ABSTRACT

COCKERHAM, REBECCA CAROLINE. Textile Digital Library System for Product Development. (Under the direction of Dr. Lisa Parrillo Chapman, Dr. Cindy Istook, and Dr. Trevor Little.)

The objective of this research was to create a system for the management of fabric samples at a vertical textile mill in order to facilitate the search, view, and retrieval of woven fabrics and provide a guide for implementation of the system. Termed the Textile Digital Library System (TDL System), the research was grouped into three parts: development, pilot testing, and evaluation. In addition to a literature review, case study research – combining qualitative and quantitative techniques which include primary data, secondary data, observation, informal interviews, and surveys – was used to gather data.

The need for the Textile Digital Library System (TDL System) was initially identified by faculty at North Carolina State University, College of Textiles as a segment of a larger research project to increase the efficiency of a vertical textile mill in South America. This initiative was considered necessary in order to accelerate the product development process of Company X. Many companies that develop fabric require methods to effectively organize, archive, and retrieve fabric designs. A TDL System offers companies the potential to store fabric designs in a manner that facilitates the categorization, search, and retrieval of designs. Implementation of systems and technologies which support and encourage design decisions are essential to creating a sustainable and efficient product development process as they can reduce the time needed for product development and design. This study will review sustainable design and product development literature, research available digital archiving software, and develop, pilot test, and evaluate a TDL System. Results from this

study will benefit companies or institutes wishing to implement a Textile Digital Library System into their fabric design and development process in order to reduce the time and cost and to ultimately improve the sustainability of the product.

Textile Digital Library System for Product Development

by
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DEDICATION

To my loving, supporting, and crazy family.

BIOGRAPHY

The author, Caroline Cockerham, was born in Greensboro, North Carolina on August 18th 1987. With a Bachelor Degree in Textile and Apparel Product Development from North Carolina State University – College of Textiles, Caroline has a specific interest in sustainable development of textiles and apparel. Her love of textiles has led her into many countries and cultures, through jungles and cornfields, and into homes and hearts. She is thankful for her experiences and looks forward to future adventures.

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Chapter 1

1 Introduction

Product development and design significantly affect the sustainability of textile and apparel products and processes. Designers should be empowered by knowledge and supported by systems which assist in the creation of higher quality products, reduce time, lessen waste, and spark innovation – starting from the ideation and conceptualization stages of product development. Implementation of systems and technologies which facilitate sustainable design decisions is essential to creating an efficient product development process. The objective of this research is to develop, pilot, and evaluate a Textile Digital Library System (TDL System) for product development in order to facilitate the search, view, and retrieval of woven fabrics and further enable rapid and sustainable design, sampling, and communication at a vertical textile mill.

The need for the Textile Digital Library System was initially identified by faculty at North Carolina State University, College of Textiles as a segment of a larger research project to increase the efficiency of a vertical textile mill in South America. This initiative was considered necessary in order to accelerate the product development process of Company X. The PI conducted a comprehensive Literature Review on sustainable textile and apparel product development in order to further identify a need for new processes or systems which could facilitate sustainable product development. The TDL System was recognized as a necessary system for sustainable product development. However, before the sustainability of the system could be tested, the development, pilot testing, and evaluation of the TDL System was necessary. Therefore, this research explains and evaluates the development of a system. The PI performed a case study analysis to determine the functional requirements of Company X as they relate to the TDL System. The on-site case study data collection period lasted for 30 days and allowed the Principle Investigator (PI) to collect primary and secondary data from Company X. Qualitative and quantitative data collection occurred by 1) observational methods, 2) conducting formal interviews with company personnel, 3) administering an external survey to industry partners, and 4) creating a system evaluation tool. Qualitative data collected consisted of photographs, physical fabric samples, and written descriptions of processes and company requirements. Quantitative data consisted of survey responses and the Functional Requirement Guide – an evaluation tool created by the PI to help determine the best digital archiving system for Company X. This research provides a literature review of sustainable textile product development and digital archiving, a case study analysis of Company X, a description of the methodology used to develop, pilot test, and evaluate a TDL System, an analysis of the study, and conclusions and recommendations for future work needed in this area.

1.1 Relevance

A Textile Digital Library System (TDL System) will create informed and intentional product development, facilitate product innovation, and improve the overall sustainability and efficiency of the textile and apparel value chain by reducing waste. Product developers need quick and easy access to fabric designs so as to discourage the wasteful, time

consuming, and unsustainable process of designing (or re-designing) and producing (or re-producing) fabric when similar or identical designs already exist. Furthermore, the TDL System is necessary to promote communication and collaboration regarding fabric designs within the interrelated departments of textile companies and between the companies and their clients. This research will benefit textile and apparel companies who wish to have an efficient, internet based method of archiving, organizing, and retrieving fabric designs.

