Theses and Dissertations--Retailing and Tourism Management

Retailing and Tourism Management

2015

A Comparative Life Cycle Assessment of Denim Jeans and a Cotton T-Shirt: The Production of Fast Fashion Essential Items From Cradle to Gate

Tara Hackett
University of Kentucky, tara_hackett1@yahoo.com

STUDENT AGREEMENT:

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

REVIEW, APPROVAL AND ACCEPTANCE

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Tara Hackett, Student

Dr. Elizabeth Easter, Major Professor

Dr. Scarlett Wesley, Director of Graduate Studies

A COMPARATIVE LIFE CYCLE ASSESSMENT OF DENIM JEANS AND A COTTON T-SHIRT: THE PRODUCTION OF FAST FASHION ESSENTIAL ITEMS FROM CRADLE TO GATE

THESIS

A Thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture
at the University of Kentucky

By

Tara Hackett

Lexington, Kentucky

Dr. Elizabeth Easter, Professor of Merchandising, Apparel and Textiles

Lexington, Kentucky

2015

ABSTRACT OF THESIS

A COMPARATIVE LIFE CYCLE ASSESSMENT OF DENIM JEANS AND A COTTON T-SHIRT: THE PRODUCTION OF FAST FASHION ESSENTIAL ITEMS FROM CRADLE TO GATE

As a result of harmful textile production, sustainability has become the movement by which the apparel industry explores solutions to improve procedures in fashion design to maintain a healthy environment. However, the issue is consumers trust the sustainability claims and marketing materials of apparel products at face value without knowing its environmental impact. The overall purpose of this research was to compare the environmental implications of widely produced and owned apparel products through a life cycle assessment approach. This life cycle assessment study examines key environmental impact categories of the materials and production phase (cradle to gate) of a pair of jeans and a cotton t-shirt. The specific purpose of this study was to identify if the production processes make a sustainable product at the point of purchase. Furthermore, this research study compares the environmental impacts of a denim jean and dyed cotton t-shirt utilizing the ReCipe 2008 LCA tool.

KEYWORDS: Life Cycle Assessment, Sustainability, Cradle to Gate, ReCiPe 2008

Tara Hackett

July 27, 2015

A COMPARATIVE LIFE CYCLE ASSESSMENT OF DENIM JEANS AND A COTTON T-SHIRT: THE PRODUCTION OF FAST FASHION ESSENTIAL ITEMS FROM CRADLE TO GATE

By

Tara Hackett

Dr. Elizabeth Easter

Director of Thesis

Dr. Scarlett Wesley

Director of Graduate Studies

July 27, 2015

ACKNOWLEDGEMENTS

The following thesis, while an individual work, benefited from the insights and direction of several people. First, my Thesis Chair, Dr. Elizabeth Easter, exemplifies the high quality scholarship to which I aspire. Dr. Easter provided timely and instructive comments and evaluation at every stage of the process. Thank you for your support and believing in me. Next, I wish to thank the complete Thesis Committee: Dr. Elizabeth Easter, Dr. Vanessa Jackson, and Dr. Scarlett Wesley. Each individual provided insights that guided and challenged my thinking, substantially improving the finished product.

In addition to the technical and instrumental assistance from my thesis committee, I have received equally important assistance from family and friends. My husband, Trae Hackett, has provided unwavering support through my journey, always offering encouragement and a listening ear. Thank you for believing in my vision. To my children, Trent, Taylor, and Teagan, for quiet times, cooperation and understanding that provided quality studying time me. Last, to my extended family and friends for filling in the gaps, supporting my decisions and providing a safe and loving place for us to grow. The help from everyone has allowed me to achieve my goals.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One

“Eco chic,” “environmentally conscious,” “ethical consumerism,” “sustainable fashion” and “clothing with a conscience” are new fashion buzzwords. Even more familiar, ‘natural,’ ‘organic’ and ‘green’ are adjectives that are intended to shape consumers’ minds and purchases towards more sustainable choices. However, really knowing so is a difficult process. Besides, how often do consumers know where their shirt’s cotton came from and how it was produced? The methods by which products are manufactured, purchased, used, and disposed of affect the environment in many ways (Joy, Sherry, Venkatesh, Wang & Chan, 2012). Therefore, sustainability gives the designer and manufacturer a chance to think more critically about fashion design and produce environmentally responsible clothing. So, Hethorn and Ulasewicz (2008) ask, “How do we design, develop, and wear fashion in sustainable ways and still participate with fashion as we know it” (p. xiii)? When considering sustainable fashion a designer must assess what sustainability means to them, the environment, and the consumer.

Sustainability is a growing phenomenon in the world of fashion today. Globalization has provided the apparel industry the opportunity to produce fashion at a rapid rate. The advancement and improved enforcement of environmental laws by regulatory authorities clearly demonstrate a growing recognition of the importance of moving towards a more sustainable model for the textile and clothing industry (Dystar, 2010). Apparel production is taking place in countries where there is little concern for air and water pollution created by textile fiber, yarn and fabric production (Hethorn & Ulasewicz, 2008). Therefore, as a result of global textile production, sustainability has become the movement by which the apparel industry explores solutions to improve procedures of apparel production in order to maintain a healthy environment. Although “manufacturers may use new designs and technology to minimize the impact of a product on the environment, their efforts are pointless if the consumer does not buy it”(Moisander, Markkula, & Eräranta, 2010, p. 73). The demand for sustainable fashion depends on the consumer’s knowledge and understanding of the issues impacting sustainability (Moisander et al., 2010) Therefore giving the consumer the opportunity to widely influence the market. People are increasingly recognizing the issues associated with sustainable consumption (Carrigan & Pelsmacker, 2009) and by purchasing and wearing eco-friendly clothing, people express choices about their own ecological footprint (Hethorn & Ulasewicz, 2008). Therefore it is the responsibility of the retailer to source and label products ethically (Ritch & Schroder, 2012).

Problem

Sustainable fashion has been around since the early 1600s, as a way of life rather than a choice. Before the Industrial Revolution, people were conserving resources because of the cost and labor it took to produce the basic necessities of life (Hethorn & Ulasewicz, 2008). Raw materials (textiles) for apparel came from nature and required a long time to transform into fabrics. The labor required to produce a high quality product contributed to the high cost of fabrics and apparel. Hence, quality fabrics were worn by the wealthy as a way to express their wealth to society. By the end of the eighteenth century industrial machines were introduced to spin yarns and weave fabrics; which accelerated the production of fabrics.

Synthetic dyes, manufactured fibers, ready-to-wear, fashion magazines and more were products of the industrial revolution and made it possible for the textile industry to grow. In the 60's fashion production and consumption changed during the postmodern era. "Novelty in fashion was much desired to mirror rapid social change" (Hethorn & Ulasewicz, 2008, p. 20). Fashion became available to all classes of people as apparel was more abundant and easily accessible which led to the development of consumerism. Stearns (1997) describes consumerism as a "society in which people formulate their goals in life partly through acquiring goods they clearly do not need subsistence or traditional display" (p. 105). As consumers began to purchase more, manufacturers responded, by providing an abundance of goods. Marketing and advertising of fashion soon followed and contributed to the greater interest in consumer consumption.

Along with the growth of the textile and apparel industries came many factors including consumer awareness, government intervention by legislations, and diversification in production. In addition, new developments in information and communication technologies enabled the use of media to inform the consumer of the impacts of the industry. The attention of the consumer has forced retailers to take action to address their concerns of the environmental, economic and social impact of through production (Jones, Hillier, Comfort, & Eastwood, 2005). Although, retailers have taken a more proactive approach though apparel production, challenges still remain in convincing a consumer of sustainable practices through apparel labelling. The United States Environmental Protection Agency (USEPA) claims that eco-labels are placed on products by manufacturers to indicate to consumers that the product meets certain environmental and human health standards (USEPA, http://www.epa.gov/greenproducts/standards/). However, the message of sustainability or eco-friendly products is sometimes falsely conveyed, assuming that consumers are unaware of the processes and procedures included in production. Unfortunately consumers trust the sustainability claims and marketing materials of an apparel product at face value without knowing its environmental impact.

Purpose

The overall purpose of this research was to compare the environmental implications of widely produced and owned apparel products through a life cycle assessment approach. This life cycle assessment study examined key environmental impact categories of the materials and production phase of a pair of jeans and a cotton t-shirt. Therefore, the specific purpose of this study was to identify if the production processes make a sustainable product at the point of purchase.

Objectives

The overall objective of the research study was to assess the life cycle of two apparel products to determine if the apparel products are fully sustainable for the consumer at the point of purchase. This study focuses on the stages of manufacturing that affect the validity of an eco-friendly labeled product. The objectives were to:

1. Assess the environment impacts of an apparel product's life cycle from cradle (raw material extraction) to gate (garment make-up & distribution).
2. Compare the environmental impacts of a pair of denim jeans and a cotton T-shirt using the Life Cycle Assessment (LCA) ReCiPe 2008 methodology.

Research Questions

This research study addresses the overall question of whether or not the product is sustainable based on the processes and procedures used during the manufacturing stages. This study answers the following questions:

1. Do companies produce a 100% sustainable product based on the processes and procedures of a sustainable design?
2. What phases of jean and cotton t-shirt production have the most significant environmental impacts?
3. How do manufacturers ensure the validity of sustainable apparel labeling through production and packaging?

Justification

During the rise of industrialization, textile manufactures were not concerned with environmental effects as a result of production or fair labor practices (Hethorn & Ulasewicz, 2008). Chemicals were emptied in nearby rivers and streams and work conditions in mills were poor. As a result, the emergence of environmentalism and social consciousness took place. Consumers began to consider ways to dispose, recycle, and reuse their clothes. They were concerned with how their clothing was produced and the impact the process had on the environment, thereby developing a conscientious lifestyle. As a response to conscience consumerism, eco-labeling began to rise as a way to inform consumers that companies care and are on board with their sustainable viewpoint.

Consumers have a desire to learn more about sustainable issues and practices that lead to sustainable living. Luke (2008) proclaims that, “consumers play a role in promoting peace and sustaining life through the choices they make when they purchase apparel and other goods” (p. 77). In the opinion of the government and the consumer, environmental issues are playing an increasingly important role in the textile industry (Sivaramakrishnan, 2012). Society has placed a focus on sustainability by highlighting issues of the environment in the media. When discussing sustainability as a whole the concern with chemicals used in apparel production that affect human health and the environment are not the only issues. Sustainability is about improving apparel production in order to maintain a healthy environment in the future and addressing/ solving social inequities (Hethorn & Ulasewicz, 2008). As manufacturers continue to design and produce sustainable products the consumer ultimately has the buying power and determines the success of the product. People are more environmentally conscience and applying their beliefs of the environment while purchasing products for their lifestyle. However, the processes and materials available from which fashion products are produced are unfamiliar to consumers, resulting in un-informed purchasing choices (Hethorn & Ulasewicz, 2008). Therefore, the company's responsibility is to examine the production process from design to point of purchase to better inform consumers of sustainable products.

Limitations of the study

This research study is a comparison study that focuses on the manufacturing of a cotton T-shirt and a pair of denim jeans. These products are significant because they are items that are widely owned by consumers in large amounts. On average, about 96% of U.S. consumers own seven pairs of denim jeans at one time.(CottonIncorporated, http://www.cottoninc.com/corporate/Market-Data/SupplyChainInsights/Driving-Demand-For-Denim-Jeans/). People from many different generations wear the t-shirt in many ways, colors, and fabrics. Today, contrary to the past, it is a staple piece for both genders (Jefferson, http://www.ooshirts.com/guides/History-of-the-T-Shirt.html). However, by using only jeans and t-shirts as a focus limits the study assuming they are the only fast fashion items consumers own in excess.

The study used data from existing life cycle assessment studies and did not conduct an actual LCA. The sample size was intentionally chosen to bring recognition of the environmental impacts of largely owned and purchased fashion items. The availability of studies conducted by companies in the US was limited and non-existent therefore, the LCAs compared were from the United States and Denmark.

The Life Cycle Assessment (LCA) is the detailed analysis of a product's design. It describes the entire life of a product, which encompasses raw material extraction, material production, manufacturing, product use, the end-of-life disposal, and all the transportation that occurs in between each stage (ANSI/ISO 14040-1997). The product's use phase and end-of-life disposal phase occur as consumer behaviors and are critical stages in a product's life cycle. However, this study addressed the environmental impact of the materials and production phase of the life cycle, excluding consumer behavior. This study is a cradle to gate life cycle assessment. Furthermore, LCAs are still in development and do not have consistent system boundaries to be used among all industries. This study focused on a limited number of environmental impact categories most important to the selected products rather than the 18 categories indicated by the ReCiPe 2008 LCA tool. The International Standard recognizes that work remains to be done and practical experience gained in order to further develop the LCA practice (ANSI/ISO 14040-1997). The research was restricted by the amount of time available to fully trace production.

Assumptions

The assumption was that the products sampled are representative of all apparel products enforcing a sustainable initiative. The information from this study encourages consumers to research the environmental impacts of their beloved denim jeans and t-shirt fashion items purchased in excess. Furthermore, this study assessed the sustainable resources and processes of a basic cotton t-shirt and denim jean utilizing a life cycle assessment.

Chapter Two

Review of Literature

The overall purpose of this research was to compare the environmental implications of widely produced and owned apparel products through a life cycle assessment approach. In addition, determine if the apparel products are fully sustainable for the consumer at the point of purchase. As apparel products are manufactured, purchased, used, and disposed of, there are many harmful techniques that affect the environment. (Joy et al., 2012). Fortunately the concept of sustainable apparel design can give the designer and manufacturer an opportunity to positively impact the environment through the production process. Because consumers are increasingly concerned for the environment, it is important that manufactures clearly label sustainable apparel products. The labeling and identification of sustainable products and production processes are not clearly defined, and inconsistently regulated by the government to ensure the validity of a sustainable garment.

In the following section, the review of literature will provide the theoretical background for the movement towards sustainable apparel production. This study focuses on the essential topics to developing an apparel garment by describing the apparel industry in relation to the life cycle assessment. Therefore, the review of literature covers globalization, fast fashion, sustainable fashion, and the life cycle assessment of an apparel product, as these are the significant issues contributing to the rise of eco-consciousness.

Overview of the Apparel Supply Chain

In the textile industry, supply chain is described as the flow of goods from the very first process encountered in the production of a product through final sale to the end consumer (Bruce, Daly, & Towers, 2004). The supply chain process of the apparel industry begins with: fiber production, yarn manufacturing, fabric manufacturing, product manufacturer, retailers, and the consumer, in that order (Keiser & Garner, 2012). The United States apparel industry is an import and domestic industry, and according to Cohen and Johnson (2012), more than half of all apparel consumed in the United States is made from textiles produced outside the country and then imported to the U.S., while less than half are produced domestically. Therefore the apparel industry supply chain is highly fragmented and inherently complex; which makes fashion manufacturing less transparent than agribusiness ((Mihm, 2010); Partridge, 2011).

In the past the apparel supply chain were very simple and operated in the same manner with each industry segment having very specific responsibilities and its own customer (Keiser & Garner, 2012). As technology evolved, the ability for businesses at specific levels has begun to cross (Keiser & Garner, 2012). Retailers have bypassed the middleman and are trying their hand at product development to secure more of the profit and claim exclusivity at a more competitive price (Keiser & Garner, 2012). Now, the apparel supply chain can be described as a complex network of suppliers and/or vendors involved directly or indirectly in fulfilling customer demand for apparel. The supply chain includes all the companies directly involved in designing, supplying material components, manufacturing, and distributing apparel as well as auxiliary business (Keiser & Garner, 2012). Products are delivered through multiple distribution channels including stores, catalogs, television, and through the Internet.

Over time, the apparel supply chain has evolved because of competitiveness. Therefore, the collaborative apparel supply chain came about because of wholesale brand manufactures wanting to remain competitive by opening their own retail stores (Keiser & Garner, 2012). Keiser & Garner (2012) say that a "Collaborative supply chain enhances a product developer's ability to compete in terms of product innovation, cost, speed to market, manufacturing expertise, sustainability, and access to technology and resources to be more flexible in its response to changing market needs" (p. 25). Today the collaborative supply chain is the most common and is the means by which the apparel industry functions. Zara is a Sweden based company that has been successful at making the collaborative supply chain work in its favor. Zara accomplishes an 8-10 week delivery response time opposed to a 40-50 week response time by committing to small and frequent shipments to keep inventories fresh. This concept convinces the customer that every time they visit the store they are guaranteed to see new merchandise, compelling consumers to frequently shop as to it, may be gone tomorrow. The cutting and dyeing process of an apparel product are crucial stages in apparel production, however Zara has invested in a dye and finishing plant to have more control over the lead times of its apparel goods (Keiser & Garner, 2012). They manage majority of the cutting process, therefore this eliminates having a manufacturer and decreases the lead-time on its apparel products. The design stage of the apparel production process is mainly determined by the consumer, and dictates the design that has so successfully been achieved by Zara (Keiser & Garner, 2012). Zara has efficiently reviewed each level of the supply chain and tailored its business to it in order to make improvements that work in their favor.

Globalization

Scientific and technological advances are two major factors that spurred industrialization without considering the negative effects (Sadar, 2010). In the years following World War II innovations and developments in textile technology and man-made fibers were impressive, as well as the growth of worldwide consumption and production of textiles (Linder, 2002). Worldwide consumption of major textile fibers increased almost four times as much between 1950 and the late 1980s from 10 to 38 million tons (Linder, 2002). The growth was attributed mainly in part to the growth of world population (Linder, 2002). World War II brought about progress in textile technology resulting in the development of new materials and the introduction of new techniques for the manufacture of known and new fibers into finished fabrics (Linder, 2002). New material innovations became a way of life and the textile industry continued to improve production technologies, experienced increased productivity and increasing automation of production (Linder, 2002). By the end of the 1980s, man-made fibers were the most important raw material for textiles next to cotton (Linder, 2002).

Sadar (2010) goes on to proclaim that, "Fashion cycles continue to change rapidly as a result of global communication and marketing, intense competition and rivalry, and expanding production capacities in developing countries, especially in China and India" (p. 144). In turn, globalization has put pressure on designers, manufactures and retailers to encourage consumerism and the adaptation of fashion cycles. At the move towards fast fashion, the apparel supply chain was unequipped for the growing demands of the fashion industry, lead times were extremely long, complex and inflexible (Barnes and Lea-Greenwood, 2006). The retail industry evolved from a production-driven industry to a more concentrated consumer-driven industry. Therefore, new concepts were introduced into the supply chain including just-in-time (Bruce et al., 2004), the agile supply chain (Christopher, Lowson, & Peck, 2004; Bruce et al., 2004) and quick response systems (Giunipero, Firoito, Pearcy, & Dandeo,2001) for improvement to response time.

Just-in-time Concept. The just-in-time management approach predates back to the 1950s as a way to gain competitive advantage. It was a strategy invented by the "father" of Toyota's production system, Taiichi Ohno. It was designed with the idea in mind of no waste or the avoidance of overproduction that results in dead stock and inefficient use of labor (Michelsen, O'Connor, & Wiseman, 2014). His theory became known as the JIT philosophy, focusing on a main goal of moving items through a production system only when needed (Michelsen et al., 2014). The JIT theory gained popularity and was introduced in the US in the late 1970s to early 1980s. JIT is an inventory pull system approach to managing the supply chain (Abuhilal, Rabadi, & Sousa-Poza, 2006). It enables the retailer to fill costumer orders at the time of purchase. Retailers were able to reduce inventory to a minimum level, keeping on hand only the amount needed (Epps, 1995). The literature highlights Dell and McDonald's by explaining that is was more efficient to sell customers burgers or computers right when the customer orders it rather than selling premade burgers or computers that have the tendency to age quickly (Michelsen et al., 2014). Therefore, custom tailored orders allow companies to satisfy orders at a lower cost and prepare for rapid production (Michelsen et al., 2014). Therefore, adopting an approach driven on a continuous delivery of items (Epps, 1995). This concept can be attributed to the success of companies such as; Hewlett-Packard, Dell, McDonald's and Walmart (Michelsen et al., 2014).

In the textiles and clothing industry JIT can be described as the delivery of finished goods just in time to be sold throughout the supply chain. The literature shows that the JIT approach is successful due to collaboration and information sharing within the supply chain, resulting in reduced holding cost (Abuhilal et al., 2006). The JIT system afforded a retailer the opportunity to trust a supplier with all their consumer needs, which in turn increased profits for the company. "They could deliberately maintain restocking thresholds at very low levels in further efforts to eliminate waste and cost, maximizing profit margins and customer satisfaction" (Michelsen et al., 2014,p. 34). A strong supplier relationship is what makes the JIT approach successful and should be one of respect, trust, and open and honest communication. Epps (1995) explains the long-term contractual relationships with vendors eliminates the need for purchase requisitions and purchase orders. By default, JIT is a retailer driven approach and information sharing concept (Bruce et al., 2004; Abuhilal et al., 2006). However, being solely reliant on one supplier poses risk for limited flexibility. There is always the possibility of natural disasters that interrupt production and cause a shortage in supply or even longer lead times than negotiated. Companies must be prepared for unexpected issues in order to maintain the flow of goods.

As a result, retailers began to look for alternatives ways to react business. According to Michelsen et al. (2014) the industry began to shift when businesses started to: secure more than one company to supply their needs at competitive prices, avoid long-term contracts with suppliers, and manufacturing their own products. The industry was turning to a more agile approach to the supply chain.

Agile Supply Chain. The concept of agility in relations to the supply chain has evolved over the course of twenty years and as of today is the essential condition for a company's survival and competition. The concept was derived by a group of scientist from Lehigh University who were attempting to describe the essential aspects of the production process (Yusuf, Sarhadi, & Gunasekaran, 1999). The study concluded that the production system must always adapt to their business environment by focusing on speed, flexibility, responsiveness and infrastructure (Christopher et al., 2004; Yusuf et al., 1999). As the agile supply chain started to evolve, the drivers of agility were analyzed and concluded as automation and price/cost consideration, widening customer choice and expectation, competitive priorities, integration and proactivity, and achieving manufacturing requirements in synergy (Yusuf et al., 1999). Historical events such as World War II brought about increased demand and backlogs of customer orders leaving the market unable to supply goods. As a result price became a dominant factor that determined customers preferences, encouraging massive automation of the production processes resulting in mass production of goods (Yusuf et al., 1999). Goods were being manufactured in abundance at a low price. Widening customer choice and expectation is another driver of agility that was spawn from the shift in customer preferences in favor of quality in the 1980s. The market made vast efforts to focus on quality manufactured goods while maintaining a competitive price (Yusuf et al., 1999).

Increasing the customer expectations for quality products helped to intensify the attention devoted to product quality initiatives (Yusuf et al., 1999). As the market was changing, responsiveness, new product introduction, delivery flexibility, quality, concern for the environment and international competitiveness became competing priorities (Yusuf et al., 1999). A main driver of agility was to develop a proactive manufactures to better identify the consumers problems and requirements and to acquire capabilities just ahead of need. However, proactivity is solely dependent on the integration and co-ordination of the company's strategic manufacturing systems (Yusuf et al., 1999). Last, in order to achieve the manufacturing requirements all drivers of agility must work together in synergy to be successful. For example, to remain competitive, manufacturers are required to produce products at lower cost, high quality and with shorter lead times and remain proactive and innovative. That includes integration both of a technical and social nature, of technology, machinery, functions, strategies, people and management is the foundation of competitive capabilities (Yusuf et al., 1999).

Conventional supply chains are indicative of longer lead times and forecast driven business strategies as a way to adjust to consumer demands. Also, conventional supply chains are inventory based, often leaving retailers over or under stocked. Consequently, the supply chain made it difficult to see "real" demand, the ability to see what customers are buying. Agile supply chains are shorter, demand-driven, inventory and information based. Additionally, agile supply chains allow retailers to be flexible to customer needs (Christopher et al., 2004).

Christopher et al. (2004) explains that the agile supply chain is significant in its own right, by being market sensitive, virtual, network-based, and process aligned. It shares up-to-date point-of-sale (POS) data that can be used across the supply chain for immediate ordering and replenishment decisions (Barnes & Lea-Greenwood, 2006). Being market sensitive suggest that the agile supply chain is closely connected to the customer, forcing the fashion retailer to identify with the consumers preferences and fashion needs (Christopher et al., 2004). The agile supply chain is also connected and integrated through shared information with all players of the supply chain, which includes the fabric manufactures, garment makers, and retailers (Christopher et al., 2004). The idea of the virtual agile supply chain gives the retailer the opportunity to keep shelves well stocked and presents the advantages of co-managed inventory (CMI). CMI is the collaboration of the supplier and retailer to manage the flow of good to the store (Christopher et al., 2004). A network based supply chain is flexible because it uses the strengths of specialist players. Due to the growth of the supply chain, retailers have a choice/ variety of suppliers (often small manufacturers) to use, that allows them to receive technological, financial and logistical support (Christopher et al., 2004). In other words, retailers do not have to put all their resources into on basket. The option to use other venues is an advantage of a network based agile supply chain. Last, the agile supply chain is process aligned, meaning that there are no boundaries between connections. There are no delays between the different stages in the chain and the transactions are paperless (Christopher et al., 2004). Rimiene (2011) proclaims that the agile supply chains are the alliances of legally separated organizations such as: suppliers, designers, producers, and logistics distinguished by flexibility, adaptability, and quick, as well as effective, responses to changing markets. Retailers, manufacturers, and all other parties that are geographically dispersed and independent of each other can operate as one business (Christopher et al., 2004).

