the fashion industry by not only business but also education knowledge and awareness can even more so be enhanced. Commonly used LCA tools such as the Higg Index create a common language on how to evaluate environmental standards between all partners in the supply chain. This common language can help the industry regarding communication and collaboration. Industry professionals need training for scientific research to be valuable. Working with simplified tools that are supported by consultancies can help the industry to understand environmental impact categories and high impactful process steps better.

The increase in knowledge can lead to more sustainable awareness and result in sustainable practices. Nevertheless, the importance of critically assess LCA results will be significant in teaching the industry about LCA. Because results are not always robust, a critical attitude is required to give value to knowledge. By implementing the Modint Ecotool into fashion education at Saxion University of Applied Sciences future professionals will be trained regarding the possibilities of LCA studies and the importance of environmental impact assessments (G. Bouwhuis, personal communication, April 11, 2017). It is important that the limitations of the tools are discussed so that students are trained to be critical towards the results. Saxion student Maaike van Middendorp states that she thinks that being able to work with the Modint Ecotool will be important in the future career and has given her more insight into sustainable challenges (M. van Middendorp, personal communication, April 18, 2017). Students from the Amsterdam Fashion Institute who are not aware of the possibilities of LCA are highly conscious of the need for sustainable changes; however, feel that their education did not give them the right tools to be able to make that change. Once presented with the concept of LCA they feel strongly that this could help students to make sustainable fashion reality in the future (AMFI students, group discussion, April 22, 2017). Integrating LCA not only in the fashion industry but also in the fashion education system will play a significant role in the development of sustainable awareness and the creation of sustainable products and supply chains.
Implementing LCA methods as standard practice within the fashion industry has the potential of giving bias results that can misguide sustainable development and require significant unnecessary investments.

### Misguiding sustainable development

Due to data quality issues, LCA results which are not accurate or up-to-date can have an adverse impact on the industry once LCA is fully integrated. New insights can change the outcome of previously conducted LCA studies that are currently used by decisions-makers throughout the industry. Because experts interpret ISO standards in a way that suits the achievement of the goal the outcomes may be biased. Because the ISO standards allow companies to select which product they choose to study freely, businesses can select products which they expect to have the least impact which can be seen as ‘greenwashing’ (Vishvajith, 2017).

Because LCA provides quantitative results, they can be interpreted as yes or no answers to sustainability challenges. When results of the LCA research are not correct and not assessed critically, this can lead to poor decision-making on a large scale. Hannah Fell explains that in general fashion brands want to be consulted with yes or no answers to complex sustainability challenges (H. Fell, personal communication, March 14, 2017). Sustainability challenges, however, require a critical assessment that can in most cases not be answered with single quantitative results. The Higg Index can potentially give fashion brands the idea that this one-top-shop approach can provide a yes or no answer to sustainability and will limit them into critically assessing problems using multiple in-depth sources. When LCA results are used incorrectly on a large scale, the industry can be effected negatively resulting in unsustainable products or supply chains portrayed as sustainable.
4.4 Conclusion

Wasting resources

LCA research can require extremely resource investments. Once resources are not invested in high-quality, practical research, they could be more effectively used for other sustainable purposes. Environmental impact data on which business decisions can be made are not restricted to scientific LCA studies. Michael S. Brown states that LCA is aiming for a level of precision that is not needed for sustainable business development. Many other valuable data sources derived directly from the industry can be used to create tools suitable to calculate environmental impact (M. Brown, personal communication, April 5, 2017). Due to the resource intensiveness of a full LCA study, the business value remains questionable. Sustainability challenges require not only a quantitative approach, but also critical thinking, logic, and collaboration within the industry. Maria Gunnarsson who is a product developer at Kings of Indigo states that their sustainable decisions are based on their experience in sustainability, information coming from the close relationship with their suppliers, and critical thinking. Gunnarsson says that using the EIM software will only verify the sustainable development decisions that the company makes and will not contribute much to the development of new products. LCA research should be used to its full potential and not solve problems that require less intensive measures or are not of high practical relevance or otherwise could have an adverse effect on the industry.

Tools that are measuring the environmental impact of apparel products show high potential to enhance sustainable development. Different tools are created to support the needs of various stakeholders and approach the subject in a variety of ways. To create awareness about certain sustainability issues LCA can be used to guide untrained individuals such as students with easily understandable quantitative information. This quantitative data should however not be perceived as black and white answers to sustainability. It is critical that the industry remains interested and critical to the underlying data. By teaching students and industry professionals about LCA, their capabilities to think with a life cycle approach will increase, and connections between sustainability issues will be recognized. It is important that LCA is used in cases that benefit actually from it and that no resources are wasted researching non-practical information. For example, Jeanologia used the EIM to prove the sustainable benefits that come with a very complicated new finishing technique. LCA research can stimulate sustainable innovation which will be treasured for the future as the current methods dominant in the textile industry have a high environmental impact and need to be replaced by sustainable innovations.
Because environmental issues are quantified, sustainable product strategies can be developed, and progress can be measured. LCA is used within the fashion industry in many different forms. Because LCA is a scientific tool, the scientific community plays a significant role in both the development and the usage. However, many consultancies have developed commercial tools based on scientific LCA methodology or data for their members. Each LCA method is used by different stakeholders as they are designed for specific customers. The global reach and the complexity of the LCA methods differ depending on the end user. Overall LCA methods are currently creating awareness within the fashion industry regarding environmental problems related to high impactful processes and materials. The usage of LCA tools has created more insight into the full supply chain of fashion companies and supported transparency. The main limitation when it comes to performing an LCA on an apparel product is the complexity of the supply chain. Mainly due to the fashion supply chain and the necessary quality of the data, LCA studies are time and resource intensive. In the fashion industry products have a short lifespan, a low price, and in general a collection consists of many different items. Nevertheless, LCA methods show strong potential to guide sustainable development within the fashion industry. By teaching students and industry professionals to work with LCA tools, the awareness and knowledge regarding environmental challenges will increase even more. However, the LCA results should never be perceived as absolute, but indicate areas for improvement and stimulate life cycle thinking. LCA methodology does not provide the answers to the current sustainability challenges, but it can guide and encourage the industry to find them through innovation. It all starts by measuring the current state and creating awareness for the existing problems. You cannot manage what you don’t measure. In the case of environmental problems related to the fashion industry, we need to measure them first before managing them.
To assess the practical relevance of LCA methodology in the transition towards a sustainable fashion industry, this thesis analyzes six different methods most commonly used. Many other methods exist for using LCA within the context of the fashion industry, and therefore this thesis provides not a complete assessment of the topic. The methods selected do offer a holistic perspective on how LCA is currently used within the global fashion industry. Because, the thesis is written in the Netherlands, one of the methods selected is specifically developed for Dutch companies. This allowed for more sources of information on a method that was designed for a particular target group as the other methods have a larger and more global focus. LCA methods intended for different users in different geographical locations are compared, which is valuable to the research. Due to the limited amount of time and personal network, fifteen interviews are held. When more interviews were performed, the study would have been more complete. Nevertheless, the data derived from the interviews was sufficient to make valuable research conclusion.

6.2 RECOMMENDATIONS FOR FUTURE RESEARCH

This study assessed the practical relevance of LCA methodology within the context of the fashion industry for the first time. Independent research on the potential of LCA methods is important in stressing the significance to future sustainable development. Future research is yet to analyze the other LCA methods used within the fashion industry. By examining all the tools used to perform LCA research, the industry will become more aware of their existence, potential, benefits, and limitations.


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