1.2 Research Objectives

The objective of this research was to create a system for the management of fabric samples at a vertical textile mill in order to facilitate the search, view, and retrieval of woven fabrics and provide a guide for implementation of the system. Termed the Textile Digital Library System (TDL System), the research was grouped into three parts: development, pilot testing, and evaluation. In order to support the main research objective, the following sub-objectives were established:

<u>Development</u>

- **SO1:** Identify the needs for the Textile Digital Library System (TDL System)
    - **SO1A:** Identify the current process of fabric sample organization

  - **SO1B:** Identify search topics and corresponding metadata which will assist product developers in browsing fabric designs.
  - **SO1C:** Identify internal and external needs for the TDL System

Pilot Testing

- **SO2:** Pilot test the digital archiving programs to determine system capabilities and limitations.
  - **SO2A:** Review existing digital archiving programs and supporting software/hardware which fulfill SO1.
  - **SO2B:** Determine initial program requirements for the TDL System
  - **SO2C:** Identify and sample three different digital archiving systems based on observation and secondary research.

Evaluation

- **SO3:** Evaluate the digital archiving programs to determine which program is best for the TDL System.
  - **SO3A:** Develop an evaluation tool to rate the different digital archiving systems.
  - **SO3B:** Determine which digital archiving program best suits the needs of Company X.

1.3 Limitations

Time was a limitation of this research as the PI only had six weeks (30 days) to develop, pilot test, and evaluate the Textile Digital Library System. The implementation and testing of the TDL System should continue over an extended amount of time in order to determine the actual effects on sustainable product development, once the program has been implemented and put into use by Company X and its clients.

Another possible limitation of this research was that it was conducted in a Spanish speaking country and the system and its information were constructed in Spanish. Conducting this research in various languages, such as English, Mandarin, or Hindi, may assist in broadening the audience of the research. Seeing that the textile industry is global and often involves the collaboration of many different cultures and languages, development of systems in various languages may be beneficial.

Finally, the implementation of the Textile Digital Library System was limited to one company. Implementing the TDL System within various companies and further comparing those results may provide diverse information about TDL Systems and indicate capabilities or limitations within one company which did not exist within another.

1.4 Definition of Terms

Textile Digital Library System: A centralized repository for digital fabric files and varied media types which manages the assimilation, explanation, cataloguing, storage, retrieval, and distribution or digital assets

Sustainability: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland Commission, 1987)

Metadata: Data describing other data (Hammer, 1999). For example, the metadata for a Pima Cotton is M70, the metadata for the color blue is CZ17, and the metadata for stripes is P100, so the complete metadata for a pima cotton, blue, striped fabric is M70CZ17P100.

Digital Archiving: The long-term storage, preservation and access to information that is born digital, created and disseminated primarily in electronic form, or for which the digital form is considered to be the primary archive (Hodge, 2000)

Digital Images: Electronic pictures taken of a scene or scanned from documents (for example: photographs, printed texts, artwork, textiles) in which the image is mapped as a grid of dots or picture elements, known as pixels. The pixels are represented by codes or *bits* which can then be reduced to a mathematical representation and can be read by a computer. (Cornell University Library, 2003)

Computer Aided Design (CAD) for Apparel Product Development: The application of computer technology to the development of a garment up to the point of production (Glock & Kunz, 2005)

Environmentally Conscious Design (ECD): A design approach in which the product's aggregate environmental impact is as small as possible across the lifecycle without compromising cost, performance, quality, and feasibility (Huang et al., 2009)

Ecological Footprint (EF): An instrument for assessing the environmental impact of a textile plant which assists in reporting to consumers and stakeholders increases or reductions of energy, resources, and waste (Herva, 2008)

Cut and Sew: An apparel manufacturing process involving the purchasing of fabric and cutting and sewing to make a garment (NAICS, 2012)

Slow Fashion: The valuation of local, transparent, and sustainable textile and apparel production and consumption (Clark, 2008)

A-POC (A Piece of Cloth): A manufacturing method that uses computer technology to create clothing from a single piece of thread in a single process. (Miyake Design Studio, 2012)

Lifetime: The duration of the life of a product starting from acquisition and ending at the moment of replacement, relating to the time of use by the consumer (Van Nes & Cramer, 2005)

Footprint: A measurement of impacts on the environment and natural resources (Wirtenberg, Russell, & Lipsky, 2009)

Handlooms: Samples produced in short runs by hand in order to create a small sample for clients

Case Study Research: an empirical inquiry that investigates a contemporary phenomenon within its real life context (Woodside, 2010)

Chapter 2

2 Literature Review

Secondary research of scholarly literature based on sustainable product development and digital archiving was conducted with the purpose of determining the methods in which a TDL System can facilitate communication, elicit sustainable design decisions, and affect the level of sustainability adopted within a textile enterprise. The following secondary research of scholarly literature considered: sustainable product development, digital archiving, and systems implementation.