Quick Response Concept. The apparel industry is a fast moving industry that has an overwhelming fashion influence where no single style stays around for a long period of time. Consequently, Quick Response (QR) is an outcome of the consumer's desire for new and diverse goods of great quality. The unstoppable movement towards change can be attributed to "mass-customization" of products with shorter seasons, market segmentation and micro merchandising, and a large number of product saturation resulting in decreased market share (Christopher et. al., 2004). Therefore, the quick response concept is simply the ability to shorten time in the supply chain (Christopher et.

al., 2004) and is often synonymous with terms such as speed-to-market and fast-fashion (Keiser & Garner, 2012, p.14).

In 1999, Lowson, King, and Hunter defined QR as:

> A state of responsiveness and flexibility in which an organization seeks to provide a highly diverse range of products and services to a customer in the exact quantity, variety and quality, and at the right time, place and price as dictated by real time customer/consumer demand. QR provides the ability to make demand-information driven decisions at the last possible moment in time ensuring that diversity of offering maximized and lead-times, expenditure, cost and inventory minimized. QR places an emphasis upon flexibility and product velocity in order to meet the changing requirements of a highly competitive, volatile and dynamic marketplace (p. 77).

Although supply chain management and agile supply chains were evolving, on average, an apparel product would take about 66 weeks to reach the retail store (Barnes & Lea-Greenwood, 2006). The improved agile supply chain and supply chain management served as the background of QR (Christopher et al., 2004) and in efforts to supply a solution, QR was developed by Kurt Salmon Associates in 1986. The literature highlights the original success of QR as the improved efficiency for basic textile products, however more recently; it will be more successful when used with fast moving high-fashion goods (Fast Fashion) (Giunipero et al., 2001). Quick response reduces the production cycle from several months to a few weeks (Taplin, 1999). QR was also created as a result of the need for competitive response from suppliers to low cost threats from overseas (Barnes & Lea-Greenwood, 2006). Therefore, QR is based on sharing critical information such as, sales information, rather than being forecast driven (Birtwistle, Siddiqui, & Fiorito, 2003). Detailed information about stock keeping units (SKU) such as, style, size, colors, sales numbers and order schedules and deliveries helps retailers to respond to consumer demand much faster (Birtwistle et al., 2003).

Fast Fashion

The apparel industry has taken a significant turn in the past 20 years due to the expansion of boundaries in the fashion industry (Djelic & Ainamo, 1999). Doyle, Moore, and Morgan (2006) contribute the boundary changes to the fading of mass production, the increase in the number of fashion seasons, and modified structural characteristics in the supply chain have forced retailers to desire low cost and flexibility in design, quality, delivery and speed to market. Before the 90s, consumer demand and fashion trends were forecasted by retailers long before hitting the market and now retailers compete with each other by offering the ability to provide runway fashions rapidly. Retailers were establishing close relationships with manufacturers that allowed them to experience improved distribution, greater variety of products on sales and shorter selling seasons (Taplin, 1999).

The industry was based on standardized styles and trends that did not change often due to the design restrictions of the factories. In the past consumers were not moved by style and fashion but by basic apparel (Bhardwaj & Fairhurst, 2010). The fad of mass production happened because the industry had begun to see an increase in the import of fashion oriented apparel for women as compared to the standardized apparel in the 1980s (Bhardwaj & Fairhurst, 2010). With the introduction of fashion goods came the increase of mark-downs in the market, deemed necessary due to the inability to sell fashion apparel during the forecasted season (Bhardwaj & Fairhurst, 2010).

Historically, the apparel industry had four distinct stages that governed the fashion life cycle. The stages were: introduction and adoption by fashion leaders; growth and increase in the public acceptance, mass conformity (maturation), and the decline and obsolescence of fashion (Bhardwaj & Fairhurst, 2010). Fashions were created on a seasonal guideline consisting of Spring/ Summer and Autumn/ Winter and were largely inspired by runway shows, trade fairs, and fabric event (Bhardwaj & Fairhurst, 2010; Birtwistle et al., 2003). Demands of fashion consumers, the need for quick reaction for emerging trends and the move away from planned forecasts has resulted in a shift in the apparel buying cycle (Barnes & Lea-Greenwood, 2006).

Consumer Driven. Fast fashion stems from the abundance of low cost apparel collections that are available as knock-offs of the luxury brands (Joy et al., 2012). It is a fast-response system to evolving trends that encourage disposability (Fletcher, 2008). Overtime, fashion has evolved into a concept similar to fast food. Just like fast food, convenient food prepared quickly and easily, fast fashion has become convenient for consumers. Since, “the speed of fashion has become increasingly faster through instant access to information through technology and quick production techniques, it is crucial that manufacturers design, manufacture, and promote so that looks are desired at the correct moment for the consumer” (Rousso, 2012, p. 114).

Bahardwaj and Fairhurst (2010) suggest that the fast fashion consumer-driven approach is still fairly new and under-researched and requires constant review of consumer behavior to understand the phenomenon. Therefore, the studies of (Barnes and Lea-Greenwood, 2006; Bhardwaj and Fairhurst, 2010; (Cachon & Swinney, 2011) have transitioned from a supplier driven approach to a consumer-driven approach to fast fashion. The consumer-driven approach assumes that the process of renovation in the fashion industry is fueled by the constant varying of consumer demands and the changes in their lifestyle (Sproles & Burns, 1994). Cachon and Swinney (2011) suggest that the consumer is also knowledgeable about the latest fashion trends and feels the need to adapt to the reality around him or her in an affordable and dynamic way. Likewise the shift represents the advent of “disposable” fashion, where the focus is on the product’s affordability rather than quality (Christopher et al., 2004). Fast fashion gives the consumer numerous apparel choices and affords them the opportunity to make a fashion mistake, because the financial and psychological investment required is minimal (Gabrielli, Baghi, & Codeluppi, 2012).

Supply Chain Driven. In the beginning, fast fashion strategies did not consider the consumer’s consumption practices (Gabrielli et al., 2012). Bhardwaj and Fairhurst (2010) examine fast fashion in terms of the consumer’s habits and consider the disposal of fashion, which puts the focus on affordability and variety rather than product quality. Therefore to satisfy the large consumer demand retailers routinely seek out new trends to purchase weekly to introduce new items and replenish stock (Tokatli & Kizilgun, 2009).

Due to the ever-changing lifestyle of the consumer and their desire for newness, pressure has been put on the established supply chain format and shifted the focus from price to fast response (Barnes and Lea-Greenwood, 2006). As a result of rapid turnover there is lower manufacturing and labor cost (Joy et al., 2012). So, retailers adopt the fast fashion strategy to reflect current and emerging trends quickly and before their competition (Fernie, 2004), with expectations of reducing demand uncertainty and generating high consumption by shortening the production cycle of apparel products during the selling season (Choi, Liu, Liu, Mak, & To, 2010).

The literature suggest that fast fashion has had an impact on the supply chain due to the consumers constant demand for newness (Barnes & Lea-Greenwood, 2006). "Traditionally in fashion industries orders from retailers have had to be placed on suppliers many months ahead of the season" (Christopher et al., 2004, p. 369). Retailers have gained power by creating partnerships with manufactures to supply product quickly. When retailers work directly with the manufacturers they are able to be demand responsive and react efficiently to sales by ordering more and getting product into the stores quickly or by canceling orders of poor performing product (Barnes & Lea-Greenwood, 2006). Consequently, when manufacturers are unable to meet the demands of the retailer, the retailer may choose to take their business elsewhere. Setting requirements for the manufacturer ensures that the supplier will supply the right product, in the right conditions at the right time (Barnes & Lea-Greenwood, 2006). In this case the retailer holds the cards as to manufacturers do not want to loose their business (Barnes & Lea-Greenwood, 2006). Making the power of the retailer stronger is the pressure placed on suppliers by the change in demand. The demand has pushed retailers to increase responsibilities to the supplier by expecting them to carry out quality control procedures, packaging, ticketing and product development (Barnes & Lea-Greenwood, 2006). Barnes and Lea-Greenwood (2006) make clear that fast fashion is a business strategy that aims to reduce the processes of the buying cycle and lead times, in order to satisfy consumer demand at its peak. Originally, customer demand was forecast-based, by the buyer, with the known risk of possibly being overstocked or under stocked (Christopher et al., 2004).

Sustainable Fashion

Sustainability includes social responsibility (human rights), energy and materials use, production, consumption, disposal, and recycling. It also describes practices and policies that reduce environmental pollution and do not exploit people or natural resources in meeting the lifestyle needs of the present without compromising the future. Sustainable fashion is living in harmony with nature and employing skilled workers in a safe and humane working environment (Partridge, 2011). As for sustainable fashion, the Nordic Fashion Association (2012) defines sustainable fashion as a dynamic process to develop and implement design philosophies and business practices for managing the economic, social and environmental factors. These factors of sustainable fashion are most often described as the “triple bottom line” that assess sustainable improvement (Hacking & Guthrie, 2008). The sustainability of a product is quantitatively assessed through the use of a Life Cycle Assessment tool that addresses only the environmental factor of the sustainable design.

Yvon Chouinard (2008) founder and owner of Patagonia, Inc. says, “sustainable production means, you take out the same amount of energy as you put in with no pollution or waste” (p.ix). Sustainable fashion is apparel produced without exhausting resources or fouling the environment. However, (Joy, Sherry, Venkatesh, Wang, & Chan, 2012) say, “While fast fashion companies can emulate luxury product, they may be less able to match deeper elements of value, such as high ethical standards in sourcing, efficient use of materials, low-impact manufacturing, assembly, and distribution; and the availability of repair and upgrade services” (p.290). Therefore Orzada and Moore (2008) stress that the “Design of textile and apparel products for a sustainable future depends on an understanding of the relationship between fiber, yarn, and fabric” (p.302).

Product Life Cycle

The product life cycle is an analysis of product’s entire life that begins with raw materials extraction and ends with disposal. However to encourage sustainability, a product’s life cycle is an ongoing circle as production continues to grow. The purpose of a product’s life cycle is to reduce its resource use and emissions to the environment as well as improve its performance throughout its life cycle. Figure 2.1 is an illustration of all phases in a product’s life cycle.

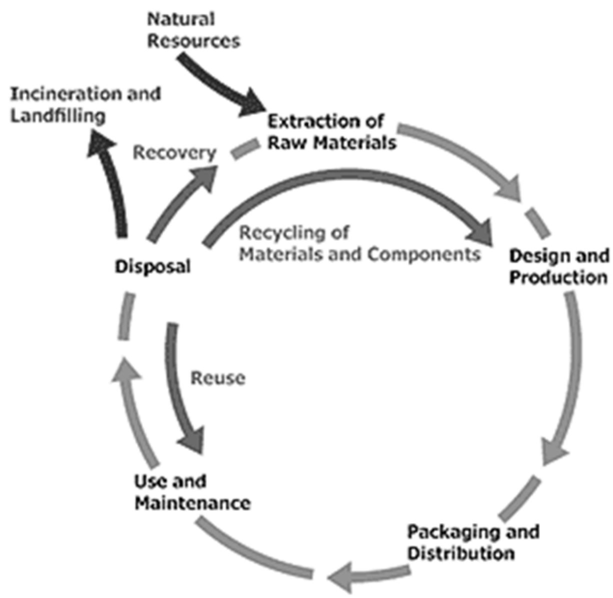

Figure 2.1. Phases of a Product’s Life Cycle. Reprinted from “What is Life Cycle Thinking?,” by United Nations Environment Programme (UNEP) & Society of Environmental Toxicology and Chemistry (SETAC), 2015, (UNEP & SETAC, 2015http://www.lifecycleinitiative.org/starting-life-cycle-thinking/what-is-life-cycle-thinking/). Copyright 2015 by Life Cycle Initiative.

Raw material procurement. The misconception of textile fibers is that synthetic fibers are perceived as “bad” (harmful to the environment) and natural fibers are perceived as “good” (environmentally friendly). However, each fiber is different and has its own sustainability challenges in the production process that cannot be ignored. The most commonly used fibers in the apparel industry are cotton, wool, silk, and flax, which are classified as natural fibers that are grown and not manufactured. Manufactured fibers are made from raw materials that come from a variety of sources, including plant, animal, and synthetic polymers (see Table 2.1) (Fletcher, 2008). The areas of large concern in this phase are attributed to large quantities of water and pesticides required for growing cotton, emissions to air and water arising from producing synthetic and cellulosic fibers, adverse impacts on water linked to natural fiber production and significant use of energy and non-renewable resources for synthetics (Fletcher, 2008).

Table 2.1

Textile fiber types

Natural Fibers		Manufactured Fibers	
Plant	Animal	From natural Polymers (Vegetable and animal)	From Synthetic Polymers
Cotton	Wool	Regenerated Cellulosic Fibers	Polycondensate Fiber
Linen	Silk	Viscose	Polyester
Hemp	Cashmere	Modal	Nylon
Jute	Mohair	Lyocell	Polymer Fiber
		Alginate Fibers	Acrylic
Ramie		Acetate	Polypropylene
Sisal		Triacetate	PVC
Banana		Elastodiene (rubber)	
Pineapple		Regenerated Protein Fibers	
Bamboo		Casein	
		Soya bean	
		Biodegradable Polyester Fibers	
		Poly (lactic acid) PLA	

Reprinted from "Sustainable fashion and textiles: design journeys," by K. Fletcher, 2008, p. 8. Copyright 2008 by Earthscan.

Manufacturing/ Production. Manufacturing is the stage when fibers are converted to fabrics and fabrics are converted to garments. In Figure 2.2, a map of the key processes, inputs and outputs of the production chain illustrate the next steps of a product's life cycle. Once raw materials have been chosen, based on the designer's vision, the road to the finished product begins. The raw fiber is converted to a yarn to prepare it for fabric construction. During yarn manufacturing, fibers are cleaned to remove dirt and residue and spun into yarns. Next, the yarn is converted to a fabric. To create the desired look of the end product, the yarns undergo large mechanical processes. Fabric manufacturing consists of weaving and knitting the yarns into fabric. In this phase of production, finishing processes such as; desizing, scouring, bleaching, dyeing, printing, and other finishing techniques are layered on to achieve the desired look. Lastly, the fabric is used to create the final product and is also called the Cut-Make-Trim (CMT) stage. Unlike, yarn and fabric manufacturing, the CMT stage is mostly a manual stage and requires the use of human labor to complete the garment. However, through every step of production significant environmental impacts exist.

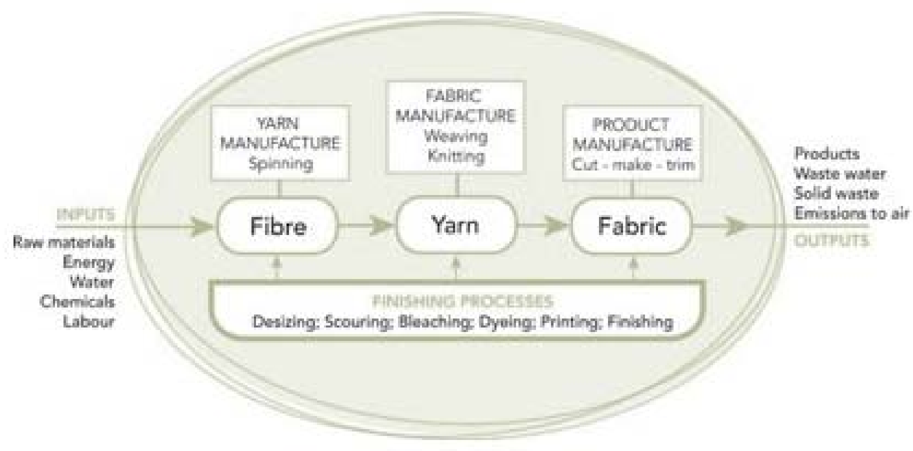

Figure 2.2. Map of key processes, inputs and outputs in the textile production chain. Reprinted from “Sustainable fashion and textiles: design journeys,” by K. Fletcher, 2008, p. 47. Copyright 2008 by Earthscan.

Fiber production is the initial source of textile production and processes, which produce many environmental impacts from the fiber-to-fabric stage (Orzada & Moore, 2008) and has been highly scrutinized for pour labor practices and toxic waste released into the environment (Payne, 2011). The processes associated with fiber production such as; washing of fiber, dyeing, finishing, and other wet processes, drying, and shipping all impact the air, water, and land quality (Orzada & Moore, 2008). Therefore, to seriously address sustainability, designers and manufactures must critically evaluate the processes used to grow or manufacture fibers and yarns, and all the processes in between to convert fibers to fabrics.

During fiber production the washing of fibers consist of using chemicals that can be extensive and include toxic, corrosive, or biologically modifying reagents (Orzada & Moore, 2008). However, fiber cleaning is necessary before moving on to the next step of creating yarns and is accomplished with the use of water or detergent. What makes the process harmful is the wastewater that contains pesticides or contaminants from natural fibers that are released into the environment. For example, scouring fibers is an in-depth cleaning procedure that removes persistent dirt from cotton, de-gum silk, or remove dirt and grease from wool (Orzada & Moore, 2008). Sodium hydroxide is an alkali used during scouring that damages fibers and leads to environmental contamination (Slater, 2005). Scouring involves hot water and detergents to remove soils, vegetable impurities, grease and other contaminants from fibers (IFC, 2007). Bleaching is another method used to clean fibers to remove the natural off-white color. Chlorine is the most common bleaching agent used that damages protein fibers and is a major cause of environmental issues, and it produces dangerous by-products during oxidation reactions (Slater, 2005).

In addition to cleaning fibers, dyeing and finishing also require chemicals and large quantities of water. Dye residuals from preparation and finishing are often found in waterways (Orzada & Moore, 2008) making the water supply harmful for the environment and people. Finishing is a basic step of fiber transformation that consumer products have received one or more treatments during production. The main processes of fabric preparation can be attributed to desizing, bleaching, mercerizing, dyeing, printing, and other specific treatments (IFC, 2007). These processes create significant wastewater effluents (IFC, 2007). In the past, fabric finishing was performed by saturating in a water bath for long periods of time however, since then improvements have been made to the process to reduce the water and energy use(Orzada & Moore, 2008). Finishes can be applied mechanically or chemically. Mechanical finishes involve the use of heat and moisture while chemical finishes use chemical substances to produce the desired end product. Finishes that create designs are applied with chemicals such as; sulfuric acid, phenol, and sodium hydroxide (Collier & Tortora, 2011) using a method similar to printing (Orzada & Moore, 2008). Alternatives to safer methods of textile finishing are available however; the environmental impacts are never fully eliminated.

Environmental hazards also come in the form of emissions to air. Air pollutants also happen during the finishing stages such as; drying, printing, fabric preparation and through wastewater treatment residues (IFC, 2007). Solvents are released into the air as residual from coating/ finishing fabrics, and from high-temperature drying ovens. Solvents released into the air are harmful because they may contain compounds like acetaldehyde, chlorofluorocarbons, dichlorobenzene, ethyl acetate, methylnaphthalene, chlorotoluene, and many others (IFC, 2007).

Distribution. Transportation to the consumer is a large factor when considering the LCA because large amounts of gas are used to transport. Now with higher gas prices the freight charges have also increased. However, the transportation piece of distribution does not only take place after manufacturing. Transportation is a large environmental factor that happens in between each step of the life cycle. With raw materials grown in one county and fabric production and garment assembly done in another, the garment crosses the globe several times before it reaches the retail floor (Payne, 2011). The distribution phase also focuses on simplifying the amount of packaging used to make the product floor ready. Extra packing added at the end of production affects the cost of the product and creates more waste that ends up landfills. It is extremely hard to quantify the transportation impact.

Consumer Use. Consumer Use of the life cycle assessment process is geared to the consumer and is no longer within the manufacturers control. This phase encourages consumers to buy only when needed and take care of clothes to prolong the life. Programs show that companies put much effort into encouraging customers about the benefits of taking great care of their cloths such as; Levi Strauss & Co. "Care tag, for our Planet", reminding consumers to wash in cold and wash less (www.levistrauss.com), mainly because consumer use has a larger environmental impact than production in some textile products (Fletcher, 2008). Therefore, from the viewpoint of a designer or manufacturer it is important to consider the use of the garment throughout its life cycle when discussing sustainability.

Table 2.2 illustrates the environmental impact by textile category reprinted from "Sustainable fashion and Textiles: design journeys"(Fletcher, 2008). The table shows that with clothing, workwear, and household textiles have a much larger environmental impact in the consumer use stage. Although, the consumer use stage is very important, there is little focus from designers on the consequences of laundering and the use and care of garments and no mentions of designing to reduce the impact of the consumer use stage (Fletcher, 2008). Studies have shown that the major environmental impacts of the consumer use stage are attributed to home laundering techniques. However, the study most widely known was performed by Franklin Associates in 1993 was the LCA of a manufactured polyester knit blouse. Results show that 82% of energy use, 66% of solid waste, over half of the emissions to air (83% carbon dioxide) and large quantities of waterborne effluents accumulate during washing and drying (Fletcher, 2008).

Table 2.2

A rough guide of relative impact of textile products throughout life by textile category.

	Production	Use	Disposal
Clothing	+	+++	+
Workwear	+	+++	+
Household Textiles	+	+++	+
Furnishings	+++	+	++
Carpet	+++	+	++

Key: +small relative impact; ++medium relative impact; +++large relative impact. Reprinted from "Sustainable fashion and textiles: design journeys," by K. Fletcher, 2008, p. 77. Copyright 2008 by Earthscan.

Although laundering habits may seem very minimal to the entire life cycle especially with furnishings and carpets, there are far larger environmental benefits when improvements and changes are made to laundering habits. The key issues of laundering are energy, water and detergent use in washing, and energy used in drying and ironing (Fletcher, 2008). Studies show the following:

- washing at lower temperatures reduces energy consumption by 10% for every 10°C reduction (Fletcher, 2008).
- eliminating tumble drying (reduces energy by 60%); and

- no ironing combined with lower washing temperatures can lead to 50% less total energy consumption of the product (Fletcher, 2008).

Detergents are also a key issue within the consumer use phase that may have a large impact on the environment. To reduce the quantity of detergent used, solutions such as

- Switching to concentrated detergent uses less chemicals and less packaging (Fletcher, 2008)
- Moving back to standard detergents is an option in order to assure consumers are using the right level of detergent when washing to avoid overdosing.
- Eliminating detergents all together and use washing balls filled with ceramic balls that ionize oxygen molecules in the water to lift dirt from clothes (as detergent would) without the use of chemicals.

On the other hand dry cleaning methods use a combination of liquid solvents and detergents. Perchloroethylene (perc), is the most commonly used liquid dry cleaning solution that is a petrochemical-based solvent (Fletcher, 2008). It is coupled with detergent and the garment and agitated in a machine to remove dirt, oils and stains. However it causes serious damage to the central nervous system, liver, kidneys and reproductive system after long periods of exposure (Fletcher, 2008). As you can see, the consumer use stage has a variety of cleaning methods that are harmful to the environment and human health over a period of time. As sustainable fashion evolves, designers and manufactures cannot ignore the consumer use stage as it has significant impact. Designing and manufacturing with the care of garments in mind will encourage consumers to think responsibly and instill value into the wardrobes. In doing so, there is a better chance of prolonging the life of beloved fashion items and successfully closing the loop of a product's life cycle.

Disposal. What choices do consumers make when their favorite apparel item is no longer meeting their needs? Do they donate it? Do they re-sell it? Or maybe they simply throw it away. The disposal stage is the end of the product life cycle and Fletcher (2008) points out that a consumer's behavior is equally about disposal as it is buying. Morgan and Birtwistle (2009) conclude that young consumers felt that fast fashion encouraged a ‘throwaway culture’ were products and fashion lost intrinsic value, encouraging consumers to replace and dispose of products before the end of their intended life cycle. Manufacturers and designers can constantly make improvements to sustainable fashion however, if the consumer is not aware of ways to help make a positive environmental impact, the work is null and void. Utilizing the LCA data helps manufacturers and designers better identify the environmental impacts and inform consumers on how to close the loop.

The facts show that the U.S. generates on average 25 billion pounds of textiles per year (EPA, 2009), which equates to about 82 pounds per U.S. resident. But of that 82 pounds per U.S. resident only 15% is donated or recycled (CTR, 2015). That leaves a whopping 85% of all textiles are released into landfills (EPA, 2009). Or roughly, 70 pounds of textiles are thrown away by consumers yearly (CTR, 2015). The disposal stage encourages recycling and donating. The goal is to reduce the amount of waste going to landfills, to help positively affect our environment.