2.1 Sustainable Product Development

Sustainable product development provides designers the opportunity to generate growth and transformation, reduce footprints, and advance innovation within a company. Brown and Eisenhardt (1995) emphasized the importance of product development stating, “Product development is among the essential processes for success, survival, and renewal of organizations, particularly for firms in either fast-paced or competitive markets” (p. 344). Products which are designed with inherent sustainable qualities and through sustainable manners are thought to have an even greater influence on the sustainability of the textile value chain than processing, manufacturing, or technology enhancements (Albino, Balace, & Deangelico, 2009). Uncertainty, complexity, and conflict surrounding the topic of textile and apparel sustainability have increased opportunities for research, innovation, and the development of new products and systems (Verona, 1999).

Designers can play a vital part in product development. The designer's function in product development includes, but is not limited to, materials choices, line planning, forecasting, product construction, technical design, and color development. These choices directly affect the sustainability of products and processes, during production and use. Beyond these functions, the designer must consider their influential power and ability to shape thinking and actions of consumers (Stegall, 2006). Huang, Liu, Zhang and Sutherland (2009) stated, "Once a product has been designed and enters into production, its environmental performance is largely fixed. The environmental impact of a product is directly influenced by the environmental attributes of the materials used" (p. 1074). Products which are designed with inherent sustainable qualities and through sustainable manners are thought to have an even greater influence on the sustainability of the textile value chain than processing, manufacturing, or technology enhancements (Albino, Balace, & Deangelico, 2009). For these reasons, the designer's role warrants knowledge, involvement, and communication in all stages of textile and apparel development – from manufacturing, sourcing, usage, and throughout the lifetime of products. In an interview by Fast Company (2012) the President, CEO, and a former designer at Nike, Mark Parker, stated the following quote regarding the importance of design:

> [It is] absolutely essential and critical to focus on innovation in a company – to give design a status to be at the table with the senior management of the company,

> helping to set [and] shape strategy and direction for the company. Designers are by nature more inquisitive, more connected, they dig a little deeper in terms of insights and turn those insights into innovation. It's critical that design isn't subjugated to the back room as a short order cook for marketing, merchandising, or sales, [design] has to be up front.

2.1.1 Communication and Collaboration for Sustainable Design

Fluid communication, collaboration, and cross-functional participation, must exist throughout business structures, beginning with design. Design must become an integrated task of study, planning, and management (Perks, Cooper, & Jones, 2005). Design cannot be limited to its traditional duty of aesthetic design in the development of new products; designers must assume many more responsibilities in order to create products that enrich lives (Perks, Cooper, & Jones, 2005). The sustainability of products is directly influenced by the product developer's ability to communicate designs and to collaborate with coworkers and clients of varying disciplines (Perks, Cooper, & Jones, 2005).

Many different agents influence the product development process, including designers, team members, management, suppliers, and customers (Brown & Eisenhardt, 1995). Brown and Eisenhardt (1995) argued that a successful product is the combination of thorough planning and communication around a target market, execution by a cross-functional team, support from senior management, as well as deeply integrated fundamentals of sustainability. These fundamentals include environmental expertise, good internal communication, and a design team with sustainable values (Simon et al., 2000). Because many different people and parts of a business influence final products, sustainable ideals must first be built into the company as whole, throughout all different departments and systems to facilitate efficient and transparent sustainable development (Simon et al., 2000). This further implies the need for designers to integrate tasks and collaborate with marketing, sales, suppliers, management, and the consumer. A sustainable product should reflect a sustainable process by which all divisions of the supply chain are connected through fluid communication and collaboration, strategies are backed by incentives and facilitate innovation, and design based thinking is implemented throughout the entire process.

The communication between designers and stakeholders is of utmost importance when implementing a plan for sustainability. Stakeholders, which include all decision makers within a company, have the ability to make influential choices and to relay messages throughout the firm and entire supply chain. These key players should understand how their decisions and actions affect the environment and need incentives and support through sustainable systems to make the correct choices. Hallstedt, Ny, Robert, and Broman (2010) stated that a combination of commitment, participation, and communication through clear goal setting and involvement of all staff will allow firms to be successful when implementing sustainable initiatives and systems. The communication of incentives and benefits of sustainability throughout the entire company, specifically between product developers and upper management, may encourage implementation of sustainable initiatives. Hallstedt et al (2010) suggested that when product developers communicate with higher management, they should engage in language that phrases words like environment and sustainability into quantifiable information that can add value to the company.

Baumgartner and Korhonen (2010) stated, “When any work is performed in a strategic manner, all individual activities serve a common purpose…All actors and their actions contribute to a common vision, an overall goal. The actors and their activities do not go in different directions, nor are they competing” (p. 73). To achieve strategic, sustainable thinking, companies must have objectives, a vision for the system, strategic principles, implementation strategies which are practical and concrete, and indicators and metrics which can measure the actions taken (Baumgartner & Korhonen, 2010). Cross functional and vertical integration of tasks, from the senior executives to designers and management, can enhance the value chain with expertise from different disciplines and angles. Companies can then begin to use sustainable product development as an opportunity for innovation and growth.

Calling for further integration of duties, design must be embedded in all activities, from new product development to management and marketing. Simon et al (2000) concluded that three fundamentals, including environmental expertise, good internal communication, and a design team with sustainable values, are necessary to sustainable design. The designer, as well as the entire company, must harness the ability to influence and affect the consumer and the industry through choices made during preliminary stages of the product development. Design cannot be considered a sub-activity incorporated only in separate activities of the product development process and designer’s education cannot be limited to the conception and drawing stage (Perks, Cooper, & Jones, 2005). Design and sustainability must occur simultaneously, fluently, and intentionally throughout all phases and departments of apparel product creation.

2.1.2 Sustainable Design Support and Assessment Tools

Design and decision supporting systems assist in sustainable product development. Rapid communication and instant access to information, specifications, and design through new systems and technologies has enabled faster reaction time, shorter lead times, and overall greater efficiency of textile and apparel processes (Glock & Kunz, 2005). Design related tools support the communication of designs and the integration of processes (Kumar & Malegeant, 2006). These design management tools help to connect the activities involved in the development process, allowing for easy communication and fast access to information.

These new technologies are challenging the traditional methods in which products are designed and made (Glock & Kunz, 2005). As design and technology are merging, designers not only need a strong creative foundation but must also possess technical skills (Simon et al. 2000). Simon et al. (2000) recommended that companies incorporate an environmental expert into the design process to cover areas that designers may be unfamiliar or unknowledgeable about; however, tools and systems could reduce or even replace the need for human capital. The integrated design process, where designers are responsible for a wide range of activities spanning outside of the conventional design process, should be supported by systems in order to create more innovative and functional products, produced faster and more cost effectively.

Hallstedt et al (2010) stated that sustainability should be built into a business strategy through incentive and disincentive approaches which are backed by decision support tools, such as eco-indexes or guidelines. To understand factors driving eco-design and sustainability, Simon, Poole, Sweatman, Evans, Bhamra, and Mcaloone (2000) explored the issues constituting eco-design by evaluating different methods. The DEEDS project (Design for Environmental Decision Support) aimed to report and analyze the appropriate tools which create success in sustainably integrated companies (Simon et al., 2000). A framework for sustainable initiatives should be built into initial tasks, thoughts, and responsibilities and further supported by incentives (Kumar & Malegeant, 2006).

Measuring and reporting expenditures are important to the tracking progress within a company. Ecological Footprints (EF), another method of measuring sustainability, concentrates specifically on the energy, resources, and waste used in the textile process (Herva, 2008). An EF is used as an instrument for assessing the environmental impact of a textile plant and to assist in reporting to consumers and stakeholders increases or reductions of energy, resources, and waste (Herva, 2008). Ecological Footprints can help point out what processes are most detrimental and further highlight areas where sustainability supporting systems are needed (Herva, 2008). An Ecological Footprint of a product can also indicate wasteful aspects or processes of product development which need modification.

Finally, Computer Aided Design (CAD) for apparel product development, defined as the application of computer technology to the development of a garment up to the point of production, can also help reduce processes and waste in product development integrating tasks and decreasing the need for traditional, time consuming methods of hand drawn patterns (Glock & Kunz, 2005). CAD can assist designers in conceptual design, pattern cutting, grading, and maker making. Traditional, two-dimensional (2D) CAD systems exist where the designer creates patterns on a computer through a point system, much like connect the dots. Three-dimensional (3D) CAD systems have helped to further integrate design and production by enabling flat, 2D pattern pieces to be sampled in 3D form on the computer, without using physical materials (Lectra, 2012). Though 3D CAD programs are complex and in a continuing process of development, they can reduce time and materials used in sampling and can assist in rapid prototyping. Drape of fabric is a major obstacle and studies have been conducted to figure out how to emulate natural fabric drape on a computer. Through the use of 3D CAD, the cut and sew process will radically change as clothing can become more customized and made to order, reducing waste of clothing which is badly fit (Lectra, 2012). The overall objective of 2D and 3D computer aided design is to improve and quicken the development process, with less error (Glock & Kunz, 2005).