The most commonly known waste management strategies are the 3 R’s, also known as reduce, reuse, and recycle. Reduce means to simply not buy. Eliminate the amount owned and purchased. The EPA (2015) encourages consumers to buy products with less packaging such as products with less added hangtags, no plastic wrap, or no plastic hangers. The reuse of products refers to using the product for the same purpose or for something completely different. Repair or reconditioning garments for new use has been around for many generations and was originally done for economic reasons (Fletcher, 2008). Repairing old items was practiced in the industry and in homes because the labor was cheaper than purchasing new textile materials and garments (Fletcher, 2008). To create new life, in home techniques were replacing shirt collar and cuffs, using old denim and knitwear to create blankets, cutting worn bed linens and clothing for household cleaning purposes, patching trousers and jackets etc. However, the modern day repairing and reconditioning of textiles and garments has decreased as a result of low prices and the demand for the latest trends (Fletcher, 2008). Reusing also considers donating unwanted items to charity groups or even to a family member or friend. “One mans trash is another man’s treasure”. This old cliché saying has a rewarding undertone in the fact that when donating not only are you preventing landfill waste but experiencing a far better reward in helping others in need. The benefits of reducing and reusing are vast, but the EPA (2015) list several important benefits for consumers such as

- prevents pollution caused by reducing the need to harvest new raw materials;
- saves energy and money;
- reduces greenhouse gas emission that contribute to the global climate change;
- helps sustain the environment for future generations;
- reduces the amount of waste to be recycled or sent to landfills and incinerators; and
- allows products to be used to their fullest extent.

Last, recycling is the process of collecting and processing materials that is considered trash and turning it into a new product. Recycling saves resources and uses less energy than the production of new items. Extracting fibers from fabrics is the mechanical process by which garments are made new. Many programs specialize in recycling old to new. Cotton Inc. established a recycling program called “The Cotton From Blue to Green” in 2006 to emphasize the natural and environmental attributes of cotton and to offer people the opportunity to give back to their community (Cottoninc.com). Cotton Inc. takes all donated denim and partners with Bonded Logic Inc. to transforms denim back to cotton fibers and into UltraTouch™Denim Insulation for homes and civic building for communities in need. Patagonia is also another company that uses recycled materials to form new sustainable products. Patagonia uses recycled nylon, recycled polyester, and recycled wool in their product lines to help lessen their environmental footprint. Using recycled nylon helps reduce the their dependency on petroleum (Patagonia.com). In 1993 they also were the first company to transform trash into fleece using plastic soda bottles, hence producing recycled polyester (Patagonia.com). The use of recycled wool reduces the land use for sheep gazing, eliminates the dyeing process by using and blending a variety of colored dyed wools, and encourages new recycling opportunities for wool products that are no longer usable (Patagonia.com). While synthetic textiles do not decompose and woolen textiles create methane when decomposed, recycling garments is a sure way to protect our nations’ landfills. The possibilities are endless with recycling and have many environmental and economic benefits.

Life Cycle Assessment

An undeniable fact is that any apparel product or textile product manufactured, requires the use of raw materials, energy, equipment, and labor, which are determined in the design and product development stage.   While decisions are being made about manufacturing, usage, maintenance, and the disposal of an apparel product, the environment impacts are also being considered (Orzada & Moore, 2008). Hence, the Life Cycle Assessment (LCA) is necessary because it is a detailed analysis of a product's design by assessing the environmental and economic impacts during the product's life cycle to ensure sustainable development. It describes the entire life of a product, which encompasses raw material extraction, material production, manufacturing, product use, the end-of-life disposal, and all the transportation that occurs in between each stage (ANSI/ISO 14040-1997). The LCA is a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ANSI/ISO 14040-1997).

Sivaramakrishnan (2012) notes that the "LCA explains in detail the waste potential, energy usage and environmental effects of each stage" (p.50). In the development stages of a sustainable product, assessment tools have been integral in the process, giving designers and manufacturers an internal report card (Curwen, Park, & Sarkar, 2013). Life cycle analyses are critical for understanding the global progress of reducing negative impacts on the environment. Currently, the LCA is the most comprehensive approach to assessing the environmental impacts of an apparel product and is graded by the ISO 14040-14043 industry standard (Sivaramakrishnan, 2012). The Life Cycle Assessment does not include social or economic impacts of sustainability.

The Life cycle assessment framework is described in four phases as seen in Figure 2.3. The assessment is based on the goal and scope, inventory analysis, impact assessment and interpretation of results (ANSI/ISO14040-1997 14040-1997). The significance of the LCA is to evaluate the impact of the production process on the environment.

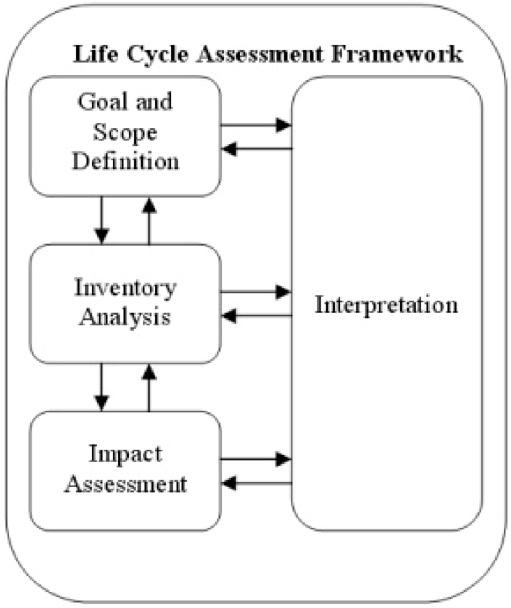

Figure 2.3. The Life Cycle Assessment Framework. Adapted from "The Life cycle assessment Part 1: Framework, goal and scope definition, inventory analysis, and applications," by G. Rebitzer, T. Ekvall, R. Frischknecht, D. Hunkeler, G. Norris, T. Rydberg, W. –P. Schmidt, B. P. Weidema, D. W. Pennington, 2004, Environmental International 30, 5, p. 4. Copyright 2004 by Environmental International.

Goal and Scope. The first phase of the LCA begins with the goal and scope which sets the context of the study. The goal and scope can be defined as, " the functional unit, which defines what precisely is being studied and quantifies the service delivered by the product system, providing a reference to which the inputs and outputs can be related. Further, the functional unit is an important basis that enables alternative goods, or services, to be compared and analyzed (Rebitzer et al., 2004). The goal and scope will also indicate:

- the system boundaries;
- any assumptions and limitations;

- the allocation metods used to partition the envrionmental load of a process when several products or functions share the same process (The Functional Unit);
- the impact categories chosen (14040-1997).

Life Cycle Inventory Analysis (LCI). The Life Cycle Inventory Analysis focuses on inventory flows to and from nature. The inventory flows are the inputs of water, energy, and raw materials and the outputs into the air, land, and water. A flow chart is typically used to illustrate the what is being assessed with in the study and process of sustainable design. The quality of the data being assessed is entirely dependent on the product's availability of information and should be checked against several resources (ISO 14040:2006). When the study is complete, the inventory analysis, the model will reveal quantitative results of the product's total emissions, waste, energy consumed, and resouces used throughout the it's life cycle (Baumann and Tillman,).

Life Cycle Impact Assessment (LCIA). After the inventory analysis, follows the impact assessment. This phases focuses on taking the results of the inputs and outputs and strategically categorizes them. Data is orgaznized into a flowchart of the processess that represent the input and output flows. During the impact assessment, the researcher should be sure to represent a full picture of the prouct's environment impact, while not loosing focus on insignificant factors (Hsu, 2009). The mandatory elements of the impact assessment are

- the selection of impact categories, category indicators, and characterization models;
- the classificaiton stage, where the inventory parameters are sorted and assigned; and
- impact measurement, indicating where the inventory in categories are characterized, using many possible LCA methodologies.

Life Cycle Interpretation. The interpretation of the study aids in ensuring the validity of the study. It is important to review the results by identifying key data elements that had a large significance to the study and the environment. The ISO 14040:2006 requires the interpretation phase to have:

- identification of significant issues based on the results of the LCI and LCIA phases of a LCA;
- evaluation of the study considering completeness, sensitivity and consistency checks; and
- conclusions, limitations and recommendations.

According to the ISO 14042, the Life Cycle Impact Assessment (LCIA) standard, the three main groups of environmental impact are resource use, human heatlh consequences, and ecological consequences. The environmental imapct groups are further divided into categories, included are: climate change, stratosphere ozone depletion, photooxidant formation (smog), eutrophicaton, acidification, water use, noise (Pennington, Potting, Finnveden, Lindeijer, Jolliet, Rydberg, Rebitzer, 2004). The LCIA also consist of mandatory and optional elements. The International Organization for standardization (ISO) 14042 (2003) states the mandatory elements of the LCIA are the impact categories, category indicators, and characterization models, impact results, and calculation of category indicator results. The optional elements as outlined in the ISO 14042 standards, are the calcultations of the magnitude of category indicators, grouping and/or weighing of results, and data quality analysis.

There are differences in conducting LCAs because many LCIAs address different questions and products, therefore, resulting in the use of different approaches. There is no single method that is applicable in all situations. Some LCAs focus on the waste and emissions of a product life cycle inventory, but often do not reflect the full extent of releases nor are they necessarily associated with the product of interest in the study (Pennington et al., 2004). Since the LCA is a comparative assessment methodology, inconsistences vary and may introduce unintentional bias (Pennington et al., 2004). LCAs can also differ in the risk and impacts estimated. Pennington et al., (2004) gives an example comparing two LCAs that analyze toxicological impacts, one may estimate impacts to the whole population whereas common toxicology impact approaches the specific exposure concentrations for individuals are compared to policy-based toxicity thresholds or standards. Furthermore, the independent developments of LCAs have led to discrepancies between methods that cannot be explained by necessity alone, therefore allowing historical factors to play an important role (Goedkoop et al., 2013).

ReCiPe 2008 LCA Method

LCAs have gained popularity since the 1990s when the first studies were conducted on products regarding sustainability. The CML (Centrum Milieukunde Leiden), the Eco-indicator 95, and the later version Eco-indicator 99 are LCA methodologies that paved the way of examining environmental impacts and are widely accepted methodologies (Goedkoop et al., 2013). The CML approaches the baseline method of characterization (the midpoint) and the Eco-indicator 99 focuses on the interpretation of results (the end point) (Goedkoop et al., 2013). It was deemed important and desirable to develop a methodology where midpoint and endpoint could be used. Therefore, the ReCiPe method and design was developed by a group of LCA experts from RIVM, CML, PRé Consultants, and Radboud University Nijmegen (see Appendix A). The ReCiPe 2008 LCA tool condenses and combines the long list of inventory results into a small limited number of environmental impact categories (midpoint and endpoint categories) (Goedkoop et al.). The method is designed according to the Cultural Theory by Thompson in 1990 that follows three perspectives: individualist (I), hierarchist (H), and egalitarian (E) (Goedkoop et al., 2013; Thompson, Ellis, & Wildavsky, 1990). Throughout the study the perspectives are subjective and affect the results of the endpoint depending on the perspectives of the researcher.

- Perspective (I) is based on the short term, undisputed impact types, technological optimism (Thompson et al., 1990)
- Perspective (H) is based on the most common policy principles in regards to time-frame and other issues (Thompson et al., 1990).
- Perspective (E) takes into account the longest time-frame and impacts that are not fully developed or established (Thompson et al., 1990).

ReCiPe 2008 indicates eighteen midpoints, much like the CML, and more importantly three endpoint categories as the main principles of the method. The basis and environmental issues linked to the midpoint and endpoint indicators are; climate change, ozone depletion, acidification, eutrophication, toxicity, human health damage due to PM_{10} and Ozone, ionizing radiation, land-use, water depletion, mineral resource depletion, and fossil fuel depletion (Goedkoop et al., 2013). Because the midpoint categories are quite difficult to understand, extensive work was put in to make the endpoint categories a short, clear and easy interpretation of the midpoints (Goedkoop et al.). As a requirement of the ISO 14044 standard the characterization factors or impact categories must be based on environmental mechanisms that link man-made interventions to a set of areas of protections (Goedkoop et al., 2013). In Figure 2.4 the structure of the ReCiPe 2008 is illustrated with midpoints and endpoints highlighted red.

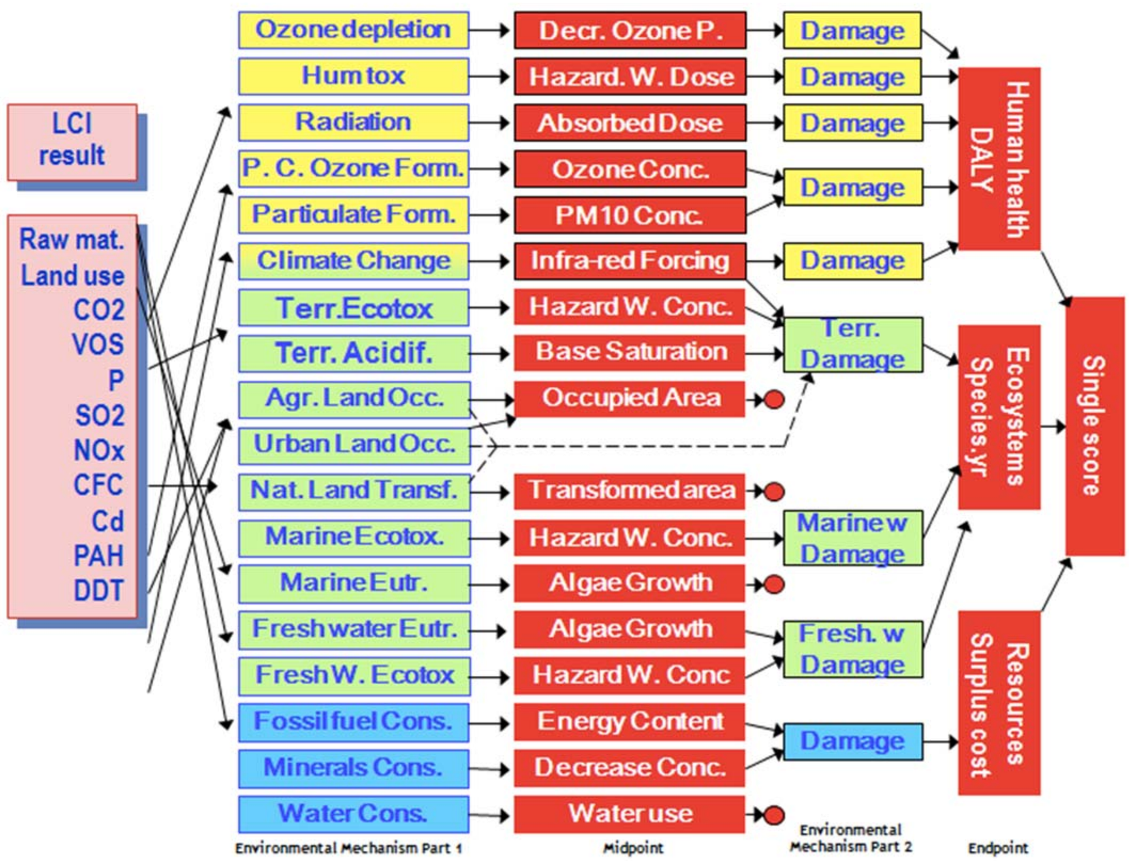

Figure 2.4. Relationship between LCI parameters (left), midpoint indicator (middle) and endpoint indicator (right) in ReCiPe 2008. Reprinted from "ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level," by M. Goedkoop, R. Heijungs, M. Huijbregts, A. D.

Schryver, J. Struijs, R. V. Zelm, 2013, p. 3. Copyright by RIVM, CML, PRé Consultants, and RUN, 2013.

Furthermore, impact categories are merely names of the environmental mechanisms, and impact indicators are measurable data points of the impact categories. Lastly, the midpoint travels through the system to an endpoint (category of damage). Therefore, the endpoint is better explained as the areas of protection that form the basis of decisions in policy and sustainable development (Goedkoop et al., 2013).. The eighteen midpoints are expressed as follows; Climate Change (CC), Ozone Depletion (OD), Terrestrial Acidification (TA), Freshwater Eutrophication (FE), Marine Eutrophication (ME), Human Toxicity (HT), Photochemical Oxidant Formation (POF), Particulate Matter Formation (PMF), Terrestrial Ecotoxicity (TET), Freshwater Ecotoxicity (FET), Marine Ecotoxicity (MET), Ionizing Radiation (IR), Agricultural Land Occupation (ALO), Urban Land Occupation (ULO), Natural Land Transformation (NLT), Water Depletion (WD), Mineral Resource Depletion (MRD) and Fossil Resource Depletion (FD). Table 2.3 is an explanation of midpoint categories, indicators, and characterization factors

Table 2.3

Overview of midpoint categories, indicators, and characterization factors.

Impact Category Name	Impact Abbr.	Indicator Name	Unit Indicator Result	Characterization Factor Name	Char. Abbr.
Climate Change	CC	Infra-red radiative forcing	kg (CO_2 to air)	Global warming potential	GWP
Ozone Depletion	OD	Stratospheric ozone concentration	kg (CFC-11[5] to air)	Ozone depletion potential	ODP
Terrestrial Acidification	TA	Base saturation	kg (SO_2 to air)	Terrestrial acidification	TAP
Freshwater Eutrophication	FE	Phosphorus concentration	kg (P to freshwater)	Freshwater eutrophication potential	FEP
Marine Eutrophication	ME	Nitrogen concentration	kg (N to freshwater)	Marine eutrophication	MEP
Human Toxicity	HT	Hazard-weighted dose	kg (14DCB to urban air)	Human toxicity potential	HTP
Photochemical Oxidant Formation	POF	Photochemical ozone concentration	kg (NMVOC[6] to air)	Photochemical oxidant formation potential	POFP
Particulate Matter Formation	PMF	PM_{10} intake	kg (PM_{10} to air)	Particulate matter formation potential	PMFP
Terrestrial Ecotoxicity	TET	Hazard-weighted concentration	kg (14DCB to industrial soil)	Terrestrial ecotoxicity potential	TETP

Table 2.3 (continued)

Overview of midpoint categories, indicators, and characterization factors.

Impact Category Name	Impact Abbr.	Indicator Name	Unit Indicator Result	Characterization Factor Name	Char. Abbr.
Freshwater Ecotoxicity	FET	Hazard-weighted concentration	kg (14DCB to freshwater)	Freshwater ecotoxicity potential	FETP
Marine Ecotoxicity	MET	Hazard-weighted concentration	kg (14-DCB[7] to marine water)	Marine ecotoxicity potential	METP
Ionizing Radiation	IR	Absorbed dose	kg (U^{235} to air)	Ionizing radiation potential	IRP
Agricultural Land Occupation	ALO	Occupation	m2xyr (agricultural land)	Agricultural land occupation potential	ALOP
Urban Land Occupation	ULO	Occupation	m2xyr (urban land)	Urban land occupation potential	ULOP
Natural Land Transformation	NLT	Transformation	m2 (natural land)	Natural land transformation potential	NLTP
Water Depletion	WD	Amount of water	m3 (water)	Water depletion potential	WDP
Mineral Resource Depletion	MRD	Grade decrease	kg (Fe)	Mineral depletion potential	MDP
Fossil Resource Depletion	FD	Lower heating value	kg (oil)	Fossil depletion potential	FDP

Adapted from “ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level,” by M. Goedkoop, R. Heijungs, M. Huijbregts, A. D. Schryver, J. Struijs, R. V. Zelm, 2013, p. 6. Copyright by RIVM, CML, PRé Consultants, and RUN, 2013.

The areas of protection that help retailers form decisions about sustainable development are the endpoints of the LCA. Table 2.4 list the areas the midpoints effect. As the basis of the ReCiPe 2008 method, the endpoint categories are explained in further detail to better understand their significance and connection.

Table 2.4

Overview of the endpoint categories, indicators and characterization factors.

Indicator Category Name	Abbr.	Indicator Name	Unit
Damage to human health	HH	Disability-adjusted loss of life years	yr
Damage to ecosystem diversity	ED	Loss of species during year	yr
Damage resource availability	RA	Increased cost	$

Reprinted from “ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level,” by M. Goedkoop, R. Heijungs, M. Huijbregts, A. D. Schryver, J. Struijs, R. V. Zelm, 2013, p. 7. Copyright by RIVM, CML, PRé Consultants, and RUN, 2013.

Human Health. The World Health Organization (WHO) describes Human Health as the state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 2015). Human health is affected directly by changing weather patterns and indirectly through the changes in water, air, food quality and quantity, ecosystems, agriculture, livelihoods and infrastructure (Confalonieri et al., 2007). The ReCiPe 2008 method assesses the damage to Human health using the DALY concept created by Hofstetter in 1998. DALY is the ‘disability-adjusted life years’ (Goedkoop et al., 2013; Hofstetter, 1998). Goedkoop et al. (2013) explains DALY to be the sum of years of life lost (YLL) and years of life disabled (YLD):

$$DALY = YLL + YLD \tag{2.1}$$

$$YLD = w \times D \tag{2.2}$$

while $\boldsymbol{w}$ equals a value between 0 (complete health) and 1 (dead), and $\boldsymbol{D}$ is the duration of the disease.

Although the DALY is a useful calculation of human health damage, it is subjective. Depending on the researcher's perspective, and specified region and time frame, calculation methods and results my vary (Goedkoop et al., 2013). Some LCIA methods calculate the DALY without applying age specific weighting (Hellweg, Hofstetter, & Hungerbuhler, 2005; Hofstetter & Hammitt, 2002). Krewitt, Pennington, Olsen, Crettaz, and Jolliet (2002) agree and calculate the YLD using a subjective assessment of weighing health disabilities. Due to the disagreements, LCIAs often exclude the use of YLD. Therefore, since the DALY calculation is subjective, debates regarding the most efficient and effective methods are very much existent. However, the ReCiPe 2008 method address the DALY Human health calculation by including years of life lost and years of life disabled, without age weighting and discounting (Goedkoop et al., 2013).

Ecosystem. The ecosystem is described as "living organisms and their dead organic matter produced by them, the abiotic environment where they live and exchange elements (soils, water, atmosphere), and the interactions between these components" (Ellis, 2014). Living organisms are continually interacting with each other and the environment to produce complex systems. Everything is connected. Moreover, Ellis (2014) explains that ecosystems use energy and cycle matter; and since energy does not cycle, ecosystems require continuous flow of high quality energy to maintain their structure and function. Therefore, when evaluating the quality of the ecosystem, energy, matter and information flows are measured (Goedkoop et al., 2013). A thriving ecosystem is one that allows flows to occur without disruption from pollution emissions created by human activity. However, when discussing the condition of the ecosystem the level at which causes the most disruption is of most importance. Ecosystems are very complex and observers and researches may evaluate and measure the boundaries differently. The ReCiPe 2008 method ensures that the focus and interpretation of the ecosystem is on the information flow at the species level (Goedkoop et al., 2013).

The level at which ecosystem quality is measured is based on "the reversible or irreversible disappearance of a species or stress on a species in a certain region during a certain time" (Goedkoop et al., 2013) . The Eco-Indicator 99 method expressed the potentially disappeared fraction of species integrated over area and time as PDF (Goedkoop et al., 2013; Goedkoop & Spriensma, 2000). Goedkoop et al. (2013) further calculates the endpoint characterization factor for the ReCiPe 2008, adapted from the Eco-Indicator 99, using the following components:

- CF_{ED} = the endpoint characterization factor for ecosystem damage
- PDF_{terr} = the characterization factor in PDF.m^2.yr, and SD_{terr} the species density factor for terrestrial systems, in species/m^2
- PDF_{fw} = the characterization factor in PDF.m^3.yr, and SD_{fw} the species density for freshwater systems in Species/m^3.
- PDF_{mw} = the characterization factor in PDF.m^3.yr, and SD_{mw} the species density for marine water systems in Species/m^3

Therefore,

$$CF_{ED} = PDF_{terr} \times SD_{terr} + PDF_{fw} \times SD_{fw} + PDF_{mw} \times SD_{mw} \qquad (2.3)$$

The species density included in the above equation is determined by finding out how many species there are, how the distribution of species is over land, fresh and marine water, and the right surface and volume to use (Goedkoop et al., 2013). The total amount and type of species and surface and volume use was acquired from GEO 2000 by UNCEP (Goedkoop et al., 2013). The distribution of species over terrestrial, freshwater and marine water was adapted from Dudgeon et al. (2006). Furthermore, the data researched in the previous sources were analyzed to give the following species densities:

- Terrestrial species density: 1.48 E-8 [1/m^2];
- Freshwater species density: 7.89 E-10 [1/m^3]; and
- Marine species density: 3.46 E-12 [1/m^3] (Goedkoop et al., 2013).

Resources. When discussing the earth's resources the most important issue is whether or the environment has a sufficient amount to sustain future generations. The Life Cycle Initiative task force has categorized natural resources into three categories that were address at the midpoint level. Natural resources are classified as biotic, abiotic and land (UNEP & SETAC, 2015). In Table 2.5, some of the resources used and their functions are categorized according to their function and properties.

Table 2.5

Overview of Resource function and properties.

Resource	Subcategory	Type	Essential property lost?	Recycling possible	Function	Time shortages can occur	Alternatives
Minerals	Metals	Stock	No	Yes	Construction	Centuries	Many, also wood, etc.
	Uranium	Stock	Yes	No	Electricity	Centuries	No (fission?)
Fossil fuel	-	Stock	Yes	No	All energy	Decades	Within the group
Wind, water, solar energy	-	Flow	Yes	No	Electricity	Indefinite	Within the group
Energy crops	(see also agriculture)	Flow	Yes	No	All energy	See agriculture	Other energy
Water	-	Fund/flow	No	Yes	Agriculture, humans, ecosystems	Present	No
Bulk resources	-	Fund	Sometimes	Sometimes	Infra-structure, housing	Centuries or longer	Within group

Table 2.5 (continued)

Overview of Resource function and properties.