A case study conducted at Liz Claiborne found that the use of CAD allowed the company to cut design time in half (Glock & Kunz, 2005). The implementation of a digital repository storing design images and information allowed the company to quickly access designs without having to recreate them from scratch and also reduced the need for external design assistance. Crawford stated the following regarding the benefits of implementing a CAD system (as cited in Glock & Kunz, 2005):

> By giving our textile designers access to the Internet and [CAD], we have expanded our toolbox for design inspiration to include virtually any image on the Web. This has afforded us the opportunity to capture new trends just in time for market, something that old-fashioned methods would not have allowed…We have reduced redundant work efforts…We have been able to reduce the time [spent designing]. (p.196)

2.1.3 Considerations for Designing Sustainably

Certain aspects should be taken into consideration when designing and when implementing systems to elicit sustainable processes and products. Those principles include minimization of material types within one product; reduction of product weight, volume, and size; selection of materials compatible for the environment and in compliance with laws; selection of reusable and recyclable materials which create minimal waste or pollution; and finally materials with low energy content (Huang et al., 2009). Albino, Balace, and Deangelico (2009) stated, "Through the efficient use of resources, low impacts and risks to the environment, and waste generation prevention since their conception stage, green products offer high quality and low overall costs to the consumer and society" (p. 86). Designers have a strong impact on the sustainability of products and processes and therefore should seek out information about processes or tools which improve sustainability.

2.1.3.1 Reduction of Waste

Waste generated during the textile and apparel production and development process emerges throughout all different departments, stages, and forms (Ganaris & Okun, 2011). Waste can be tangible, in the form of materials or water, or it can be intangible, in the form of time or energy and waste can be created by production as well as consumers. Growing textile waste throughout the entire apparel supply chain is filling landfills and polluting the environment (McGill, 2009). In 2009, the equivalent of 375 million t-shirts were consumed in the United Kingdom alone and 74 percent of this was down cycled into the landfill (McGill, 2009). Birtwistle and Moore (2007) conducted research regarding the consumers' role in the creation of waste. The consumer's perception that clothing is disposable, cheap, and easily replaceable has greatly added to waste. Consumers were grouped into three main categories; fashion innovators, fashion followers, and fashion laggards. The fashion innovators were impulse buyers seeking self-gratification through shopping and were the largest contributors to waste generation by textiles and apparel (Birtwistle & Moore, 2007). In addition, cheap prices supplement the throwaway fashion attitude as faded styles can easily be replaced. Birtwistle and Moore (2007) found that most consumers were unaware of the negative environmental effects and consumer education was suggested in order to extend the lifespan of clothing.

As consumers perceive clothing to be cheap and disposable, McGill (2009) explained the implications and effects on the environment, suggesting that fast fashion should slow down. McGill (2009) criticized companies who rapidly source and restock year-round, such as fast fashion companies, for creating expansive waste. To create clothing quickly enough to keep up with the fashion innovators, more problems are created. McGill (2009) stated that the speed in which clothing is produced also effects the sustainability of the system as poor quality checks frequently lead to defects, shorter lifetime of clothing, and increased waste. McGill (2009) concluded that in order to reduce the waste, the fashion industry should slow down.

From farming, to ginning, spinning, weaving, dying, finishing, inspecting, distributing, and retailing, many processes are involved in the textile and apparel supply chain. Tracking and regulating supply chains can be very difficult (McGill, 2009). In order to respond to demand, contractors often hire sub-contractors to complete orders on time- creating even more complexities and problems (McGill, 2009). Vertical operations, where all processes are contained to one facility, have assisted in making supply chains more efficient as they increase cross functional tasks and collaboration between different departments. Any possible reduction of processes can create a more sustainable supply chain and reduce waste. Furthermore, reducing waste can be achieved by implementing systems and technologies which combine steps, simplify operations, and reduce errors (McGill, 2009).