Resource	Subcategory	Type	Essential property lost?	Recycling possible	Function	Time shortages can occur	Alternatives
Land (surface)	For urban use	Fund/flow	Sometimes	Sometimes	Living, transport, working	Present	Intensify use
	For agricultural use	Fund/flow	Sometimes	Sometimes	Feeding, energy corps	Present	Intensify use
	For natural areas	Fund/flow	Sometimes	Sometimes	Recreation, “sustainability”	Present	No
	Water surface	Fund/flow	Sometimes	Sometimes	Recreation, transport	Present	Intensify
Silvicultural extraction	Hunting, fishing, herb collection	Fund/flow	Yes	No	Feeding, medicines, energy (in Third World)	Present	Agriculture
	Wood for construction	Flow	Yes	Sometimes	Housing, furniture	Present	Metals, bulk resources

Adapted from “ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level,” by M. Goedkoop, R. Heijungs, M. Huijbregts, A. D. Schryver, J. Struijs, R. V. Zelm, 2013, p. 11. Copyright by RIVM, CML, PRé Consultants, and RUN, 2013.

However, the ReCiPe method is based on abiotic resources only, which consist of mineral and fossil fuel resources. The model is based on the marginal increase in costs due to extraction of resources (Goedkoop et al., 2013). The marginal cost increase (MCI) is expressed as:

$$MCIr = \frac{\Delta Costr}{\Delta Yieldr} \qquad (2.4)$$

Where r is the cost of a commodity (US$/kg) divided by the extraction or the yield (kg) of the resource. MCI is expressed in US dollars. The marginal cost increase has a insignificant meaning and could be quite small therefore, in order to show significance the MCI must be multiplied by a factor that expresses the amount used (Goedkoop et al., 2013). So, the present value cost (PVC) is determined. The PVC is:

$$PVCr = \sum T \frac{Pr,t\ X\ MCIr}{(1 \mp d)t} \qquad (2.5)$$

Therefore, “the PVC to society due to an extraction can be calculated by summing the marginal cost increase for each year *t* in the future, multiplied by the annual consumed amount in that year (Pr,t in kg per year) divided by the increase cost due to the discount rate” (Goedkoop et al., 2013, p. 12).

Overall, the environmental impacts are expressed at the midpoint and endpoint levels. Once all impact categories have been coupled with impact indicators midpoint and endpoint characterization factors are linked together by formulas. The midpoint characterization level is expressed:

$$I_m = \sum_i Q_{mi}\ m_i \qquad (2.6)$$

m_i is the magnitude of intervention, Q_{mi} the characterization factor that connects intervention ***i*** with midpoint impact category *m, and* I_m is the indicator result for midpoint impact category *m* (Goedkoop et al., 2013)**.** Next the endpoint characterization level is expressed in two ways. The first approach is expressed:

$$I_e = \sum_i Q_{ei}\, m_i \qquad (2.7)$$

Where m_i is the magnitude of intervention i, Q_{ei} is the characterization that connects i with the endpoint category e and I_e is the indicator result for endpoint impact category e (Goedkoop et al., 2013). Starting from the intermediate midpoints, the second approach to the endpoint level results is expressed:

$$I_e = \sum_m Q_{em} I_m \qquad (2.8)$$

I_m is the indicator result for midpoint impact category m, Q_{em} is the characterization factor that connects midpoint impact category m with endpoint impact category e and I_e is the indicator result for endpoint impact category e (Goedkoop et al., 2013).

The entire ReCiPe 2008 LCA tool has not be placed in this study nor explained in its entirety due to the length of the report. A full detailed report of the procedures and methods of the ReCiPe 2008 LCA tool can be found at http://www.lcia-recipe.net/file-cabinet.

Summary

The related literature provides an understanding of the major factors that affect the sustainability of an apparel product. The emergence of sustainability in the fashion industry stems from the Fast fashion strategies that are consumer driven. Due to the overabundance of goods that fast fashion promotes, sustainability has been neglected. As noted by Barnes & Lea-Greenwood (2006) the aim of fast fashion is to reduce the processes involved in the buying cycle and lead times for getting new product to the stores, in order to satisfy consumer demand at its peak. The literature shows the impact of fashion on a retailer's profits and discusses the strategies used to acquire goods rapidly. Fast fashion is important to consider when developing a product because the sustainable design must include the aesthetic features to follow the emerging fashion trends appealing to the environmental concerns of the consumer. The factors influence the disposal of the garment (the consumer's responsibility) and the production phase (the manufacturer's responsibility).

In the 21st century sustainability is often paired with corporate social responsibility, to place responsibilities on the retailers and manufacturers to be aware of their carbon footprint on the environment. Sustainable fashion also coincides with social responsibility in regards to the developing stages of an apparel product. Creating sustainable fashion consist of the retailer & manufactures making an informed decision to be socially responsible, environmentally sustainable, economically viable, and designing with integrity. Therefore, the fashion industry must work diligently to become more transparent with manufacturing procedures for the consumer's knowledge.

Life Cycle Assessments are critical to sustainable fashion, because they trace the steps and procedures of production to ensure the sustainability of the garment. Although LCAs are widely used by retailers, they are very time consuming and costly. As environmental concerns become more of a global issue LCAs will help quantify a company's environmental footprint. Equally, as consumers demand to know the environmental of the products they purchase, LCAs will gain importance across the industry and help manufacturers meet customer needs and concerns. However, the results of a LCA have to be interpreted and weighed therefore, the results are not straightforward all the time and simple enough to determine one product over the other (B.V., 2000). Therefore producing data from the LCA gives the manufacturer a convincing way to ensure and market to the consumer the environmental advantages of purchasing a sustainable product.

Chapter Three

Methodology

The overall purpose of this research was to compare the environmental implications of widely produced and owned apparel products through a life cycle assessment approach. In general, apparel products undergo a long list of processes during the production phase and have resulted in decades or even centuries of developments, in a mix of continued improvements or clarification of existing production processes and changes when new opportunities arise (Nielsen & Nielsen, 2009). The expectation is that the results can be used for further research to explore labeling issues and techniques of the development stages of sustainable fast fashion.

The following section will summarize the methodology used to compare the results from the initial life cycle assessments of a denim jean and cotton t-shirt. It will focus on the most important impact categories consumers should be concerned with upon purchasing. This research can be used as a reference tool to help reduce the carbon footprint through the designing process of sustainable fashion on widely manufactured products. Furthermore, this research will justify the abundance of consumer purchases, on denim jeans and t-shirts, in regards to the environmental impact. This study compares the environmental impacts of a denim jean and dyed cotton t-shirt utilizing the ReCipe 2008 LCA tool. Therefore, the methodology will include the goal and scope and inventory analysis of a life cycle assessment.

The environmental impact potentials are expressed at midpoint and endpoint. The midpoint characterization level is expressed:

$$I_m = \sum_i Q_{mi}\ m_i \tag{3.1}$$

m_i is the magnitude of intervention, Q_{mi} the characterization factor that connects intervention $\boldsymbol{i}$ with midpoint impact category m, and I_m is the indicator result for midpoint impact category m (Goedkoop et al., 2013). Next the endpoint characterization level is expressed in two ways. The first approach is expressed:

$$I_e = \sum_i Q_{ei}\, m_i \qquad (3.2)$$

Where m_i is the magnitude of intervention i, Q_{ei} is the characterization that connects i with the endpoint category e and I_e is the indicator result for endpoint impact category e (Goedkoop et al., 2013). Starting from the intermediate midpoints, the second approach to the endpoint level results is expressed:

$$I_e = \sum_m Q_{em}\, I_m \qquad (3.3)$$

I_m is the indicator result for midpoint impact category m, Q_{em} is the characterization factor that connects midpoint impact category m with endpoint impact category e and I_e is the indicator result for endpoint impact category e (Goedkoop et al., 2013).

Research Design

This study is a comparative analysis of life cycle assessments conducted on the Levi's® 501® jeans and a colored cotton t-shirt by EDIPTEX. The qualitative research design was used to determine the most efficient method to analyze the environmental impacts of a single pair of jeans and a cotton t-shirt. Data was analyzed and compared in accordance with a life cycle assessment framework.

Goal and Scope

The study is based on life cycle assessment (LCA) principles according to the ISO 14040 standards where all significant processes from "cradle to gate" are included. Cradle to gate is an assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (ex. before it is transported the consumer). This LCA compares the environmental impacts of widely owned fashion items using an accounting method in a short-term LCA. Although the Gabi 6 LCA software was not available for this study, the ReCipe 2008 LCA method was utilized to compare existing LCA results under the same parameters.

Functional Unit. The functional unit is the comparison of two high volume fast fashion items. The production of 1 pair of Levi's® 501® medium stonewash jeans and 1 color dyed T-shirt. The weight of the jeans is around 340g and the weight of the T-shirt is around 250g.

System Boundaries. The study addressed the cradle to gate phases of the life cycle of a denim jean and T-shirt. The system boundaries assessed were raw materials production, fabric production, garment manufacturing and transportation and distribution.

Materials phase. The material phase covers cotton cultivation needed to produce 1 pair of denim jeans and 1 T-shirt. Cotton cultivation often requires fertilizers for the land, the use of large amounts of water, and pesticides to prevent insect, worms and weeds (Laursen et al., 2007). This study includes the procedures used in the extraction of cotton for the production of 1 pair of denim jeans and 1 T-shirt.

Production phase. A large amount of environmental impacts occur in this phase due to the steps taken to prepare cotton for the finished product. The production phase includes fiber and yarn manufacturing, finishing processes (pre-treatment and dyeing) and garment manufacturing and make-up. All phases of production were considered in the LCA and the most important environmental impacts were assessed.

Environmental Impact Categories. Environmental impact potentials were expressed at a midpoint and endpoint level. The environmental impact categories and their descriptions used in this study are shown in Table 3.1. The following categories were adapted from the life cycle assessment of a Levi's® 501® jean conducted by Levi Strauss & Co. Present in the ReCiPe 2008 methodology as essential environmental impact categories are; Ozone Depletion (OD), Terrestrial Acidification (TA), Human Toxicity (HT), Photochemical Oxidant Formation (POF), Particulate Matter Formation (PMF), Terrestrial Ecotoxicity (TET), Freshwater Ecotoxicity (FET), Marine Ecotoxicity (MET), Ionizing Radiation (IR), and Natural Land Transformation (NLT) that were excluded from this study. Furthermore, the results will reveal the significant damage the midpoint category indicators have on the endpoint categories; human health, ecosystems and resources. Adding the endpoint categories is the basis of the ReCiPe 2008 method.

Table 3.1

Impact Categories and descriptions.

Environmental Impact Categories		
Category	Description	Units
Climate Change	Global warming potential of greenhouse gases release to the environment	kg CO_2-e
Water Consumption	Net freshwater taken from the environment minus water returned to the same watershed at the same quality or better	liters
Eutrophication	Oxygen depletion as a result of nitrogen and phosphorous deposit into freshwater or marine environments	g PO_4 -e
Land Occupation	Total land occupied to support the product system assessed	m^2 -yr
Abiotic Depletion	A measure of the depletion of non-renewable sources that includes fossil energy, metals, and minerals	mg Sb-e

Adapted from "The Life Cycle of A Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans," by Levi Strauss & Co., 2015, p.10. Copyright 2015. Adapted from "ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level," by M. Goedkoop, R. Heijungs, M. Huijbregts, A. D. Schryver, J. Struijs, R. V. Zelm, 2013, p. 6. Copyright by RIVM, CML, PRé Consultants, and RUN, 2013.

Climate Change. The climate change impact category has many environmental mechanisms that affect human health and the ecosystem. However, this study focuses on the global warming potential of radiative forcing, measuring the effect of small emissions of carbon dioxide (CO_2) and other greenhouse gases into the environment. The final results are expressed in terms of damage to human health and the ecosystems.

Water Consumption. For water consumption, results are expressed at the midpoint level simply because there is no model available providing an endpoint level. As a feature of the ReCiPe 2008 LCA tool, water consumption is measured simply by the amount of water used throughout production. Water consumption is a large factor that also affects human health and the ecosystem, but is largely classified as a threat to our natural resources. Therefore this study focuses on water lost and damaged rather than recycled water.

Eutrophication. Eutrophication is a combination of freshwater and marine environments. It is the excessive richness of nutrients in a lake or body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from the lack of oxygen. Eutrophication is expressed at the endpoint level in terms of damage to the ecosystem. Phosphorus and nitrogen are the substances contributing to the nutrient rich waters causing eutrophication in freshwater and marine environments. Phosphorus is an essential nutrient for all life forms. However, elevated amounts of phosphorus cause plants to naturally soak up more nitrogen before all phosphorus is depleted, therefore, causing excessive algae growth in bodies of freshwater.

Land Occupation. This study assess the damage land occupation has to the ecosystem. Land Occupation concentrates on the area of land being used during the production raw materials growth and production process; and the transformation of the certain area of land. For this study Land Occupation results are expressed at the midpoint and endpoint levels.

Abiotic Depletion. Abiotic depletion is the loss of naturally occurring minerals, fossil energy and metals. Abiotic, meaning non-living, resources are addressed in terms of their availability in future generations. Results are based on the overall cost of resources lost during extraction and production. In this study abiotic depletion is expressed at the midpoint and endpoint level, yielding results regarding the damage to the world's natural resources**.**

Inventory Analysis

Data was collected from existing LCAs of a pair of denim jeans and a T-shirt. The data for the denim jeans was collected using "The Life Cycle of a Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans," Levi Strauss & Co. LCA performed in 2014 (see Appendix B). The methodology used in the LCA was the ReCiPe 2008 tool. The data used for the T-shirt was obtained from the "EDIPTEX – Environmental assessment of textiles," by the Danish Environmental Protection Agency (see Appendix C). The methodology used in the LCA of a cotton t-shirt was the EDIP unit process database. Each set of result was subjectively re-evaluated using the guidelines of the ReCiPe 2008 method tool. To better compare the environmental impact of two fashion staple items, like system boundaries were assessed. It is noted that the validity of the data varies depending on processes considered in the original studies. For example, the cultivation and harvesting of cotton varies from country to country depending on the levels of development. Where data was uncertain, it was omitted from this study due to the inability to run a LCA representative model using the Gabi 6 software. Data was collected in the previous LCAs from every phase of the supply chain up through consumer use and disposal. Additionally inventory data was obtained from company reports.

Utilizing the guidelines of the ReCiPe 2008 LCA method and the "Life Cycle of a Jean" as a resource, environmental impact categories were determined and data was reported according. As a requirement of LCA modeling, accounting for input and output inventory is essential to reach accurate results of environmental impacts. Therefore, input/ output data is entered by life cycle phase. Figure 3.1 illustrates the life cycle phases of a jean from cradle to grave. For this study, only cradle to gate phases was considered for comparison and illustrated by phases 1-4 in figure 3.1.

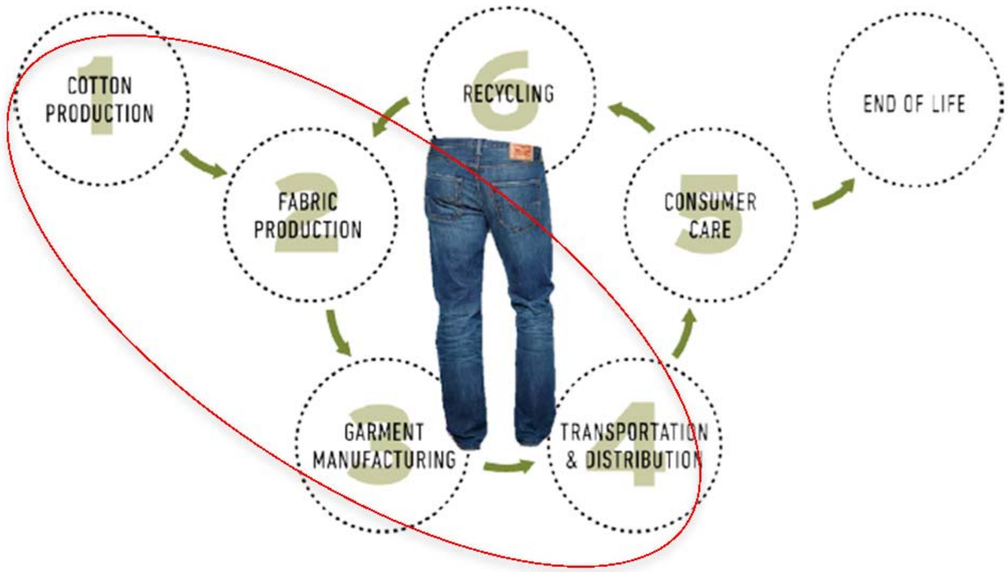

Figure 3.1. The life cycle of a Levi's® 501® jean. Adapted from "The Life Cycle of A Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans," by Levi Strauss & Co., p.9. Copyright 2015.

The data collected in the LCA of the Levi's® 501® jean was collected from the following phases:

- Spinning
- Dye, Weave, Finish
- Cut & Sew
- Garment Finish; and
- Product transport (LeviStrauss&Co., 2015).

Data collection was not applicable in the distribution centers, retail, and consumer care phases, see Appendix B, Table B1. The type of data included from the spinning phase was fiber type, fiber country of origin and fiber loss. The significant sources to the dye, weave, and finish phase was the loss of fibers and chemical use. The cut & sew phase focuses on cutting efficiency, material use, sundry material/ weight, and packaging material/ weight. The chemicals used during make-up were collected from the garment phase. Transport mode and distance was considered and collected from all phases of the supply chain.

Input/ Output inventory data for the colored cotton t-shirt was also accounted for by life cycle phase. Figure 3.2 illustrates the life cycle phases of a cotton t-shirt from cradle to grave. For this study, only the cradle to gate phases were considered for comparison and noted as the materials phase, production phase and transport phase in figure 3.2. In the impact assessment section of the LCA, the life cycle phases were re-named to compare results for environmental impact at the same point in the life cycle.

The remaining steps of the life cycle assessment according to the International Standard ISO 14040 series are the impact assessment and interpretation. Chapter 4 reports the environmental impacts by climate change, water consumption, eutrophication, land occupation and abiotic depletion.

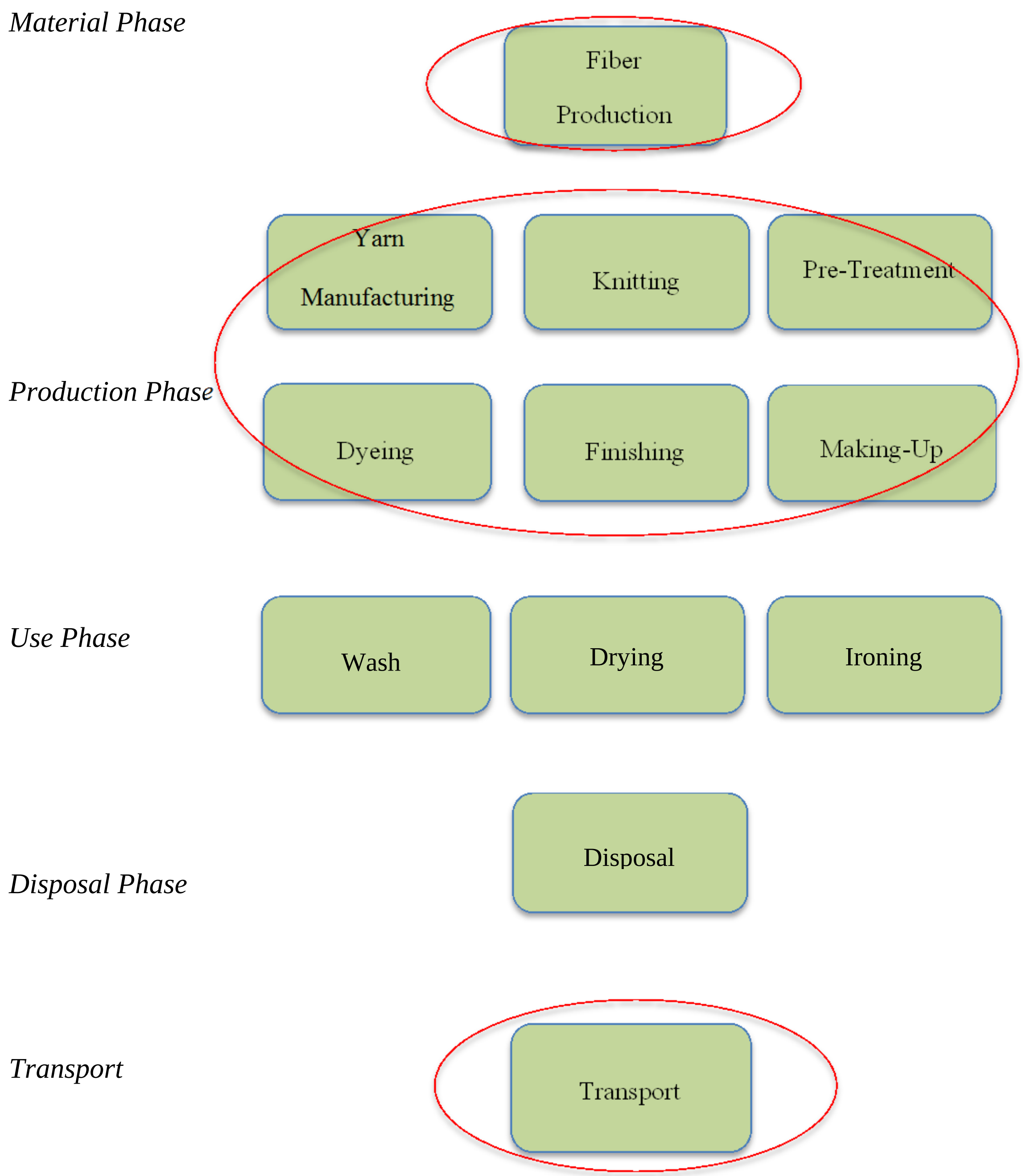

Figure 3.2. Life cycle, flow and phases of a cotton t-shirt. Adapted from "EDIPTEX – Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kritensen, 2007, p. 42. Copyright 2007 by the Danish Environmental Protection Agency.

Chapter Four

Results

The overall purpose of this research was to compare the environmental implications of widely produced and owned apparel products through a life cycle assessment approach. In addition, determine if the apparel products are fully sustainable for the consumer at the point of purchase. The expectation is that the results are used for further research to explore labeling issues, improve production processes, and inform consumers of the initial environmental impact fast fashion items have at the point of purchase. This study focuses on the impact results from cradle to gate (raw materials to point of purchase) therefore the result percentages have been adjusted from the original study due to specified parameters of this study. The results of this study are presented according to the production process and environmental impact categories.

Impact Assessment

The impact assessment is expressed according to the impact categories and the system boundaries (cradle to gate). To determine the results, the ReCiPe 2008 LCA methodology was used. As a result of software availability, the inputs and output data required for modeling a LCA are not exact for the products chosen. However, the input and output flows listed are representative of the processes used in the production of a pair of jeans and a cotton t-shirt. Full life cycle results of the Levi's® 501® jean and the cotton t-shirt are included in Appendix B & C.

The categories of the life cycle process differed between the Levi's® 501® jeans and the colored cotton t-shirt but each phase was represented. However, each phase is present in both life cycle assessments. The life cycle of the Levi's® 501® is categorized as:

- Fiber Cultivation & Harvest – The harvest and cultivation of raw materials.
- Fabric Assembly– Yarn spinning, dyeing, weaving, and fabric finishing
- Cut, Sew, & Finish – Garment manufacture
- Sundries & Packaging – Garment hardware and packaging
- Transport & Retail – Transportation between phases and distribution to retail store.

The life cycle phases of the T-shirt have been re-categorized to better compare the results by phase. See Appendix C, Figure C1 for the life cycle flow and phases of a color cotton t-shirt used in the "EPIDTEX-Environmental Assessment of Textiles"(Laursen et al., 2007). The life cycle of the cotton t-shirt is categorized as:

- Fiber Cultivation & Harvest– The harvest and cultivation of raw materials.
- Fabric Assembly - Yarn manufacturing & knitting
- Finishing - Pre-treatment, dyeing, & finishing
- Making-up – Garment manufacturing & packaging.
- Transport & Retail – Transportation between phases and distribution to retail store.

Climate Change. The effects of climate change are dictated by the global warming potential from the amounts of greenhouse emissions released into the environment as a result of textile production. In the end, increase of temperature causes damage to human health and damage to ecosystem diversity.

Levi's® 501® Jeans. In the production of one pair of jeans, the most significant impact of global warming occurs during the fabric assembly phase. However, when considering the entire life cycle (cradle to grave), the largest impact occurs during the consumer use phase. Although the transport and retail phase is assumed to have a large climate change impact from diesel to fuel trucks, this phase provides the second largest impact at 19% of the life cycle. Figures 4.1 & 4.2 show the impact of climate change expressed in kg and percentages to the environment. Full life cycle results can be found in Appendix C.