When concerning reduction of waste in the apparel production process, researchers, industry, and government organizations have identified the main topics of interest as minimization and treatment of chemical and water waste, efficient recycling techniques, raw material control, reusing textiles, energy saving practices, and chemical alternatives (Ganiaris & Okun, 2001). Companies have much to gain when optimizing waste, including increased efficiency within manufacturing, increased savings of materials, and reduced input to landfills (Ganiaris & Okun, 2001). Efficiency of operations can create large savings and can prevent fabric waste. Developments in technology of the cutting, spreading, and marker making processes have assisted in the optimization of fabric. Fabrics with minimum defects, which are well packaged, and have minimal shade disparity will be more efficient and create less waste in cutting rooms (Ganiaris & Okun, 2001).

Rissanen (2005) expanded on the idea of optimizing fabric use noting that a majority of fabric waste is generally created in the marker making process and more efficient markers can create less waste and save companies money. Historically, fabric was considered a precious resource, fabric was cut as little as possible in order to reduce waste, and garments were designed to use as much of the fabric as possible, for example, the Japanese kimono and the Indian sari (Rissanen, 2005). However, current manufacturing processes allow fabric to be so quickly and cheaply generated making fabric less precious (Rissanen, 2005). An example of a method currently used to optimize fabric is A-POC, or A Piece of Cloth. A-POC is a manufacturing method that uses computer technology to create clothing from a single piece of thread in a single process. Issey Miyake, a Japanese fashion designer, has been successful in designing with A-POC methods where fabric is optimized (Miyake, n.d.). Cross-functional design and manufacturing teams help to bridge creative and technical talents and encourage innovation such as A-POC. Rissanen (2005) concludes that the modification of current practices and the combination of technology, design, and manufacturing expertise can help to create a more responsible fashion network, resulting in less waste.

2.1.3.2 Recycling and Reuse

Recycling and reuse of textiles are methods which can reduce waste or prolong product lifetime. Both are important factors for product developers to consider during the initial stages of product conceptualization. There are many options for recycling textiles; however, McGill (2009) stated that the increased mixing of different fibers within garments in order to decrease costs and obtain specific fabric hand have made recycling less feasible. Rissanen (2005) reaffirmed that problems involving the mixing and sorting of materials and processing involved makes recycling difficult, suggesting that avoiding waste through better design is a more efficient method.

Design for Recycling, a model within the *Design for X* theory, is a method in which products are designed with consideration to their ability to be recycled (Holt & Barnes, 2010). DFX models aim to decrease products from becoming waste and product developers should choose the model most suitable for their target market. Product developers attempting to *Design for Recycling* should consider both the positive and negative impacts of recycling as certain barriers do exist (Holt & Barnes, 2010). Barriers to apparel recycling include: economic feasibly, lack of equipment and technology, and low consumer awareness as some consumers perceive recycled materials to be of lower quality (Larney 2010). Without considerable profit, recycling is not feasible. Farrant, Olsen, and Wangel

(2010) found that the act of collecting, handling, and processing the used garments through recycling used more energy than just reusing the item. Recovery and collection methods consist of repairing and reusing, refurbishing, remanufacturing, cannibalization, and recycling (Kumar and Malegeant, 2006). Though recovering/recycling may consume more energy than reuse, recycling textiles was preferred over disposal and should be considered by designers (Kumar and Malegeant, 2006). With the correct tools, information, and awareness, textile and apparel firms would be more likely to take advantage of these opportunities. Recycling apparel could create jobs, reduce waste, save space in landfills, and reduce certain costs for manufacturers.

2.1.3.3 Materials

Material selection is another method designers can use to reduce waste and reduce environmental impact. Important choices regarding materials include: material performance, quality, feasibility, extraction, processing, manufacturing, distribution, use, and end of life. Design principles that should be followed for sustainable product development include minimization of material types within one product; reduction of product weight, volume, and size; selection of materials compatible for the environment and in compliance with laws; selection of reusable and recyclable materials which create minimal waste or pollution; and finally materials with a low energy content. These guidelines are only applicable early in the design process and must be systematically incorporated into the development of clothing (Huang et al, 2009). For example in the case of cotton, Capagain (2006) stated that farming and production uses about 2.6 percent of water globally and Ingram (2002) stated that cotton uses 25 percent of the agricultural pesticide worldwide. Huang et al. (2009) suggested that environmental impact, cost, and performance of materials must be optimized for environmentally conscious design. Material choices have wide ranging effects which should be considered by product developers.

Huang, Liu, Zhang, and Sutherland (2009) proposed that materials selection was a key element in environmentally conscious design and believe that decisions regarding materials should be integrated into the design process as early as possible. Environmentally conscious design (ECD), is defined as a design approach in which the product's aggregate environmental impact is as small as possible across the lifecycle without compromising cost, performance, quality, and feasibility (Huang et al., 2009). The major aspects that must be accounted for in ECD are materials extraction, materials processing, manufacturing, distribution, use, and end of life. All of these factors are in some manner affected by the materials choice. Every possible impact of a material should be considered at the design stage while satisfying the necessary function of the product (Huang et al., 2009).