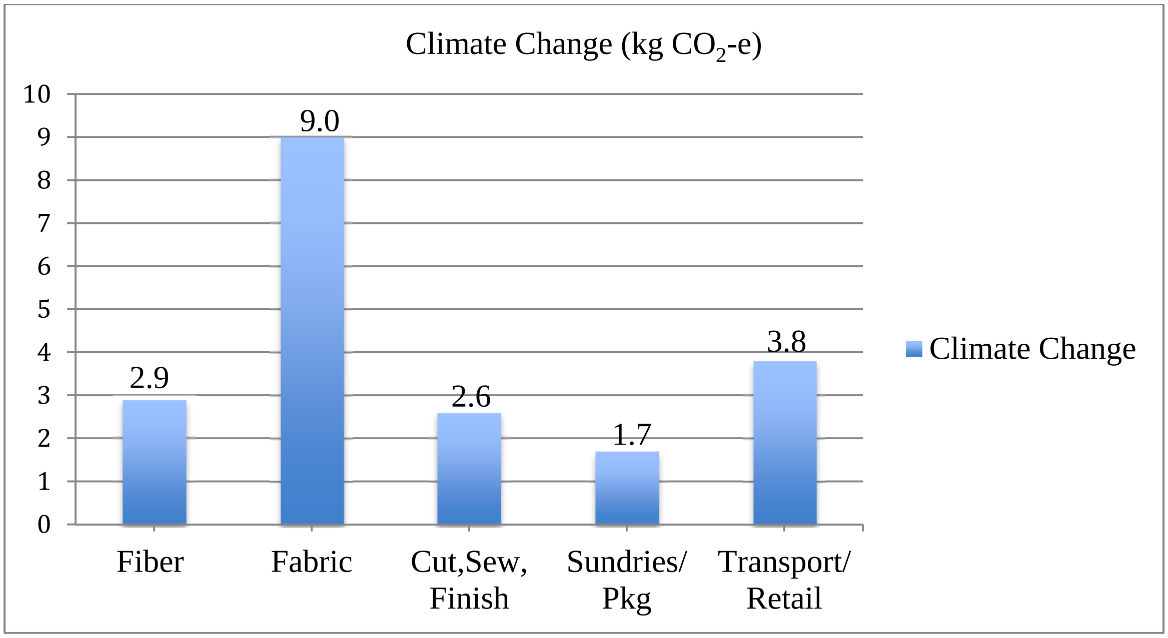

Figure 4.1. Climate Change (kg CO_2-e) by life cycle phase from cradle to gate in the production of one pair of jeans. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

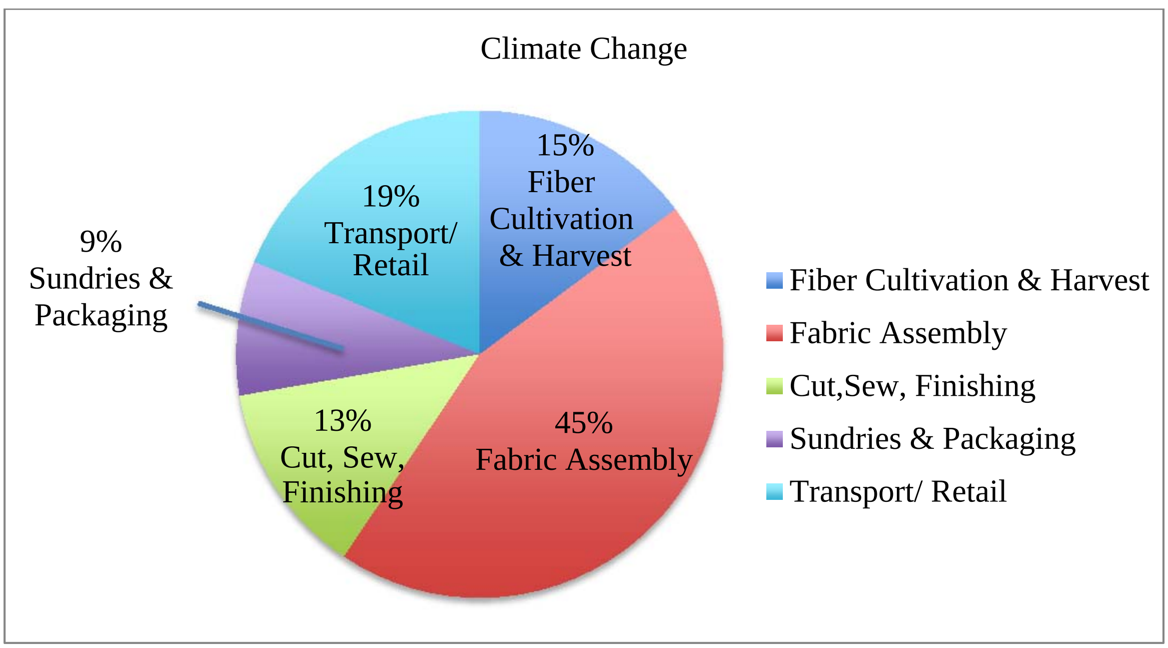

Figure 4.2. Percent of Climate Change by life cycle phase from cradle to gate in the production of one pair of jeans. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

Colored Cotton T-Shirt. Figure 4.3 shows the percentage of climate change impact to the environment over the production (cradle to gate) process of the life cycle. The impact of climate change is referring to the greenhouse effect as a result of production. The environmental impacts are expressed in impacts related to energy.

In the fiber production stage, climate change is most representative of the production of artificial fertilizer and the burning of fossil fuels released into the air. During the production phase, fabric assembly contributes the most to climate change, with roughly 65% of electricity consumption from yarn manufacturing and knitting. The next most significant impact stems from the pre-treatment, dyeing, and finishing stage of the t-shirt. These processes account for roughly 25% of the production process and climate change can also be attributed to electricity consumption from machinery. Garment makeup and packaging is minimal and is about 1% of total consumption accounted due to the ability to reuse resources. Last, the transport/ retail phase accounts for 2% of the production process and reflects the use of diesel and petrol used. Full results of climate change can be found in Appendix D.

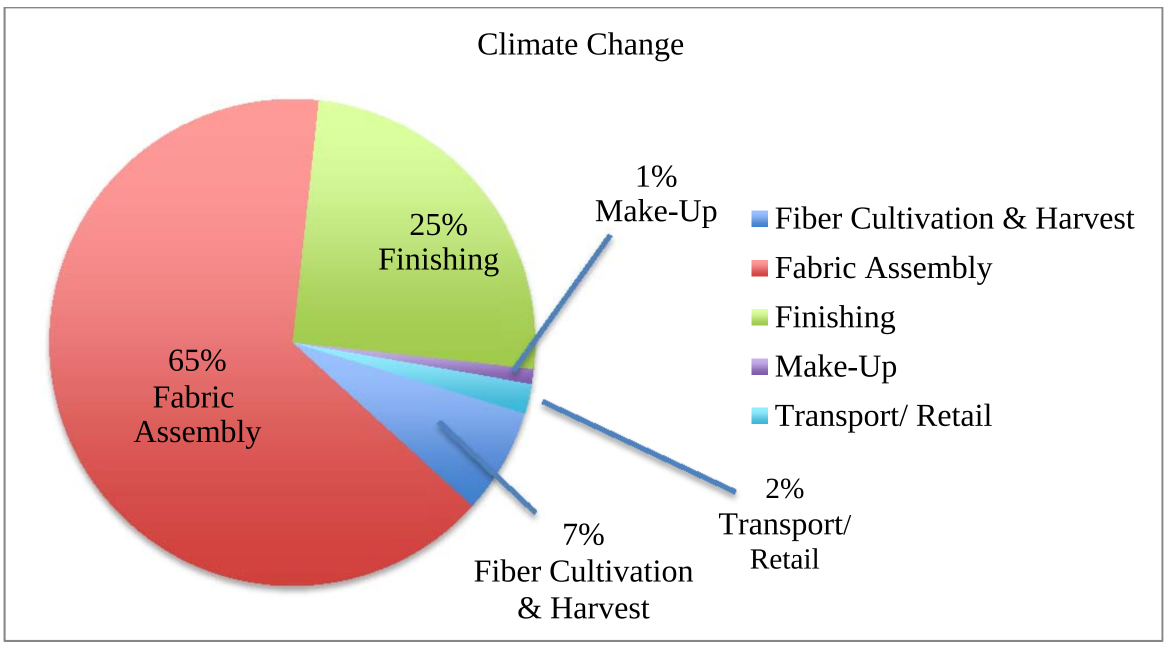

Figure 4.3. Percent of Climate Change by life cycle phase from cradle to gate in the production of one colored cotton t-shirt. *Note.* The make-up phase has little to no impact on climate change due to the reuse of resources. Adapted from the "EDIPTEX

Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, pp. 52-53. Copyright 2008 by the Danish Environmental Protection Agency.

Water Consumption. Water can be a scarce or abundant resource depending on different parts of the world, making it very essential to human life and the ecosystem. Therefore, the water consumption stemming from apparel production can cause serious damage to human health, ecosystem diversity and natural resource availability.

Levi's® 501® Jeans. The leading cotton-producing countries included in the life cycle study executed by Levi Strauss & Co. were United States, Brazil, India, Pakistan, China and Australia. The production phase of the life cycle contributes a large amount to water consumption. In this study the large amounts of water damaged or lost occurs during the fiber cultivation phase. In the production of fabric, the consumption of water is 8% of the cradle to gate process and is attributed to yarn spinning and the fabric finishing process. The transport & retail phase have less than 1% of water consumption and is not shown in the graphs, but included in the overall life cycle. Figure 4.4 & 4.5 show the liters of water and percentages by life cycle phase. Full results can be found in Appendix C.

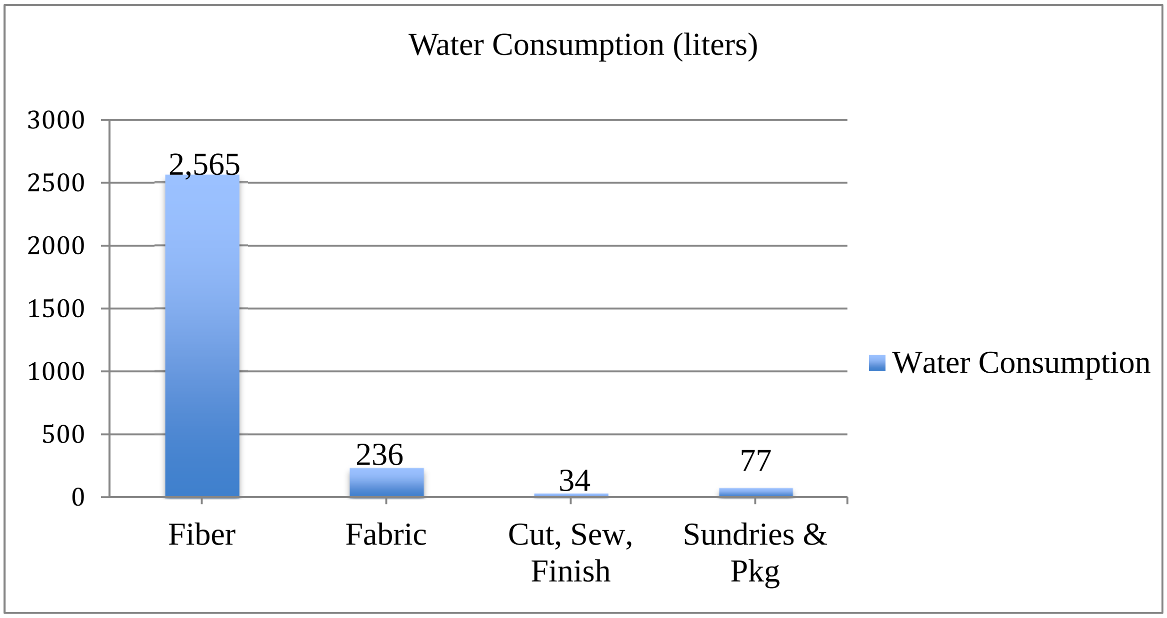

Figure 4.4. Water Consumption (liters) by life cycle phase from cradle to gate in the production of one pair of jeans. *Note.* Transport/ Retail contributes less than 1% and is not shown on the graph but included in the overall total. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

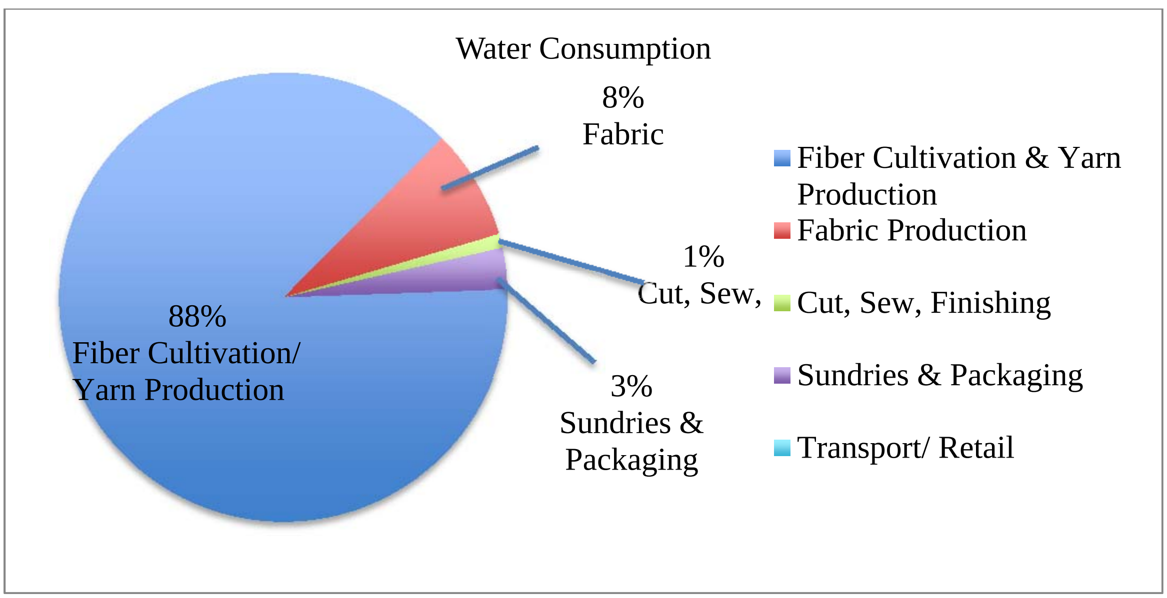

Figure 4.5. Percent of Water Consumption by life cycle phase from cradle to gate in the production of one pair of jeans. *Note.* Transport/ Retail contributes less than 1% and is

not shown on the graph but included in the overall total. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

Colored Cotton T-Shirt. The results generated for water consumption from the "EDIPTEX Environmental Assessment of Textiles" study were not reported in terms of liters consumed per one t-shirt by production phase. Result were reported per m3 and was assumed and calculated as:

- Assumed: 50 cm of water needed during one growth season which is 5,000 m3 per hectare therefore,
- 5,000 * 0.3/785 = approx. 2 m3 water per kg of packed raw cotton (Laursen et al., 2007).

Water consumption was also accounted for in the data for yarn spinning. Data was generalized for all yarn types and water consumption was 2.2 liters/kg. Data used in the EDIPTEX Environmental Assessment of Textiles was also used in this study and was not manipulated for cradle to gate purposes. Figure 4.6 shows estimated amounts of water consumption during the life cycle. Full results of water consumption can be found in Appendix D.

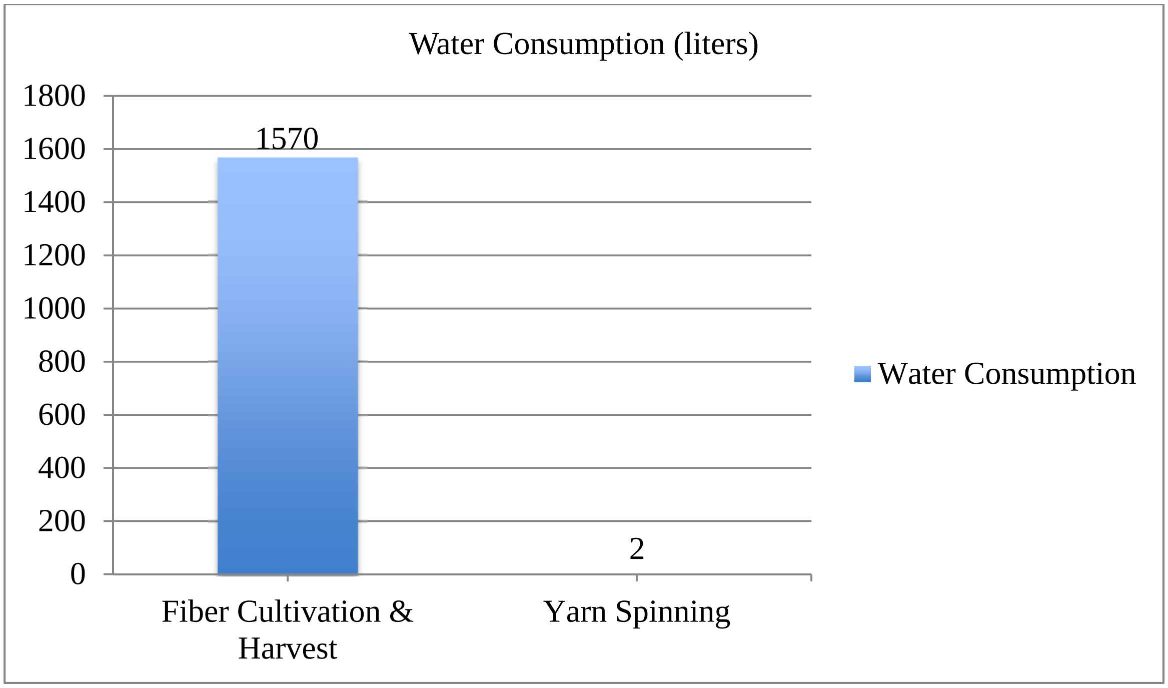

Figure 4.6. Water Consumption (liters) by fabric cultivation and yarn spinning of cotton. Adapted from the "EDIPTEX Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, pp. 223-227. Copyright 2008 by the Danish Environmental Protection Agency.

Eutrophication. Eutrophication is a significant impact category because human activity has accelerated the process causing nitrogen and phosphorous deposits into our nation's aquatic ecosystem, with damage to drinking water sources, fisheries, and recreational bodies of water (Carpenter et al., 1998). Likewise contributing to the ecological quality of inland and marine waters. Eutrophication causes damage to human health and ecosystem diversity.

Levi's® 501® Jeans. All stages of the life cycle contribute to eutrophication and should be improved to reduce the amount of harmful deposits entering into bodies of water. In the production of one pair of jeans, the fiber cultivation stage has the largest impact to the environment. The sundries & packaging stage is close behind with 21% of the production process. Figures 4.7 and 4.8 show g PO_4-e and percentages by production stage from cradle to gate.

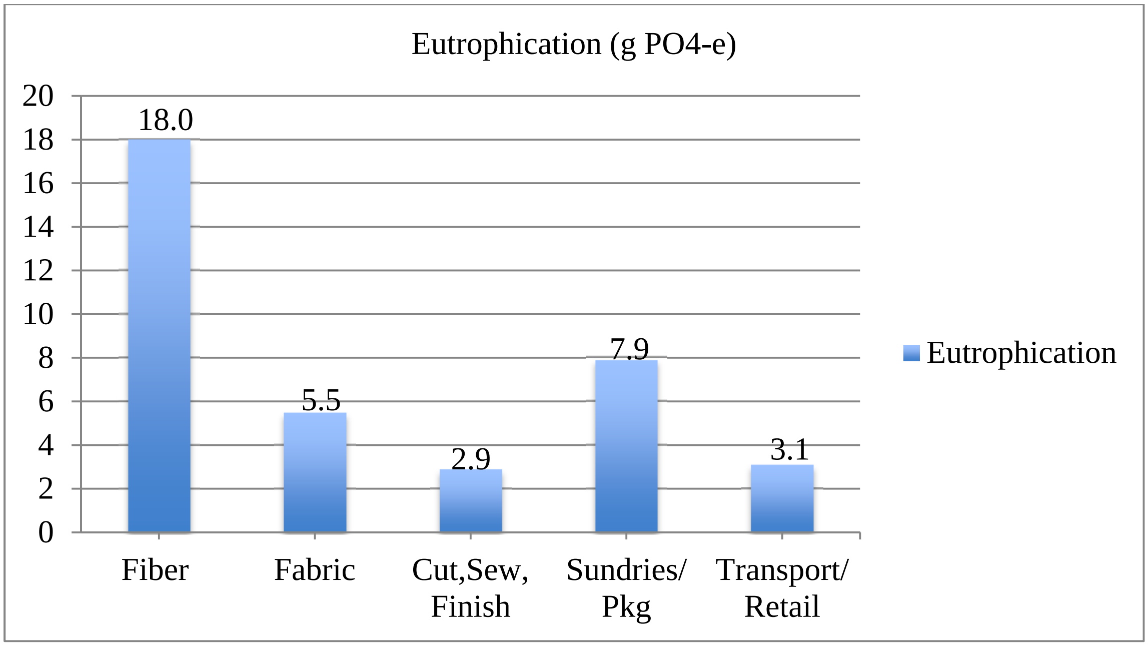

Figure 4.7. Eutrophication (g PO_4-e) by life cycle phase from cradle to gate in the production of one pair of jeans. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

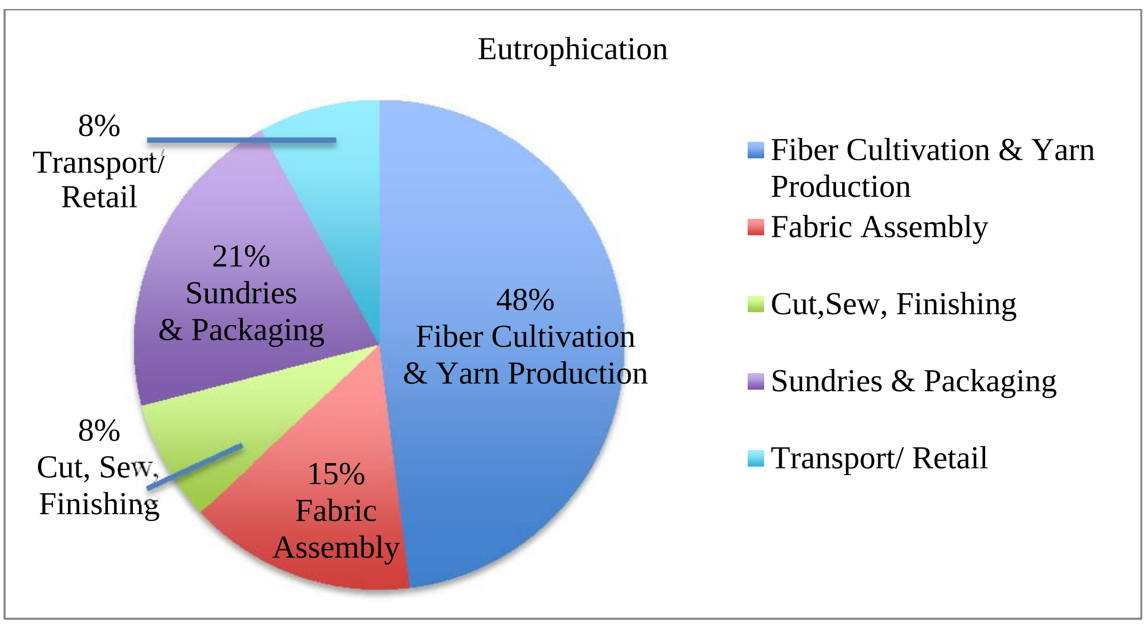

Figure 4.8. Percent of Eutrophication by life cycle phase from cradle to gate in the production of one pair of jeans. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

Colored Cotton T-Shirt. Figure 4.9 shows the percentage of the Eutrophication impact to the environment over the production (cradle to gate) process of the life cycle. In the "EDIPTEX Environmental Assessment of Textiles" study the impact of eutrophication is referred to as nutrient loading and is nitrogen and phosphorous deposits into our nation's aquatic ecosystem, with damage to drinking water sources, fisheries, and recreational bodies of water (Carpenter et al., 1998). The environmental impacts are expressed in impacts related to energy.

In the fiber production stage, eutrophication is most representative of the production of artificial fertilizer and the burning of fossil fuels released into water. During the production phase, fabric assembly contributes the most to eutrophication, with about 66% of electricity consumption from yarn manufacturing and knitting. The next most significant impact comes from the pre-treatment, dyeing, and finishing stage of the t-shirt. These processes account for roughly 20% of the production process and eutrophication can also be attributed to electricity consumption. During garment makeup and packaging energy was saved due to the ability to re-use resources therefore eliminating nutrient loading to bodies of water. Last, the transport/ retail phase accounts for 3% of the production process and is reflective of the burning of fossil fuels transportation. Full results of eutrophication can be found in Appendix D.

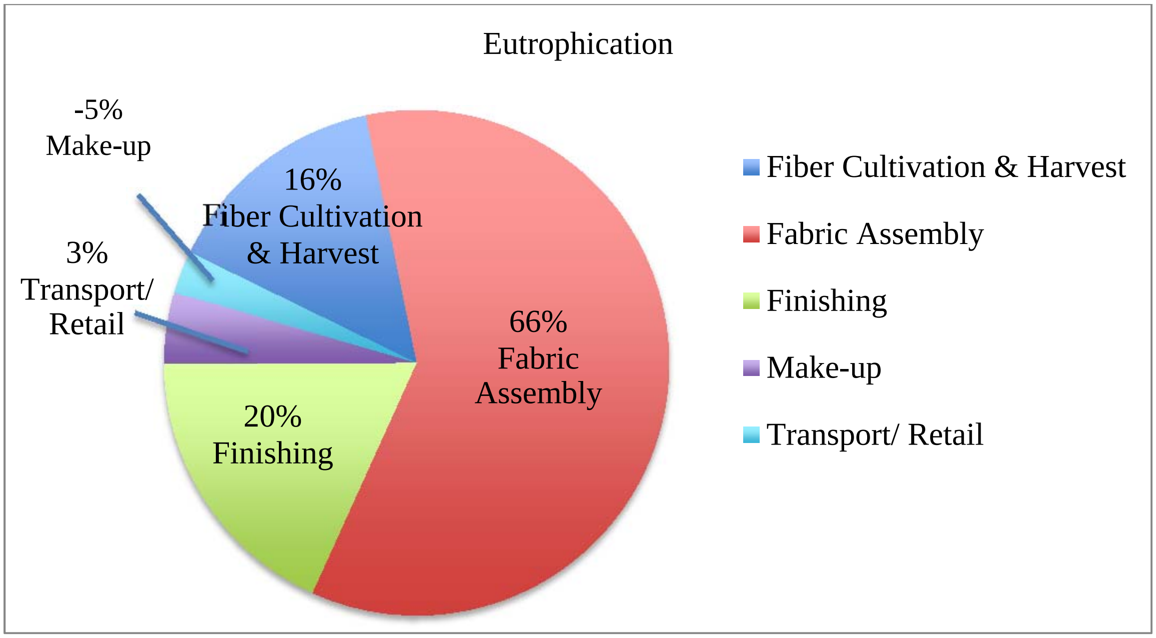

Figure 4.9. Percent of Eutrophication by life cycle phase from cradle to gate in the production of one colored cotton t-shirt. *Note*. The negative number represents saved consumption and has a positive impact on eutrophication. Adapted from the "EDIPTEX Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p. 49. Copyright 2008 by the Danish Environmental Protection Agency.

Land Occupation. Damage to the ecosystem is a result of land occupation or land transformation. Although land occupation is most obvious during the fiber cultivation phase, land occupation is considered for the transformation of land in the building of factories.

Levi's® 501® Jeans. Land is needed for such things as the harvesting and cultivation of food, fiber, and forest products. The following stages require land occupation for factories. In the production of apparel products land occupation is most significant in the fiber cultivation stage. After the fiber cultivation stage the impact of land occupation reduces significantly and uses less than 1 m^2/year. Figures 4.10 and 4.11 show the wide margin between phases in the production of one pair of jeans. Full results for abiotic depletion can be found in Appendix C.

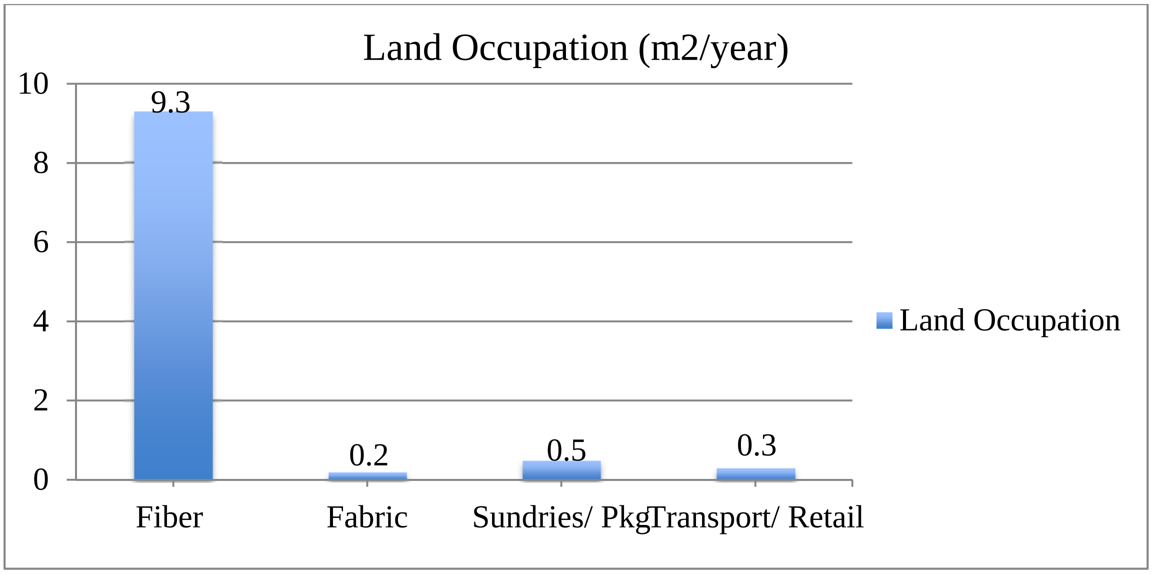

Figure 4.10. Land Occupation (m^2/year) by life cycle phase from cradle to gate in the production of one pair of jeans. *Note.* The cut, sew, & finishing phase has no contribution to land occupation during production therefore; this phase has been omitted from the graph. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

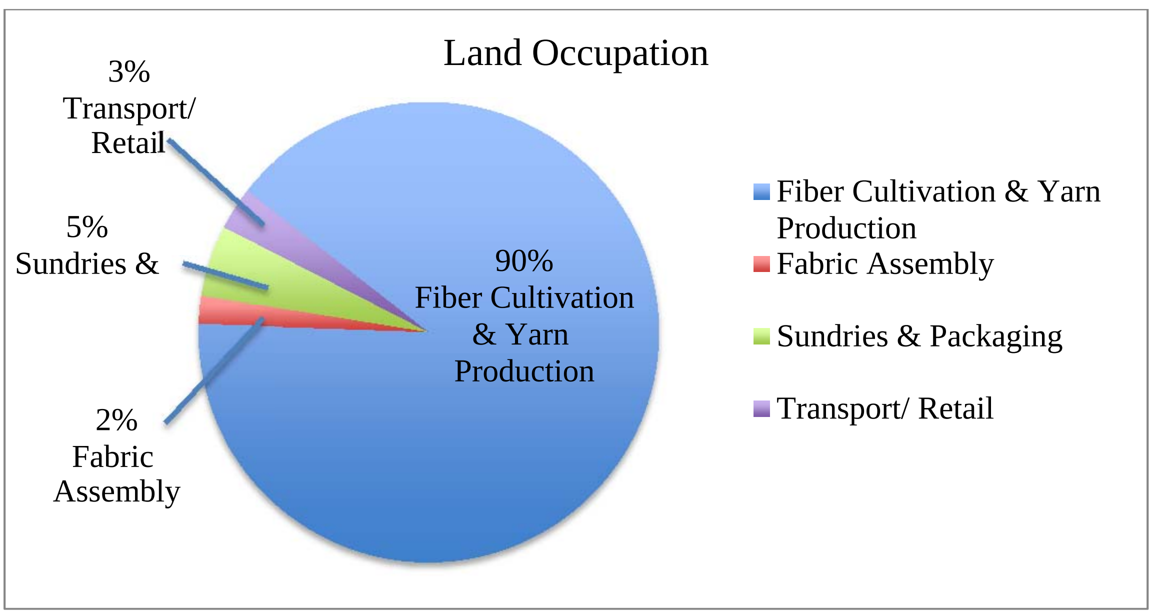

Figure 4.11. Percent of Land Occupation by life cycle phase from cradle to gate in the production of one pair of jeans. *Note.* The cut, sew, & finishing phase has no contribution to land occupation during production therefore; this phase has been omitted

from the graph. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

Colored Cotton T-Shirt. The EDIPTEX Environmental Assessment of Textiles LCA does not report data for land occupation and is not reported in this study. Due to the availability and financial expense of the Gabi 6 LCA software a LCA model was not feasible for this study. However, with the existing data inputs & outputs, a similar model can be designed using the ReCiPe 2008 method to provide results that best represent land occupation by life cycle phase.

Abiotic Depletion. Abiotic depletion measures gradual loss of minerals, fossil fuels and metals as a result of apparel production. The loss of natural resources affects all three endpoint impact categories.

Levi's® 501® Jeans. In this study abiotic depletion is the loss of non-renewable and renewable resources as a result of the production processes of a pair of jeans. The impact of abiotic depletion is largest in the sundries and packaging phase of production at 118.5 mg and accounts for 78% of the cradle to gate life cycle. The other phases are quite minimal in comparison. However, the fiber cultivation & harvest phase contributes 19.9 mg (13%) to the life cycle phases. Next, the fabric assembly, cut, sew, & finish, and transport/ retail have small impacts to abiotic depletion to help balance out the environmental impact overall. Figures 4.12 and 4.13 show a wide difference of impact from cradle to gate. Full results for abiotic depletion can be found in Appendix C.

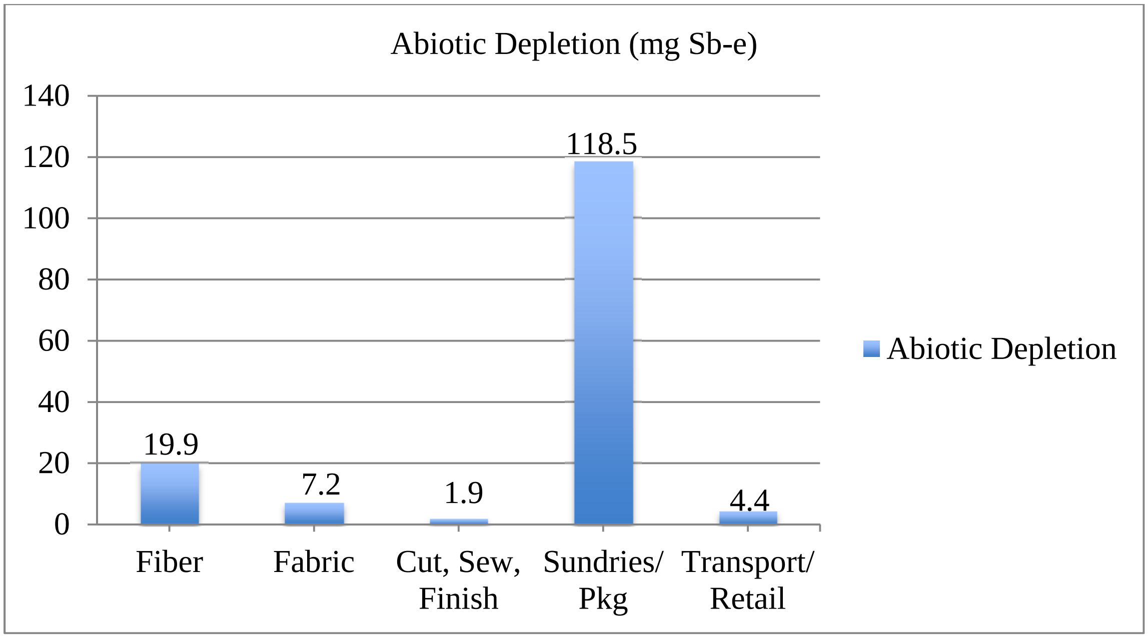

Figure 4.12. Abiotic Depletion (mg Sb-e) by life cycle phase from cradle to gate in the production of one pair of jeans. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

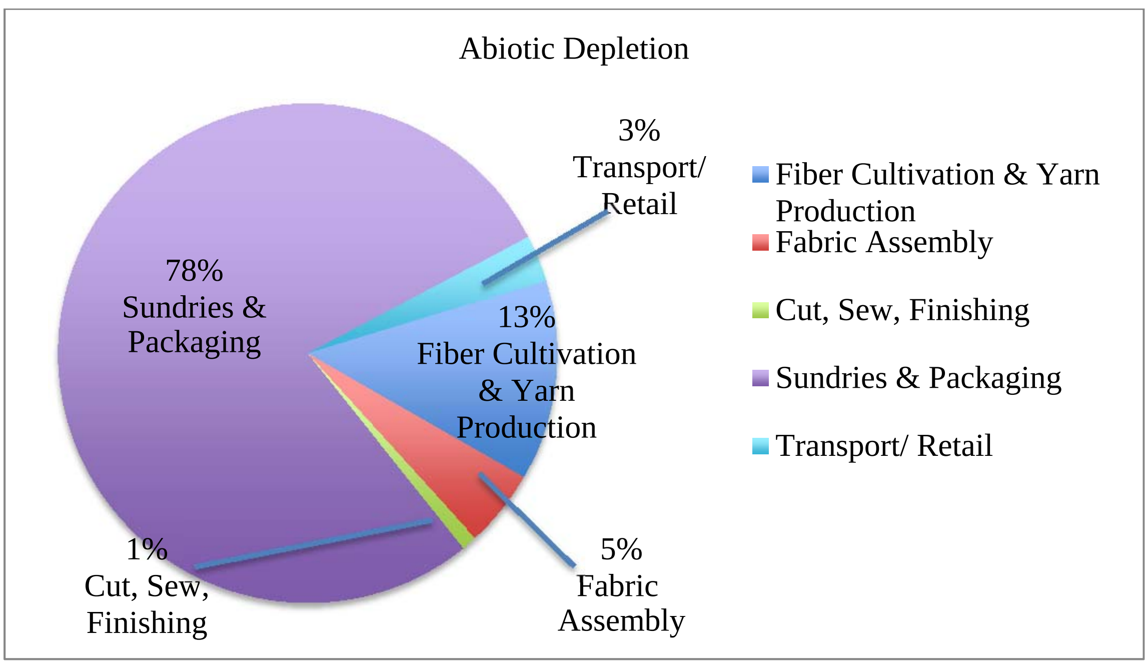

Figure 4.13. Percent of Abiotic Depletion by life cycle phase from cradle to gate in the production of one pair of jeans. Adapted from "The Life Cycle of a Jean," by Levi Strauss & Co., 2015. Copyright 2015 by Levi Strauss & Co.

Colored Cotton T-Shirt. Figure 4.14 shows the percentage of abiotic depletion impact to the environment over production (cradle to gate) process of the life cycle. Although phases are included beyond the cradle to gate phase, results show that the materials phase has the largest impact on the environment. The impact of abiotic depletion is referring to the loss of crude oil, natural gas, and hard coal resources.

In the fiber production phase, abiotic depletion is most representative of the production of artificial fertilizer and pesticides and the transportation of fibers. During the production phase, fabric assembly makes up about 17% of resource consumption. Electricity energy generated and lost from yarn spinning and fabric finishing is the primary reason for abiotic depletion in the production phase. The next most significant impact stems from the pre-treatment, dyeing, and finishing of the t-shirt. These processes account for roughly 26% of the production process and abiotic depletion can be attributed to the energy used to heat water, electrical energy for drying during finishing and electricity used from machinery for pre-treatment. Garment makeup and packaging is about 3% of total consumption accounted for during the production phase. The transport phase takes up about 10% of the production process from cradle to gate and refers to the consumption of petrol and diesel. Full results for abiotic depletion can be found in Appendix D.

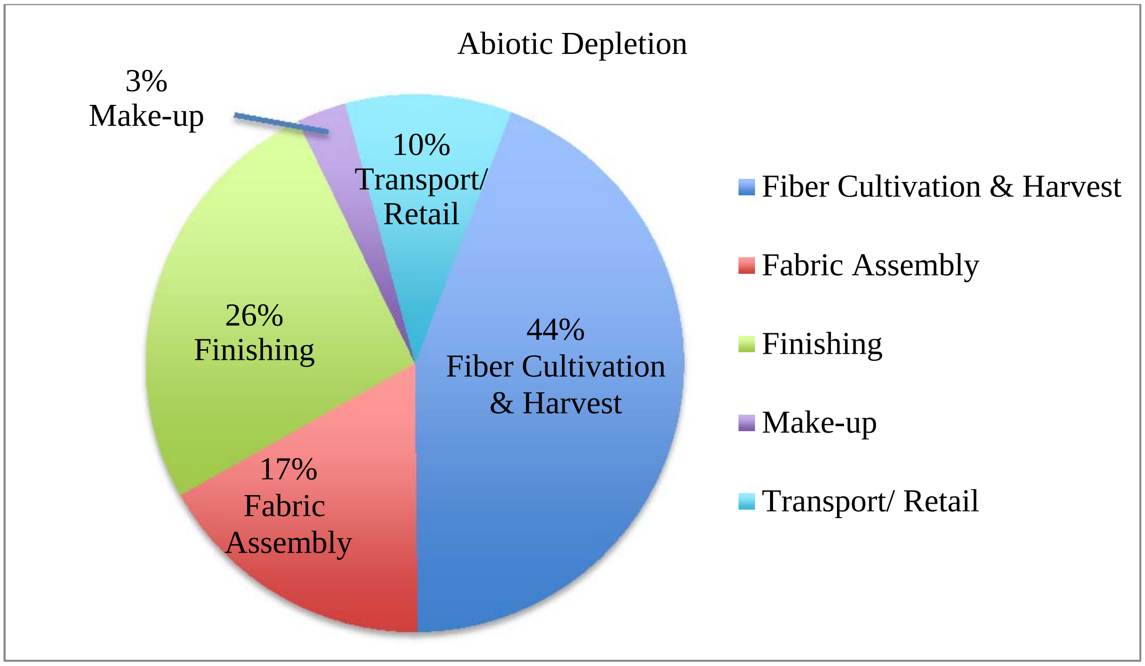

Figure 4.14. Percent of Abiotic Depletion by life cycle phase from cradle to gate in the production of a colored cotton t-shirt. Adapted from the "EDIPTEX Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p. 49. Copyright 2008 by the Danish Environmental Protection Agency.

Interpretation of Results

Climate Change. The impact for climate change in the production of one pair of jeans and cotton t-shirt is similiar. In accordance with the life cycle phase, fabric assembly has the largest impact. Climate change is attributed to the electricity consumed during the yarn manufacturing and fabric finishing to achieve the soft hand of a fabric. The process is more rigorous in the production of a cotton t-shirt because a t-shirt is expected to have a softer hand than denim jeans, therefore, requiring an extra softening process to achieve the desired feel. When comparing the two items based on results, the cotton t-shirt has a greater impact on climate change and is connected to global warming that has an endpoint impact to human health and the ecosystem.

Water Consumption. Water Consumption results mainly reflect liters of water consumed, and not reused, in the cultivation and harvest of cotton. The largest impact is experienced in the fiber cultivation stage (raw materials extraction) in the production of both products compared. The amount of liters is very close and, in this study, is assumed to be equal because results are in terms of amount grown and not a single product. However, water consumption does not only occur in the fiber production phase but in the entire life cycle. Water is essential to the production of textiles. Although the t-shirt data only shows data for the spinning phase, it is assumed water was used and consumed throughout the cradle to gate process. Jeans require water that is lost during fabric assembly and typically is a result of the finishing and dye processes. Water is consumption in both products is not avoidable but essential. Adjustments to the impact of water consumption can be affected by recycling water throughout the life cycle process. Therefore, due to the lack of information, jeans require the most water to be used. In turn, water consumption will affect our future generation in human health, ecosystem diversity and resource availability.

Eutrophication. Water quality is a large concern when discussing environmental impacts. Eutrophication is the continued act of nutrient deposits into freshwater aquatic systems. The main problems for bodies of freshwater are phosphorus and nitrogen deposits from outside sources. The results show eutrophication occurs in two very different phases of production between a jean and t-shirt. Jeans show eutrophication is the most prominent in the fiber cultivation and harvest phase. This is a result of chemicals used causing nutrient rich runoff water. Water full of rich nutrients causes the depletion of oxygen in freshwater aquatic systems, Therefore starting the negative impact of eutrophication. On the other hand, the greatest impact to eutrophication happens in the fabric assembly phase in the production of a cotton t-shirt. The fabric assembly phase also uses chemicals that release nutrients into water consumed, but eutrophication impact also comes from the electricity energy consumed. This is a direct impact of oxygen depletion. Ultimately, over a period of time, production activities will result in oxygen depletion and lead to the death of fish species. The endpoint impact is to human health and ecosystem diversity.

Land Occupation. Land Occupation results were available for jeans only and had the greatest presence in the fiber cultivation and harvest stage. Land occupation contributes to 90% of production from the fiber phase. This mainly is the result of land used for crop production. As a result the earth loses trees as a natural resource. It is not as important in the remaining phases of the cradle to gate processes, due to the factories and mills not requiring as much land to operate. Unlike other environmental impacts, land occupation has an impact that is immediate to the availability of natural resources. Other environmental impacts show results that happen over time and affect the quality of the environment in the future.

Abiotic Depletion. Abiotic depletion is a large environmental issue to consider in textile production because it uses so many natural resources that the earth cannot get back. The results of the cotton t-shirt shows significant impact in the fiber cultivation and harvest phase. On the other hand, the largest impact of abiotic depletion occurs in the sundries and packaging phase for the production of a pair of jeans. This phase uses fossil fuels, metals and miners that are non-renewable resources. In the production of jeans, sundries production refers to all materials needed for the garment other than the fabric. Sundries production included molding and forming of metals used for the zippers and rivets and application process. This process uses an enormous amount of energy from electricity consumption, Therefore causing this phase to have a large impact on the environment. Without the use of sundries, the garment make-up phase would not have such a large impact. Although, the make-up phase in the cotton t-shirt still has an environmental impact from abiotic depletion the impact is considerably less. The impacts of activities used have and endpoint impact on resource availability in future generations.

Chapter Five

Conclusion

The overall purpose of this research was to compare the environmental implications of widely produced and owned apparel products through a life cycle assessment approach. In addition, determine if the apparel products are fully sustainable for the consumer at the point of purchase. The research focused on the important environmental impacts as a result of jeans and t-shirt apparel production. This study used existing life cycle assessments to compare two apparel items that are normally purchased together by consumers.

The overall objective of the research study was to assess the life cycle of a product to determine if it is a sustainable product for the consumer, at the point of purchase. The first objective was to assess the environment impacts of an apparel product's life cycle from cradle (raw material extraction) to gate (garment make-up & distribution). As the goal and scope of the study, the research results and discussion followed a detailed structure of a LCA as proposed by the ISO 14040 series standards. Furthermore, the scope of the LCA was to focus on the life cycle of a denim jean and cotton t-shirt from cradle to gate rather than the entire life cycle from cradle to grave. This decision was to analyze the sustainability of a product from manufacturing.

Next the results of two LCAs were combined to evaluate the results using the ReCiPe 2008 method. Data results were analyzed and discussed in regards to the impact categories indicated by the ReCiPe 2008 method. The environmental impacts were climate change, eutrophication, water consumption, land occupation and abiotic depletion. The research study shows that the most significant contributions to the environmental impact related to processes, chemicals, and energy consumed originated from the fiber cultivation and harvest phase production.

The resounding message within the life cycle assessments was that cradle to gate apparel production is controlled by the retailer/manufacturer, therefore suggesting that there is always room for improvement. Improvements should occur in the fiber production phase by switching to organic cotton, which requires the use of less harmful chemicals and not as many. Evaluating the choice of dyes and their potential impact on the environment, before hand in the fabric assembly phase, helps in reducing the negative impacts to human health and ecosystem diversity. The reuse of dye water for other products can reduce water consumption and provide new avenues of textile dyeing. As a result, a retailer/manufacturer can save energy and reduce consumption of pesticides during fiber production and minimize waste.

Fiber Cultivation and Harvest

The cultivation and harvest of cotton is the most resource intensive, politically debated and socially unfair process of an apparel product's lifecycle (Camp, Scott, Clark, Duane, & Haight, 2010). The concerns and issues are both environmental (negative affects of harmful chemicals) and socially (respect to the farmers and their families livelihoods) connected.

To produce a pair of jeans and a t-shirt, the processes start with the extraction of raw materials (i.e. Cotton). However, cotton must be harvested in large amounts and for several months before extraction. This means that pesticide and fertilizing treatments are applied frequently throughout harvest, causing chemicals to be present in runoff water through the duration. Artificial fertilizers and pesticides have a large effect on human health and are the chemicals widely used in fiber cultivation.

The chemicals needed for cotton growth can potentially damage the quality of the crop and the health of the farmers managing the crop. In addition to the fiber cultivation and harvest phase, residual chemicals remain in the fiber and continue to cause toxic impacts to humans during the fiber processing phase and do not disappear till the fiber becomes a fabric and undergoes wet processing procedures. On the other hand, organic cotton is an alternative to prevent toxic impacts on human health and the actual crop. In many instances organic cotton cultivation uses organic manure for crop growth which eliminates pesticides and fertilizers; reducing the affects of greenhouse gases (climate change) and nutrient loading (eutrophication). However, energy related environmental impacts are not completely eliminated because organic cotton harvest utilizes mechanical weed control and transport to spread manure (Laursen et al., 2007). Although, organic cotton is safer to harvest and helps to create a more sustainable apparel product, the financial concerns associated with organic cotton lack government funding and are more expensive for retailers/manufacturers to use.