2.1.3.4 Lifetime

Different aspects influence the lifetime and decision to replace a product, including the inherent characteristics of the product, situational or external influences, and consumer characteristics (Van Ness & Cramer, 2005). Within these categories lie other motives for replacement, such as wear and tear, need for improved safety, desire for improvement of comfort, quality or design, and overall new desires (Van Nes & Cramer, 2005). The development of dynamic and quality products that can be upgraded or repaired is an important aspect of increasing product lifetimes and the sustainability of products (Van Nes & Cramer, 2005). Lifetime is defined as the duration of the life of a product starting from acquisition and ending at the moment of replacement, relating to the time of use by the consumer (Van Nes and Cramer, 2005). Items with a long lifetime, also known as *slow fashion* items, should be designed intentionally for the target market and with added value to the consumer (Clark, 2008). Clark (2008) explained how the oxymoronic term slow fashion could possibly be the saving grace of the fashion industry today. The term slow fashion describes the valuation of local, transparent, and sustainable production (Clark, 2008). The producer and consumer can become closely connected, giving more value and a longer life to clothing (Clark, 2008). Cooper (2005) concurred that the reduction of *throughput resources* and the creation of a circular economy by extending the product lifetimes could create more sustainable consumption. Product life extension is defined as increased longevity through greater durability and the ability to maintain the product through repair or reuse, combined for better efficiency and sufficiency (Cooper, 2005). In order to prolong the life of products, designers should consider energy use throughout lifetime and develop products which support longevity (Cooper, 2005). Cooper (2005) further explained that possessions are a key component of the consumer's identity and designers should create products which identify with the consumer, encourage attachment, and age with dignity.

Van Nes and Cramer (2005) discussed manners in which the product development process can move towards a more sustainable consumption pattern, determining that the nature of the product can lead towards better behavior on the consumer end. Generally, stakeholders assumed that creating a longer lifetime of products prevented consumers from buying new products and reduced profits for the company (Van Nes and Cramer, 2005). This theory ignored the idea that extending product lifetimes may actually increase profit by creating a better product and forming new venues for services, like repairs and upgrades. Van Nes and Cramer (2005) stated that effective design of products for extended life was dependent upon four stages of product development. Firstly, the company must have a strategy in place and make the decision to attempt creating higher quality, more durable products. Secondly, planning and objectives must be established and checked by a list of requirements. The third stage included actual development where objectives are turned into designs, while the fourth stage encompassed production and bringing the product to market. Researchers concluded that adherence to these stages will increase the longevity of products (Van Nes and Cramer, 2005).

In a related study, Van Nes and Cramer (2006) discussed the optimization of product lifetimes and the relationship of sustainable consumption with reference to these lifecycles. The aim of lifetime optimization is to reduce replacement by creating inherently sustainable products which elicit better behaviors by the consumer, regardless of the consumer's consciousness of environmental issues. Different motives for replacement were discussed, including the idea that understanding buying behavior can allow designers to create more intentional products. Though controversy exists regarding extended lifetime and decreased consumption, researchers believe that increased lifetimes will actually make the product and company more competitive. Van Nes and Cramer (2006) specified four stages and design activities within these stages which will create longer lasting products; formulation of a strategy, product planning, actual development, and realization of the product. Lifetime aims should be translated into a general design objectives and requirements; decisions which would take place in the second stage of the development process (Van Nes and Cramer, 2006). Designers should also consider that longer lifetimes can create greater lifecycle impact as the product is used. Creating products which do not use energy during their usage and have *real discontinuous environmental impact* may solve this issue, for example, products which do not require laundering (Van Nes & Cramer, 2006). Understanding the reasons for consumption and replacement is vital to creating longer lasting product and the creation of dynamic and flexible products is fundamental to optimize the lifetime of clothing.

As a product is kept longer, it is prevented from entering the waste cycle, adversely the longer one keeps a product, the greater its lifecycle impact becomes through laundering and consumer care. Abstract design concepts which use no energy during the consumer phase with real discontinuous environmental impact are a vital part of planning and a possible resolution to the issue of increased energy consumption during consumer use (Van Nes & Cramer, 2005). With further regard to product lifetimes, the International Fabricare Institute [IFI] (1988) published a report explaining the accepted number of years garments are normally kept. Awareness of the garment lifetimes may help designers to better understand correct input materials which would appropriately optimize product lifetimes. Determined by the IFI, the Average Life Expectancy of Textile Items in Years is stated in Table 1.