Water Consumption

The results of this study show that water consumption had the most significant impact in the fiber cultivation and harvest phase due to the large amounts of water used to grow cotton. Cotton irrigation is important to the viability of the crop and the yield is determined by how well the process is managed. Cotton harvest and cultivation varies among many countries due to the climate. In the U.S., 65% of cotton is produced under non-irrigated conditions (Cotton Incorporated, 2010). This means that the amount of rainfall that occurs yearly is sufficient for the crop and does not need extra water. The large differences in crop yield are because irrigation supplements rainfall, ensuring enough water reaches the root of the crop. Since the occurrence of rainfall is random it requires farmers to irrigate the land in order to stay competitive with other farmers producing cotton. Although the amount of water used varies by country, the overall amount utilized in apparel production is large and determines the yield of the crop. Thereby, making it difficult to reduce the environmental impact of water consumption in the fiber cultivation and harvest stage.

Yet, water consumption still has a significant impact in the production phase from the dyeing and finishing processes. Large amounts of water combined with reactive dyes are used to prepare dye baths. Conventional reactive dyes account for 70% of dyes used for cotton (Cotton Incorporated, 2010). The percentage of dye that moves from the dye bath to the fiber and permanently bonds is low. Therefore, removing the amount of dye that does not affix permanently is extensively rinsed and washed, causing an increase in water consumption in addition to the dye baths. Water is an essential resource needed in apparel production but, the adoption of higher value dyes (dyes with higher affinity rates that require less water) and low-liquor-ratio jet dyeing machines (high quality machines with low ratio of water to material) can significantly reduce the amount of water consumed and wasted.

Energy Consumption

Energy consumption is present in all phases of the life cycle however, in the production of a pair jeans and t-shirt, energy is the largest in the production (finishing, fabric assembly and garment make-up) phase**.** Energy consumption during the life cycle is a reflection of the processes that require a lot electrical energy from the machinery used in pesticide and artificial fertilizers, yarn manufacturing and garment assembly. Energy consumption also occurs from the vehicles used in all areas of transport. Energy consumption is linked to every process in the lifecycle so, when using more efficient methods and machinery, energy consumption is reduced as an added benefit. Furthermore, apparel production links the environmental impacts of water, energy and chemical consumption in all phases of the lifecycle as a result of each process. Motivation to adopt sustainable technologies and practices results in significant savings in resources and environmental benefits (Cotton Incorporated, 2010).

There is no doubt that all textile production impacts the environment (Chen & Burns, 2006) but, the retailer/ manufacturer has the ability to influence the production processes up to the point of purchase to create a more sustainable design and a product that has a reduced environmental impact. It is impossible to create an apparel item that is considered a 100% sustainable garment that does not have any environmental impact. Subsequently, the decisions made on the basis of sustainability can influence the consumer's habits in the use phase. When retailers/ designer provide consumers with their efforts to reduce their carbon footprint, consumers can make educated purchasing decisions on popular fast fashion items with sustainability in mind.

A move towards sustainable apparel production is not only the retailer's responsibility but also a response to consumer demand. The more consumers know of sustainable practices, the more likely the apparel industry can provoke change. Continuing to make sustainability an expectation allows the retailer/ manufacturer to ensure the validity of a sustainable apparel product. Cotton Incorporated (2010) indicates "that while consumers have become more environmentally aware, their understanding of textile manufacturing and the effects on the environment is limited, as is their willingness to pay more for environmentally friendly textile products" (p.1). The efforts and improvements made towards sustainability should act as a badge of honor. Identifying processes and removing the barriers of apparel production; and specifying the actions you want the consumer to take helps strengthen the sustainable validity of an apparel product (Luke, 2008). This will enable the consumer to make sustainable choices in their selection of sustainable fashions. At the point of purchase, manufacturers can use this opportunity to boast about their achievements through packaging and hang tags. Evidence such as: websites and sustainable seals explaining the improvements encourage the consumer to take a step further into the product, Therefore gaining confidence that the retailer is concerned with the consumer's needs and their views on sustainability.

Life Cycle Assessment Data

Both LCAs utilized in this study utilized data from a broad range of sources, which created variability between products. This caused uncertainty of important data to include by life cycle phase. A well-known hurdle in life cycle assessments is the access to good and trustworthy data. Having strong relationships with suppliers and business partners within the supply chain make it easier to obtain strong accurate data for LCA modeling. Petersen, Handfield, and Ragatz (2005) have concluded that a valuable and strong relationship with suppliers facilitates better decision-making by the product development team and promotes the development of a better design.

There are uncertainties with any LCA model used to determine environmental impacts. Depending on whether the LCA model is simplistic or more complex, the parameters may vary leaving many input and output flows unaccounted for. More complex models, that capture as many input and output inventory flows possible, have the advantage of representing more accurate environmental impacts as a result of textile production. However, it is impossible to capture all elements in the life cycle of a product, as pointed out in chapter 4 with the elimination of results for land occupation in the development of a cotton t-shirt.

It should be noted that the production of cotton varies from country to country and is difficult to capture all countries with like procedures and requirements. Therefore assumptions were made in the life cycle assessment of a cotton t-shirt and data was generalized. In the finishing phase, the LCA of a jean considered a long list of chemicals related to dyes and finishes whereas, the t-shirt analyzed only one reactive dye and one acid dye that represents the entire study.

Limitations of Study

This research study focused on the manufacturing of a cotton T-shirt and a pair of denim jeans. These products were significant because they are items that are widely owned by consumers in large amounts. However, by using only jeans and t-shirts as a focus limits the study, assuming they are the only fast fashion items consumers own in excess. Although the processes within each life cycle phase are very similar between jeans and a t-shirt, the finishing procedures used to achieve the look and feel of the end product are different, and would be beneficial to compare like products of the same wash. Likewise, the data used from "The Life Cycle of a Jean,"(LeviStrauss&Co., 2015) study was based on sales and production data from 2012 and the LCA of a cotton t-shirt from "EDIPTEX – Environmental assessment of textiles,"(Laursen et al., 2007) was based on data from 1990 in regards to all processes that consume electrical energy.

For comparison, the study used data from previous life cycle assessments and does not conduct an actual LCA. Due to the availability of resources, the inventory data was not modeled in the Gabi 6 software. The Gabi 6 software is LCA software that can be downloaded for a 30-day trail but does not come with pre-loaded inventory datasets that supports textile production. The company also offers other software options and textile datasets for a sizable fee. To be beneficial for purchase, the University of Kentucky would need substantial reasoning to continue an ongoing license of the Gabi 6 professional software beyond the work of the this study. These issues made it difficult to perform a LCA using software therefore, affecting the validity of comparison based on the ReCiPe 2008 methodology.

Many life cycle assessments have been performed on various textile products outside of the United States. The LCA used for the cotton t-shirt provided statistical data from sources in Denmark and the jeans LCA was conducted for a US based company.

Using data from different countries affect the input and output flows at different phases. Last, time was a hindrance in the collection of data.

Recommendations for Future Research

Based on the results and software obstacles, it is recommended that LCA software be used to complete a life cycle assessment. A comparative analysis should be completed using the same methodology in order to compare the environmental impacts of similar products to each other. Previous LCAs have completed a comparison analysis but there is a need for future work on fast fashion items that consumers normally purchase together. Life cycle assessment research, available with statistical data, is needed yearly to account for the changes in fiber production, a company's sustainable initiative, availability of suppliers, and factors that contribute to harm to human health, ecosystem diversity, and resource availability.

Research is recommended to explore sustainable labeling as an extension of life cycle assessments. Future research can investigate the connection between a consumers purchasing decisions based on how much information is made available regarding the company's efforts towards sustainable production on fast fashion items. Last, Gabi 6 software is an easy tool to use, however the databases lack processes for textile production and are not readily available. Collaboration with industry retailers will help ensure that data is accurate and apparel products are widely represented in LCAs.

Appendix A

Definition of Terms

Abiotic Depletion - A measure of the depletion of non-renewable sources that includes fossil energy, metals, and minerals (LeviStrauss&Co., 2015)

Agile Supply Chain – Is market sensitive with the ability to respond to actual real time changes in demand. The use of information technology to share data between buyers and suppliers (Bruce et al., 2004).

Climate Change - Global warming potential of greenhouse gases released into the environment (LeviStrauss&Co., 2015).

Cradle to Gate – An assessment of a partial product life cycle from manufacture (cradle) to the factory gate (gate) (Dupont, 2008).

Eutrophication - Oxygen depletion as a result of nitrogen and phosphorous deposit into freshwater or marine environments (LeviStrauss&Co., 2015)

Fast Fashion – Low cost clothing collections based on current, high-cost luxury fashion trends; a fast-response system that encourages disposability (Fletcher, 2008).

Globalization – The fast and unstoppable advances in information technologies, market deregulation and large reductions in transport cost (Puig, Marques, & Ghauri, 2009).

Just-in-time – An inventory pull system approach to managing the supply chain (Abuhilal, Rabadi, & Sousa-Poza, 2006)

Land Occupation – Occupation of a certain area of land during a certain time and or the transformation of a certain area of land (Goedkoop et al., 2013).

Life Cycle - An analysis of a product’s entire life that begins with raw materials extraction and ends with disposal.

Life Cycle Assessment (LCA) - A compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ANSI/ISO14040-1997).

Quick Response – A state of responsiveness and flexibility in which an organization seeks to provide a highly diverse range of products and services to a customer in the exact quantity, variety and quality, and at the right time, place and price as dictated by real time customer/consumer demand (Lowson et al., 1999).

ReCiPe 2008 – The implementation of an LCIA method that is harmonized in terms of modeling principles and choices, but which offers results at both the midpoint and endpoint level (Goedkoop et al., 2013, p. 1).

Sundries – Hardware, buttons, snaps and ornaments that are attached to the garment (Tortora & Merkel, 1996).

Sustainability – An activity that can be continued indefinitely without causing harm and meeting a current generation's needs without compromising those of future generations (Fletcher, 2008).

Water Consumption - Net freshwater taken from the environment minus water returned to the same watershed at the same quality or better (LeviStrauss&Co., 2015).

Appendix B

The ReCiPe 2008 method is a life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level. As supporting methodology material for this study, the full ReCiPe report can be accessed at www.lcia-recipe.net/home. Additional reports are provided to better understand normalization and characterization and CSV files to be used with the Simapro LCA software. Due to the lengthy report, the ReCiPe 2008 was unable to be added to this thesis. To be lead directly to the full report, copy and paste the address below into a web browser.

ReCiPe 2008:

https://35f23ee4-a-62cb3a1a-s-sites.googlegroups.com/site/lciarecipe/file-cabinet/ReCiPe_main_report_MAY_2013.pdf?attachauth=ANoY7cozb4El3bKOMksKK4iuWvwkPqz9houGoGLaZLxS1zMPDCD0J1tbw_18QM5ocZdhPPSWBAhdsWXUlK_G6ToHsQVKr7IDDsrXQWq3gaNzM54b3KpCmYG4zfT_BKkCMQ6H0ItuYMrG9ASMVQLEwT3EKXdcpYQnz6CUjpRvYHwEkGEr9YEHzEbsXH9Rm6v9RrPmCoaq_-gGgm2hY51cpr3l3QKsE25hAgx1zWOOPQe_pxBEsqU_0_yV3Wx7hkGy3OzqssRhE5p3&attredirects=0

Appendix C

"The Life Cycle of a Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans," (LeviStrauss&Co., 2015) sustainability report was used as a comparison throughout this thesis. Due to the lengthy report, the "Life Cycle of a Jean" was unable to be added to this thesis. However, appendix C includes tables with supporting data results and inventory analysis for the jean. To be lead directly to the full report, copy and paste the address below into a web browser.

"The Life Cycle of a Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans":

http://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf

Table C1

Sources of data collected within the Supply Chain

Phase	Product Data	Facility of General Data
Spinning	Fiber Type	Energy Water Packaging Waste
	Fiber Country of Origin	
	Transport Mode and Distance	
	Fiber loss	
Dye, Weave, Finish	Fiber loss	
	Chemical Use & Transport mode & Distance	
Cut & Sew	Transport Mode & Distance	
	Cutting Efficiency	
	Material Use	
	Sundry Material and Weight	
	Packaging Material and Weight	
Garment Finish	Chemical Use	
	Transport Mode & Distance	
Distribution Centers	N/A	
Product Transport	Transport Mode & Distance	
Retail	N/A	Energy
Consumer Care	N/A	Consumer washing habits

Reprinted from “The Life Cycle of A Jean. Understanding the environmental impact of a pair of Levi’s® 501® jeans,” by Levi Strauss & Co., p.48. Copyright 2015.

Table C2

Levi's® 501® Jean Life cycle Impact

	Fiber	Fabric Assembly	Cut, Sew, Finish	Sundries & Packaging	Transport, Logistics, Retail	Consumer Care	End of Life	Total
Climate Change (kg Co_2-e)	2.9	9.0	2.6	1.7	3.8	12.5	0.9	33.4
	9%	27%	8%	5%	11%	37%	3%	100%
Water Consumption (liters)	2,565	236	34	77	10	860	0	3781
	68%	6%	1%	2%	0%	23%	0%	100%
Eutrophication (g PO_4-e)	18.0	5.5	2.9	7.9	3.1	7.9	3.5	48.9
	37%	11%	6%	16%	6%	16%	7%	100%
Land Occupation (m^2/year)	9.3	0.2	0.0	0.5	0.3	1.7	0.0	12.0
	78%	1%	0%	4%	2%	14%	0%	100%
Abiotic Depletion (mg Sb-e)	19.9	7.2	1.9	118.5	4.4	17.9	0.1	29.1
	12%	4%	1%	70%	3%	11%	0%	100%

Reprinted from "The Life Cycle of A Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans," by Levi Strauss & Co., p.47. Copyright 2015

Appendix D

The “EDIPTEX – Environmental Assessment of Textiles,” (Laursen et al., 2007) working report was used as a comparison throughout this thesis. Due to the lengthy report, the “EDIPTEX – Environmental Assessment of Textiles” was unable to be added to this thesis. However, appendix D includes tables with supporting data results and inventory analysis for the t-shirt only. Supporting information includes background data for the t-shirt, cotton harvest and cotton yarn spinning. To be lead directly to the full report, copy and paste the address below into a web browser.

http://orbit.dtu.dk/en/searchall.html?searchall=EDIPTEX+-+Environmental+Assessment+of+Textiles&uri=

Table D1

System structure in the EDIPTEX database for the T-shirt

	Ref. no.: EDIPTEX
1 T-shirt (cotton)	(TX0-02)
1 materials phase:	(TX6-1-04)
0.4 kg cotton fiber (incl. cultivation and harvest)	(TX1-01-1)
1 production phase:	(TX6-2-11)
0.2727 kg bleach H2O2 (knitted cotton)	(TX24-1-03)
0.28 kg yarn manufacture (cotton yarn)	(TX21-1)
0.275 kg T-shirt knitting	(TX22-1-02)
0.2727 reactive dyeing (3%) of cotton goods	(TX25-01-01)
0.27 kg drying final fixing + set of m² weight	(TX27-3-06)
0.27 kg softening cotton textile	(TX6-2-16)
1.773 m² fabric inspection + rolling onto cardboard roll	(TX27-3-08-06)
1 cutting and stitching	(TX28-1-02)
1 packing	(TX28-2-03-02)
1 use phase:	
12.5 kg household wash, 60 °C, with prewash	(TX33-1-202)
12.5 kg tumbler drying cotton (vented), cupboard dry	(TX33-3-01)
150 min. Ironing cotton or other cellulose	(TX33-3-01)
1 disposal phase:	(TX6-4-02)
0.25 kg waste incineration of cotton	(TX41-1-01)

Table D1 (continued)

System structure in the EDIPTEX database for the T-shirt.

	Ref. no.: EDIPTEX
1 transport phase:	(TX6-5-02)
0.07 kg petrol combusted in petrol engine	(E32751)
800 kg km container ship 2-t. 28000 DWT, terminated	(O3715T98)
66.8 kg km lorry > 16 t diesel out-of-town, terminated	(O32694T98)
66.8 kg km lorry > 16 t diesel urban traffic, terminated	(O32695T98)
66.8 kg km lorry > 16 t diesel motorway, terminated	(O32693T98)

Reprinted from "EDIPTEX – Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p.81.

Table D2

Estimated transportation between phases of a cotton T-shirt.

Transport	Quantity for one T-shirt	Kg km
Transport of cotton	0.40 kg transported 2000 km by ship	800 kg km by ship
Transport of yarn	0.28 kg transported 200 km by lorry	56 kg km by lorry
Transport of knitted fabric	0.275 kg transported 200 km by lorry	55 kg km by lorry
Transport of dyed fabric	0.27 kg transported 100 km by lorry	27 kg km by lorry
Transport from factory to shop, lorry	0.25 kg transported 200 km by lorry	50 kg by lorry
Transport of discarded T-shirt (with household refuse)	0.25 kg transported 50 km by lorry	12,5 kg by lorry

Reprinted from “EDIPTEX – Environmental assessment of textiles,” by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p.83.

Table D3

System structure Lorry transport in the EDIPTEX database for the T-shirt.

Process no. in EDIPTEX database	Name of process	Transport need
O32715T98	Container ship, 2-t, 28000 DWT, Terminated	800 kg km by ship
O32695T98	Lastbil >16t, diesel urban traffic Terminated	66,8 kg km by lorry
O32694T98	Lastbil >16t diesel out of town landev. Terminated	66,8 kg km by lorry
O32693T98	Lastbil, >16t diesel motorway.Terminated	66,8 kg km by lorry
E32751	Petrol consumed in petrol engine	0,07 kg petrol

Reprinted from "EDIPTEX – Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p.84.

Table D4

Source identification for environmental impact potentials related to energy (Climate Change and Eutrophication).

	Greenhouse effect	Acidification	Nutrient loading	Photochemical ozone formation
Materials Phase	8% of total contribution	14% of total contribution	20% of total contribution	32% of total consumption
Fiber production	Originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	Originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	Originating primarily from burning fossil fuels and energy for production of N artificial fertilizer	Originating from burning fossil fuels
Production phase	10% of total contribution	8% of total contribution	8% of total contribution	7% of total contribution
Yarn manufacturing	60% of this phase's contribution originates from electricity consumption in this process	78% of this phase's contribution originates from electricity consumption in this process	71% of this phase's contribution originates from electricity consumption in this process	The main part, approx. 36%, of this phase's contribution originates from un-burnt fuels in connection with transport
Knitting	12% of this phase's contribution is due to electricity consumption	14% of this phase's contribution is due to electricity consumption	11% of this phase's contribution is due to electricity consumption	Not significant
Pre-treatment	8% of this phase's contribution is due to electricity consumption	3% of this phase's contribution is due to electricity consumption	7% of this phase's contribution is due to electricity consumption	16% of this phase's contribution is due to un-burnt fuel in connection with transport

Table D4 (continued)

Source identification for environmental impact potentials related to energy (Climate Change and Eutrophication).

	Greenhouse effect	Acidification	Nutrient loading	Photochemical ozone formation
Dyeing	11% of this phase’s contribution is due to electricity consumption	6% of this phase’s contribution is due to electricity consumption	10% of this phase’s contribution is due to electricity consumption	20% of this phase’s contribution is due to un-burnt fuel in connection with transport
Finishing	9% of this phase’s contribution is due to electricity consumption	4% of this phase’s contribution is due to electricity consumption	8% of this phase’s contribution is due to electricity consumption	18% of this phase’s contribution is due to un-burnt fuel in connection with transport
Making-up	Credit of minimal contribution due to assessed reuse potential	-4% credit of contribution due to assessed reuse potentials	-6% credit of contribution due to assessed reuse potentials	10% due to incomplete burning fossil fuels
Use Phase	82% of total contribution	78% of total contribution	68% of total contribution	26% of total contribution
Washing (households)	24% of this phase’s impact contribution originates from electricity consumption for heating water in the washing machine	24% see greenhouse effect for explanation	24% see greenhouse effect for explanation	24% see greenhouse effect for explanation
Tumbling drying	68% of this phase’s impact potential is due to consumption electricity for tumbler dryers	68% of this phase’s impact potential is due to consumption electricity for tumbler dryers	68% of this phase’s impact potential is due to consumption electricity for tumbler dryers	68% due to incomplete burning in connection with transport

Table D4 (continued)

Source identification for environmental impact potentials related to energy (Climate Change and Eutrophication).

	Greenhouse effect	Acidification	Nutrient loading	Photochemical ozone formation
Ironing	8% of this phase's impact potential is due to consumption electricity for irons	8% of this phase's impact potential is due to consumption electricity for irons	8% of this phase's impact potential is due to consumption electricity for irons	8% due to incomplete burning in connection with electricity generation
Disposal Phase	Credit of impact potentials due to exploitation of energy from incineration, approx. -2% of total	Credit of impact potentials due to exploitation of energy from incineration, approx. -1% of total	Credit of impact potentials due to exploitation of energy from incineration, approx. -1% of total	Approx. 1% of this phase's total contribution originates from incineration of the T-shirt
Incineration				
Transport Phase	2% of total contribution	2% of total contribution	4% of total contribution	342% of total contribution
Transport	Transport with diesel and petrol driven vehicles	Burning fossil fuels	Burning fossil fuels	Burning fossil fuels

Table D5

Source identification of the most intensive processes in the life cycle of the T-shirt (Abiotic Depletion).

	Crude Oil	Natural gas	Hard coal
Materials Phase	36% of total consumption	38% of total consumption	1% of total consumption
Fiber Production	Primarily from production of artificial fertilizer and pesticides, and transport of fibers.	Primarily from production of artificial fertilizer and pesticides, and transport of fibers.	Primarily from production of artificial fertilizer and pesticides
Production Phase	6% of total consumption	43% of total consumption	9% of total consumption
Yarn Manufacturing	56% primarily for electricity generation for spinning the yarn	1% primarily for electricity generation for spinning the yarn	80% of this phase's total coal consumption due to electricity consumption
Knitting	6% primarily due to electricity consumption	No importance	16% of this phase's total coal consumption due to electricity consumption
Pre-treatment	8% primarily due to electricity consumption	30% primarily due to electricity consumption	16% of this phase's total coal consumption due to electricity consumption
Finishing	9% primarily from electrical energy used for drying	34% primarily from electrical energy used for drying	1% of this phase's total coal consumption due to electricity consumption
Making-up	7% of this phase's total crude oil consumption due to reuse of textile in another product	2% of this phase's total crude oil consumption due to reuse of textile in another product	-2% of this phase's total crude oil consumption due to reuse of textile in another product

Table D5 (continued)

Source identification of the most intensive processes in the life cycle of the T-shirt (Abiotic Depletion).

	Crude Oil	Natural gas	Hard coal
Use Phase	46% of total consumption	32% of total consumption	91% of total consumption
Washing (households)	24% of this phase's contribution, primarily from consumption of Danish electricity	24% of this phase's contribution, primarily from consumption of Danish electricity	24% of this phase's contribution, primarily from consumption of Danish electricity
Drying	68% of this phase's contribution primarily from electricity consumption from tumbler drying	68% of this phase's contribution primarily from electricity consumption from tumbler drying	68% of this phase's contribution primarily from electricity consumption from tumbler drying
Ironing	8% primarily from consumption of Danish electricity	8% primarily from consumption of Danish electricity	8% primarily from consumption of Danish electricity
Disposal Phase	-2% of total crude oil consumption can be credited	-14% of total crude oil consumption can be credited	-1% of total crude oil consumption can be credited
Incineration	Incineration of the T-shirt recovers energy in the form of heat, and this replaces burning natural gas	Incineration of the T-shirt recovers energy in the form of heat, and this replaces burning natural gas	Incineration of the T-shirt recovers energy in the form of heat
Transport Phase	15% of total consumption	1% of total consumption	No importance
Transport	Consumption of petrol and diesel	Consumption of petrol and diesel	

Reprinted from "EDIPTEX – Environmental assessment of textiles," by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p.49.

Table D6

Consumption of chemicals - cotton cultivation

Type	Active Substance	Dose per chemical (active substance)	Dose per kg packed raw cotton (g/kg)
Insecticide	Methyl Paration	1,88kg/ha	2,5
	Aldicarb	0,72 kg/ha	1
	Malathion	5,5 kg/ha	7
Herbicide	Trifluralin	0,85 kg/ha	1
	Fluometuron	0,81 kg/ha	1
	Glyphosate	1,15 kg/ha	1,5
Fungicide	Quintozene (PCNB)	0.75 kg/ha	1
	Captan	-	-
Growth Enhancer	Ethephon	1,10 kg/ha	1,5
Defoliation agent	Paraquat	0,34 kg/ha	0,5
	Natrium Chlorat	2,83 kg/ha	3,5

Reprinted from “EDIPTEX – Environmental assessment of textiles,” by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p.218. Copyright 2008 by the Danish Environmental Protection Agency.

Table D7

Electricity consumption (all energy data for processes in kWh per kg spun yarn)

Process	Ring spindling			OE spinning		
	100 % carded cotton or 100 synthetic, Ne 16s	100 % carded cotton or 100 synthetic, Ne 24s	67 % polyester and 33 % cotton, Ne 36s (carded)	100% carded cotton or 100% synthetic, Ne 10s	100% carded cotton or 100% synthetic, Ne 16s	100% carded cotton or 100% synthetic, Ne 24s
Opening	0.20	0.20	0.25	0.20	0.20	0.20
Carding	0.18	0.18	0.27	0.16	0.17	0.17
Pre-blending	-	-	0,13	-	-	-
Stretching	0.06	0.06	0.09	0.06	0.06	0.07
Roving	0.24	0.32	0.28	-	-	-
Spinning	1.12	1.95	2.83	0.60	1.11	2.04
Air conditioning (only humidity)[1]	0.21	0.31	0.47	0.10	0.16	0.24
Light[1]	0.09	0.12	0.19	0.04	0.06	0.08

Table D7 (continued)

Electricity consumption (all energy data for processes in kWh per kg spun yarn).

Process	Ring spindling			OE spinning		
	100% carded cotton or 100 synthetic, Ne 16s	100% carded cotton or 100 synthetic, Ne 24s	67% polyester and 33% cotton, Ne 36s (carded)	100% carded cotton or 100% synthetic, Ne 10s	100% carded cotton or 100% synthetic, Ne 16s	100% carded cotton or 100% synthetic, Ne 24s
Total in kWh/kg yarn	2.10	3.14	4.51	1.16	1.76	2.80
Total MJ/kg Yarn	7.6	11.3	16.2	4.2	6.3	10.1

Note (1). These figures are different because it does not take the same amount of time to produce one kg of different types of yarn.

Reprinted from “EDIPTEX – Environmental assessment of textiles,” by S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen, F. M. Kristensen, 2007, p.223.

Appendix E

Per the "Publication Manual of the American Psychological Association", copyright permission is required from the copyright holder when reprinting or adapting tables and figures. Copyright permission was requested and approved from ReCiPe 2008 team and Levi Strauss & Co., for the use of material in "ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level" and "The Life Cycle of a Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans". Permission was requested from the Technical University of Denmark for the use of materials in "EDIPTEX – Environmental assessment of textiles" and is awaiting approval.

UK
UNIVERSITY OF
KENTUCKY

College of Agriculture,
Food and Environment
Retailing and Tourism Management
318 Erikson Hall
Lexington, KY 40506-0050
859 257-4917
fax 859 257-1275
www.uky.edu

ReCiPe

Dear ReCiPe team,

I am requesting permission to reprint and use tables and figures from the following work:

Author: M. Goedkoop, R. Heijungs, M. Huijbregts, A. D. Schryver, J. Struijs,
R. V. Zelm
Title: ReCiPe 2008. A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level.
Year: 2009
Pages: 133
A copy of the material can be found on the company's website at:
http://www.lcia-recipe.net/file-cabinet

I am requesting the right to use this material in my thesis work titled, "A Comparative Life Cycle Assessment Of Denim Jeans and A Cotton T-Shirt: The Production of Fast Fashion Essential Items from Cradle To Gate," in partial requirement for the degree of Master of Science in Merchandising, Apparel, and Textiles at the University of Kentucky. I am requesting to use the material in both print and electronic formats.

If permission is granted, would you please sign and date this letter below. Return this letter to tara.hackett@uky.edu, including credit line, fees and any other conditions. Signing this request letter confirms that you own the copyright to the above material.

Your permission is greatly appreciated. If additional information is required, please do not hesitate to contact me at the email address or phone number listed below.

Sincerely,

Tara Hackett

Tara Hackett, Graduate Student
University of Kentucky
Retailing and Tourism Management
318 Erikson Hall
tara.hackett@uky.edu
(614) 633-8290

Elizabeth Easter

Dr. Elizabeth Easter, Professor
University of Kentucky
Retailing and Tourism Management
318 Erikson Hall
eeaster@uky.edu
(859) 257-7777

PRé Consultants BV
Stationsplein 121
3818 LE Amersfoort
The Netherlands

PRé

The request is approved with the understanding that full credit will be given to the source.

PRé Consultants BV
Stationsplein 121
3818 LE Amersfoort
The Netherlands

(Signature)

PRé Consultants BV

(Company Name)

15 July 2015

(Date)

UK UNIVERSITY OF KENTUCKY

July 14, 2015

College of Agriculture,
Food and Environment
Retailing and Tourism Management
318 Erikson Hall
Lexington, KY 40506-0050
859 257-4917
fax 859 257-1275
www.uky.edu

Ms. Cynthia Lee
Senior Paralegal of Brand Services
Levi Strauss & Co.
1155 Battery St
San Francisco, CA 9411

Dear Ms. Cynthia Lee,

I am requesting permission to reprint and use tables and figures from the following work:

Author: Levi Strauss & Co.
Title: The Life Cycle of A Jean. Understanding the environmental impact of a pair of Levi's® 501® jeans.
Year: 2015
Pages: 51
A copy of the material can be found on the company's website at:
http://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf

I am requesting the right to use this material in my thesis work titled, "A Comparative Life Cycle Assessment Of Denim Jeans and A Cotton T-Shirt: The Production of Fast Fashion Essential Items from Cradle To Gate," in partial requirement for the degree of Master of Science in Merchandising, Apparel, and Textiles at the University of Kentucky. I am requesting to use the material in both print and electronic formats.

If permission is granted, would you please sign and date this letter below. Return this letter to tara.hackett@uky.edu, including credit line, fees and any other conditions. Signing this request letter confirms that you own the copyright to the above material.

Your permission is greatly appreciated. If additional information is required, please do not hesitate to contact me at the email address or phone number listed below.

Sincerely,

Tara Hackett

Tara Hackett, Graduate Student
University of Kentucky
Retailing and Tourism Management
318 Erikson Hall
tara.hackett@uky.edu
(614) 633-8290

Elizabeth Easter

Dr. Elizabeth Easter, Professor
University of Kentucky
Retailing and Tourism Management
318 Erikson Hall
eeaster@uky.edu
(859) 257-7777

An Equal Opportunity University

The request is approved with the understanding that full credit will be given to the source.

(Signature)

LEVI STRAUSS & CO.

(Company Name)

7/20/15

(Date)

College of Agriculture,
Food and Environment
Retailing and Tourism Management
318 Erikson Hall
Lexington, KY 40506-0050
859 257-4917
fax 859 257-1275
www.uky.edu

July 17, 2015

Technical University of Denmark
Anker Engelunds Vej 1
Building 101A
2800 Kgs. Lyngby
dtu@adm.dtu.dk

Dear DTU Department,

I am requesting permission to reprint and use tables and figures from the following work:

Authors: S. E. Laursen, J. Hansen, H. H. Knudsen, H. Wenzel, H. F. Larsen,
F. M. Kritensen,
Title: EDIPTEX – Environmental assessment of textiles
Year: 2007
Pages: 230
A copy of the material can be found on the company's website at: http://orbit.dtu.dk/fedora/objects/orbit:110259/datastreams/file_7635219/content

I am requesting the right to use this material in my thesis work titled, "A Comparative Life Cycle Assessment Of Denim Jeans and A Cotton T-Shirt: The Production of Fast Fashion Essential Items from Cradle To Gate," in partial requirement for the degree of Master of Science in Merchandising, Apparel, and Textiles at the University of Kentucky. I am requesting to use the material in both print and electronic formats.

If permission is granted, would you please sign and date this letter below. Return this letter to tara.hackett@uky.edu, including credit line, fees and any other conditions. Signing this request letter confirms that you own the copyright to the above material.

Your permission is greatly appreciated. If additional information is required, please do not hesitate to contact me at the email address or phone number listed below.

Sincerely,

Tara Hackett

Elizabeth Easter

Tara Hackett, Graduate Student
University of Kentucky
Retailing and Tourism Management
318 Erikson Hall
tara.hackett@uky.edu
(614) 633-8290

Dr. Elizabeth Easter, Professor
University of Kentucky
Retailing and Tourism Management
318 Erikson Hall
eeaster@uky.edu
(859) 257-7777

The request is approved with the understanding that full credit will be given to the source.

____

(Signature)

____

(Company Name)

____

(Date)

Bibliography

14040-1997, A. I. *Environmental management - Life cycle assessment - Principles and framework*.

Abuhilal, L., Rabadi, G., & Sousa-Poza, A. (2006). Supply Chain Inventory Control: A Comparison Among JIT, MRP, and MRP With Information Sharing Using Simulation. *Engineering Management Journal, 18*(2).

B.V., P. C. (2000). The Eco-indicator 99 A damage oriented method for Life cycle Impact Assessment Methodology Report.

Barnes, L., & Lea-Greenwood, G. (2006). Fast fashioning the supply chain: shaping the research agenda. *Journal of Fashion Marketing and Management, 10*(3), 259-271. doi: 10.1108/13612020610679259

Bhardwaj, V., & Fairhurst, A. (2010). Fast fashion: response to changes in the fashion industry. *The International Review of Retail, Distribution and Consumer Research, 20*(1), 165-173. doi: 10.1080/09593960903498300

Birtwistle, G., Siddiqui, N., & Fiorito, S. S. (2003). Quick response: perceptions of UK fashion retailers. *International Journal of Retail & Distribution Management, 31*(2), 118-128. doi: 10.1108/09590550310462010

Bruce, M., Daly, L., & Towers, N. (2004). Lean or agile: A solution for supply chain management in the textiles and clothing industry? *International Journal of Operations & Production Management, 24*(2), 151-170. doi: 10.1108/01443570410514867

Cachon, G. P., & Swinney, R. (2011). The value of fast fashion: Quick response, enhanced design, and strategic consumer behavior. *Management Science, 57*(4), 778-795.

Camp, S., Clark, G., Duane, L., & Haight, A. (2010). Life cycle analysis and sustainability report - Levi Strauss & Co. *ENVS 195: Sustainability Science*, 1-23

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications, 8*(3), 559-568.

Carrigan, M., & Pelsmacker, P. d. (2009). Will ethical consumers sustain their values in the global credit crunch? *International Marketing Review, 26*(6), 674-687. doi: 10.1108/02651330911001341

Chen, H. L., & Burns, L. D. (2006). Environmental Analysis of Textile Products. *Clothing and Textiles Research Journal, 24*(3), 248-261. doi: 10.1177/0887302x06293065

Choi, T.-M., Liu, N., Liu, S.-C., Mak, J., & To, Y.-T. (2010). Fast fashion brand extensions: An empirical study of consumers preferences. . *Journal of Brand Management, 17*(7), 472-487.

Chouinard, Y. (2008). Foreword *Sustainable Fashion Why Now?* New York: Fairchild Books, Inc.

Christopher, M., Lowson, R., & Peck, H. (2004). Creating agile supply chains in the fashion industry. *International Journal of Retail & Distribution Management, 32*(8), 367-376. doi: 10.1108/09590550410546188

Cohen, A. C., & Johnson, I. (2012). *J. J. Pizzuto's Fabric Science* (10th ed.). New York: Fairchild Books.

Confalonieri, U., Menne, B., Akhtar, R., Ebi, K. L., Hauengue, M., Kovats, R. S., . . . Woodward, A. (2007). Climate Change 2007: Impacts, Adaption and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 391-431). Cambridge, UK.

Cottoninc.com. Blue Jeans Go Green. Retrieved March 24, 2015, 2015, from http://www.bluejeansgogreen.org/About-Us/Program-History/

Cotton Incorporated (2010). Supply chain insights. Driving demand for denim jeans. Retrieved June 3, 2015, from http://www.cottoninc.com/corporate/Market-Data/SupplyChainInsights/Driving-Demand-For-Denim-Jeans/

Cotton Incorporated, (2010). Supply chain insights. Sustainable Dyeing Solutions. Retrieved July 22, 2015, from http://www.cottoninc.com/corporate/Market-Data/SupplyChainInsights/sustainable-dyeing-solutions/Sustainable-Dyeing-Solutions-02-10.pdf. (pp. 1-2).

Cotton Incorporated, (2010). Why irrigate cotton? Retrieved July 22, 2015 from http://www.cottoninc.com/fiber/AgriculturalDisciplines/Engineering/Irrigation-Management/Why-Irrigate-Cotton/

CTR. (2015). The Facts about Textile Waste (Publication no. http://www.weardonaterecycle.org/images/textile-recycling-issues.png). Retrieved March 11, 2015

Curwen, L. G., Park, J., & Sarkar, A. K. (2013). Challenges and Solutions of Sustainable Apparel Product Development: A Case Study of Eileen Fisher. *Clothing and Textiles Research Journal, 31*(1), 32-47. doi: 10.1177/0887302x12472724

Djelic, M., & Ainamo, A. (1999). The coevolution o fnew organizational forms in the fashion industry. *Organization Science, 10, No. 5*, 622-637.

Doyle, S. A., Moore, C. M., & Morgan, L. (2006). Supplier management in fast moving fashion retailing. *Journal of Fashion Marketing and Management, 10*(3), 272-281. doi: 10.1108/13612020610679268

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z.-I., Knowler, D. J., Leveque, C., Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews, 81*(2), pp. 163-182.

Dupont. (2008). A glossary of common sustainability terms.   Retrieved July 20, 2015, from http://www.corbiplastics.com/pdf/Glossary_of_SustainabilityTerms_EU.pdf

Dystar. (2010). Sustainability in textile processing.

Ellis, E. (2014). Ecosystem. In J. E. Duffy (Ed.), *Encyclopedia of Earth*.

EPA. (2009). (Publication no. http://www.epa.gov/osw/nonhaz/municipal/pubs/msw2009rpt.pdf). (EPA530-R-10-012). Retrieved March 10, 2015

EPA. (2015). Reducing and Reusing Basics.   Retrieved March 23, 2015, 2015, from http://www2.epa.gov/recycle/reducing-and-reusing-basics

Epps, R. W. (1995). Just-in-time inventory management: Implementation of a successful program. *Review of Business, 17*(1), 5.

Fernie, J., & Azuma, N. (2004). The changing nature of Japanese fashion. Can quick response impove supply chain efficiency? European Journal of Marketing, 38(7), 790-808. doi: 10.1108/03090560410539258

Fletcher, K. (2008). Sustainable fashion and textiles: design journeys. New York: Earthscan.

Gabrielli, V., Baghi, I., & Codeluppi, V. (2012). Consumption practices of fast fashion products: A consumer-based approach. *Journal of Fashion Marketing and Management, 17*(2), 206-224.

Giunipero, L. C., Fiorito, S. S., Pearcy, D. H., & Dandeo, L. (2001). The impact of vendor incentives on Quick Response. *The International Review of Retail,* *Distribution and Consumer Research, 11*(4), 359-376. doi: 10.1080/09593960126379

Goedkoop, M., Heijuns, R., Huijbregts, M., Schryver, A. D., Struijs, J., & Zelm, R. v. ReCiPe. Retrieved May 16, 2015, from http://www.lcia-recipe.net/home

Goedkoop, M., Heijuns, R., Huijbregts, M., Schryver, A. D., Struijs, J., & Zelm, R. v. (2013). ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level (First ed., pp. 133).

Goedkoop, M., & Spriensma, R. (2000). The Eco-indicator 99. A damge oriented method for Life Cycle Impact Assessment (2nd ed.).

Hacking, T., & Guthrie, P. (2008). A framework for clarifying the meaning of Triple Bottom-Line, Integrated, and Sustainability Assessment. *Environmental Impact Assessment Review, 28*(2-3), 73-89. doi: 10.1016/j.eiar.2007.03.002

Hellweg, S., Hofstetter, T. B., & Hungerbuhler, K. (2005). Discounting and the Environment. Should Current Impacts be Weighted Differently than Impacts Harming Future Generations? *The International Journal of Life Cycle Assessment, 8*(1), 8-18. doi: 10.1065/Ica2002.09.097

Hethorn, J., & Ulasewicz, C. (2008). *Sustainable Fashion Why Now?* New York: Fairchild Books, Inc.

Hofstetter, P. (1998). *Perspectives in Life Cycle Impact Assessments: a structured approach to combine models of the Technoshpere, Ecosphere and Valuesphere*. Boston, MA: Springer US.

Hofstetter, P., & Hammitt, J. K. (2002). Selecting Human Health Metrics for Enviromental Decision-Support Tools. *Risk Analysis, 22*, 965-983.

Hsu, S. L. (2009). *Life Cycle Assessment of Materials and Construction in Commerical Structures: Variability and Limitations.* (Master of Engineering in Civil and Environmental Engineering), Massachusetts Institute of Technology.

IFC. (2007). Environmental, Health, and Safety Guidelines for Textile Manufacturing.

ISO. (2003). *Enviromental Management: life cycle impact assessment: examples of application of ISO 14042* (1st ed.). Geneva: ISO.

Jefferson, T. History of the T-shirt. Retrieved June 2, 2015, from http://www.ooshirts.com/guides/History-of-the-T-Shirt.html

Jones, P., Hillier, D., Comfort, D., & Eastwood, I. (2005). Sustainable Retailing and Consumerism. *Management Research News*, 28(1), 34-44.

Joy, A., Sherry, J. F., Venkatesh, A., Wang, J., & Chan, R. (2012). Fast Fashion, Sustainability, and the Ethical Appeal of Luxury Brands. *Fashion Theory, 16*(3), 273-296. doi: 10.2752/175174112X13340749707123

Keiser, S. J., & Garner, M. B. (2012). *Beyond Design The Synergy of Apparel Product Development* (3rd. ed.). New York: Fairchild Books.

Krewitt, W., Pennington, D. W., Olsen, S. I., Crettaz, P., & Jolliet, O. (2002). Inidicators for human toxicity in Life Cycle Impact Assessment.

Laursen, S. E., Hansen, J., Knudsen, H. H., Wenzel, H., Larsen, H., & Kristensen, F. M. (2007). EDIPTEX - Environmental assessment of textiles (Vol. Working Report; No. 24, pp. 230).

LeviStrauss&Co. (2015). The Life Cycle of a Jean - Understanding the environmental impact of a pair of Levi's 501 jeans. Retrieved May 11, 2015 http://levistrauss.com/wp-content/uploads/2015/03/Full-LCA-Results-Deck-FINAL.pdf

Linder, S. H. (2002). Technology and Textiles Globalization. *History and Technology, 18*(1), 1-22.

Lowson, B., King, R., & Hunter, A. (1999). The Role of Quick Response *Quick Response: The Managing the Supply Chain to Meet Consumer Demand* (pp. 77-84). Chichester: John Wiley & Sons, LTD.

Luke, R. (2008). Popular Culture, Marketing, and the Ethical Consumer *Sustainable Fashion. Why Now?* (pp. 77-94). New York: Fairchild Books, Inc.

Michelsen, C. J., O'Connor, P., & Wiseman, T. (2014). Just in Time. *Defense AT&L, 43*(2), 32-36.

Mihm, B. (2010). Fast Fashion in a Flat World: Global sourcing strategies. *International Business and Economics Research Journal, 9*(6), 55-63.

Moisander, J., Markkula, A., & Eräranta, K. (2010). Construction of consumer choice in the market: challenges for environmental policy. *International Journal of Consumer Studies, 34*(1), 73-79. doi: 10.1111/j.1470-6431.2009.00821.x

Morgan, L. R., & Birtwistle, G. (2009). An investigation of young fashion consumers' disposal habits. *International Journal of Consumer Studies, 33*(2), 190-198. doi: 10.1111/j.1470-6431.2009.00756.x

Nielsen, A. M., & Nielsen, P. H. (2009). Comparative life cycle assessment of the Elemental T-shirt produced with biotechnology and a Conventional T-shirt produced with conventional technology. from http://improve.novozymes.com/Documents/LCA_elemental_t-shirt_and_biotechnology.pdf

NordicFashionAssociation. (2012). The Nice Consumer: Framework for achieving sustainable fashion consumption. Retrieved October 12, 2013, from http://www.nicefashion.org

Orzada, B., & Moore, M. A. (2008). Environmental Impact of Textile Production *Sustainable Fashion* (pp. 299-325). New York: Fairchild Books, Inc.

Partridge, D. J. (2011). Activist Capitalism and Supply-Chain Citizenship. *Current Anthropology, 52*(S3), S97-S111. doi: 10.1086/657256

Patagonia.com. Recycled Nylon. from http://www.patagonia.com/us/patagonia.go?assetid=37606

Patagonia.com. Recycled Polyester. Retrieved March 24, 2015, from http://www.patagonia.com/us/patagonia.go?assetid=2791

Patagonia.com. Recycled Wool. Retrieved March 24, 2015, from http://www.patagonia.com/us/patagonia.go?assetid=93863

Payne, A. (2011). The Life-cycle of the Fashion Garment and the Role of Australian Mass Market Designers. *The International Journal of Environmental, Cultural, Economic and Social Sustainability, 7*(3), 237-246.

Pennington, D. W., Potting, J., Finnveden, G., Lindeijer, E., Jolliet, O., Rydberg, T., & Rebitzer, G. (2004). Life Cycle Assessment Part 2: Current impact assessment practice. *Environment International, 30*, 721-739.

Petersen, K. J., Handfield, R. B., & Ragatz, G. L. (2005). Supplier integration into new product development: coordinating product, process and supply chain design. *Journal of Operations Management, 23*(3-4), 371-388. doi: 10.1016/j.jom.2004.07.009

Puig, F., Marques, H., & Ghauri, P. N. (2009). Globalization and its impact on operational decisions: The role of industrial districts in the textile industry. *International Journal of Operations & Production Management, 29*(7), 692-719. doi: 10.1108/01443570910971388

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., . . . Pennington, D. W. (2004). Life cycle assessment part 1: framework, goal and scope definition, inventory analysis, and applications. *Environ Int*, *30*(5), 701-720. doi: 10.1016/j.envint.2003.11.005

Rimiene, K. (2011). Supply chain agility concept evolution (1990-2010). *Economis and Management*, *16*, 892-899.

Rousso, C. (2012). *Fashion Forward. A guide to Fashion Forecasting*: Fairchild Books.

Sadar, A. (2010). *Fashion and Sustainable Development*. Paper presented at the 41st Internation Symposium on Novelties in Textiles: Oral Presentation, Slovenia, Ljubljana.

Sivaramakrishnan, C. N. (2012). Life cycle analysis of textiles. *Colourage, 59*(1).

Sproles, G. B., & Burns, L. D. (1994). *Changing Appearances: understanding dress in contemporary society*. New York: Fairchild Publications.

Stearns, P. N. (1997). Stages of Consumerism: Recent works on the issues of periodization. *The Journal of Modern History*, 69, 102-117

Taplin, I. M. (1999). Statistical Review: Continuity and change in the US apparel industry: A statistical profile. *Journal of Fashion Marketing and Management, 3*(4), 360-368. doi: 10.1108/eb022572

Thompson, M., Ellis, R., & Wildavsky, A. B. (1990). *Cultural Theory*. Boulder, Colorado: Westview Press.

Tokatli, N., & Kizilgun, O. (2009). From manufacturing garments for ready to wear to designing collection: Evidence from Turkey. *Environment and Planning*, *41*, 146-162.

Tortora, P. G., & Merkel, R.S. (1996). *Fairchild's Dictionary of Textiles.* New York: Fairchild Publications.

UNEP, & SETAC. (2015). The Life Cycle Initiative. Retrieved June 2, 2015, from http://www.lifecycleinitiative.org/starting-life-cycle-thinking/what-is-life-cycle-thinking/

USEPA. (November 20, 2013). Introduction to Eco-labels and Standards. from http://www.epa.gov/greenproducts/standards/

WHO. (2015). World Health Organization. Retrieved May 20, 2015, from http://www.who.int/about/en/

Yusuf, Y. Y., Sarhadi, M., & Gunasekaran, A. (1999). Agile manufacturing: The drivers, concepts and attributes. *International Journal of Production Economics, 62*, 33-43.

VITA

Education Institution

B.S. Degree Management, May 1999; Minor, Business Communications University of Kentucky, Lexington, KY

Professional Experience

Senior Technician, University of Kentucky, Lexington, KY, Aug. 2014 – May 2015

Lab Technician, University of Kentucky, Lexington, KY Jan. 2013 – May 2014

Merchandise Planner, Citi Trends, Savannah, GA, Aug. 2008 – July 2009

Planning Procurement Coordinator, American Signature Inc., Columbus, OH,

Sept. 2006 – Aug. 2008

Assistant Buyer, Belk Store Services Inc., Charlotte, NC, Jan. 2005 – June 2006

Merchandise Assistant, Belk Store Services Inc., Charlotte, NC, March 2003 – Dec. 2004

Assistant Store Manager, Limited Too Inc., Charlotte, NC, Jan. 2002 – Feb. 2003

Assistant Store Manager, Limited Too Inc., Louisville, KY, Jan. 2000 – Aug. 2001

Scholastic & Professional Honors

The Honor Society of Agriculture, Gamma Sigma Delta, 2014 - 2015

Recipient of Buster Award, 2013-2014

Retailing and Tourism Management Departmental Periodic Program Review, 2014

Appointed to National Fire Protection Association 1971 Annex Task Group, 2014

Cotton Inc. Blue Jeans Go Green Denim Drive Coordinator, 2013-2014

Tara Hackett