Table 1. Average Life Expectancy of Textile Items in Years (IFI, 1988)

Average Life Expectancy of Textile Items in Years			
Type of Apparel Item	**Lifetime (Years)**	**Type of Apparel Item**	**Lifetime (Years)**
Bathing Suits	2	**Shirts**	
Bath Robes		Dress	2
Lightweight	2	Sports	2
Heavy or Quilted	3	Wool or Silk	2
Wool	3	**Ski Jackets (Including Down)**	2
Blazers		**Skirts**	2
Cotton and Blends	3	**Slacks**	
Immitation Suede*	3	Lounging and Active Sport	2
Wool	4	Dress	3
Coats and Jackets (Outterwear)		**Socks**	1
Childrens	2	**Sports Coats**	
Cotton and Blends	3	Cotton and Synthetic Blends	3
Down	3	Immitation Suede*	3
Fur	10	Wool and Wool Blends	4
Immitation Suede*	3	**Suits**	
Leather and Suede	5	Cotton and Synthetic Blends	2
Plastic	2	Summer-weight Wool	3
Wool	4	Immitation Suede*	3
Blouses	3	Silk	3
Choir Robes	6	Washable	2
Dresses		Winter-weight Wool	4
Casual	2	**Sweaters**	3
Office	3	**Ties**	1
Silk	2	**Underwear**	
Evening		Foundation Garments	1
High Fashion	3	Panties	1
Basic	5	Slips	2
Formal Wear	5	**Uniforms**	1
Gloves		**Vests**	2
Fabric	1		
Leather	2		
Rainwear and Windbreakers			
Film and Plastic Coated	2		
Fabric, lined, and unlined	3		
Rubber and Plastic	5		

2.1.4 Levels of Sustainability

All companies who employ sustainable strategies obtain different levels of sustainability and experience different issues. Understanding the level obtained can highlight areas of possible improvement and adjustments to strategies. Sustainability is a key competency for textile firms as enterprises stand to reduce risk, decrease costs, increase profit, build reputation, increase future growth trajectory, create innovative products, and create disruptive change (Hart, Milstein, & Caggiano, 2003). Baumgartner and Ebner (2010) explored different profiles and maturity levels of sustainability efforts in corporations so as to highlight disparities between intentions and actual implementation. Sustainability in product development warrants a fundamental change in business strategies as well as choices made at the conceptualization stage (Huang et al., (2009). Processes and technologies can become as environmentally, socially, and economically viable as possible, however, the value, benefits, and sustainability of the actual product must first be taken into consideration and must be carried out through the entire product cycle (Cooper, 2005).

Baumgartner and Ebner (2010) classified sustainability strategies into four categories – introverted, extroverted, conservative, and visionary. An introverted strategy is the lowest level of sustainability involvement a company can undertake as it only includes aspects which protect the company from potential risks involving social and environmental problems. Companies with extroverted strategies tend to be less grounded in sustainability and more focused on the marketing and public relations opportunities which can increase the value of the brand. Furthermore, Albino, Balice, and Dangelico (2009) stated three factors of motivation for sustainably driven companies – legitimacy, competitiveness, and social responsibility (Albino, Balice, and Dangelico, 2009). These factors of motivation coupled with strategies for implementation can create a more sustainable company.

The extroverted strategy was divided into two groups; conventional and transformative (Baumgartner & Ebner, 2010). The conventional strategy was based on marketing whereas the transformative approach sought to actually change market perceptions by driving the ideals of sustainability, which proved more successful than conventional methods. The conservative strategy was explained as a tactic centered on cost efficiency. Corporations who adopt this strategy may have to make initial capital investments but will save money in the long run. The final and aspirational sustainability tactic was the visionary strategy. This approach entailed a very advanced commitment to sustainability where the corporation took all possible advances and perspectives to become more sustainable. Baumgartner and Ebner (2010) argued that companies must decide whether they are going to compete on product differentiation or cost leadership. Each individual company must determine how to best integrate sustainability into their business activities and continue to build their initiative with complete commitment to sustainability fundamentals.

The Sustainable Value Model (Figure 1) by Hart , Milstein, and Caggiano (2003) exemplified each stage of progression as a company develops their sustainable profile and is comparable to Baumgartner and Ebner's (2010) sustainability profiles. The Sustainable Value Model represents the characteristics of attaining sustainability and the positive outcomes for a corporation. Figure 1 depicts the interrelated stages of adoption, from internal to external, today to tomorrow, explaining the strategies, drivers, and benefits during each stage.

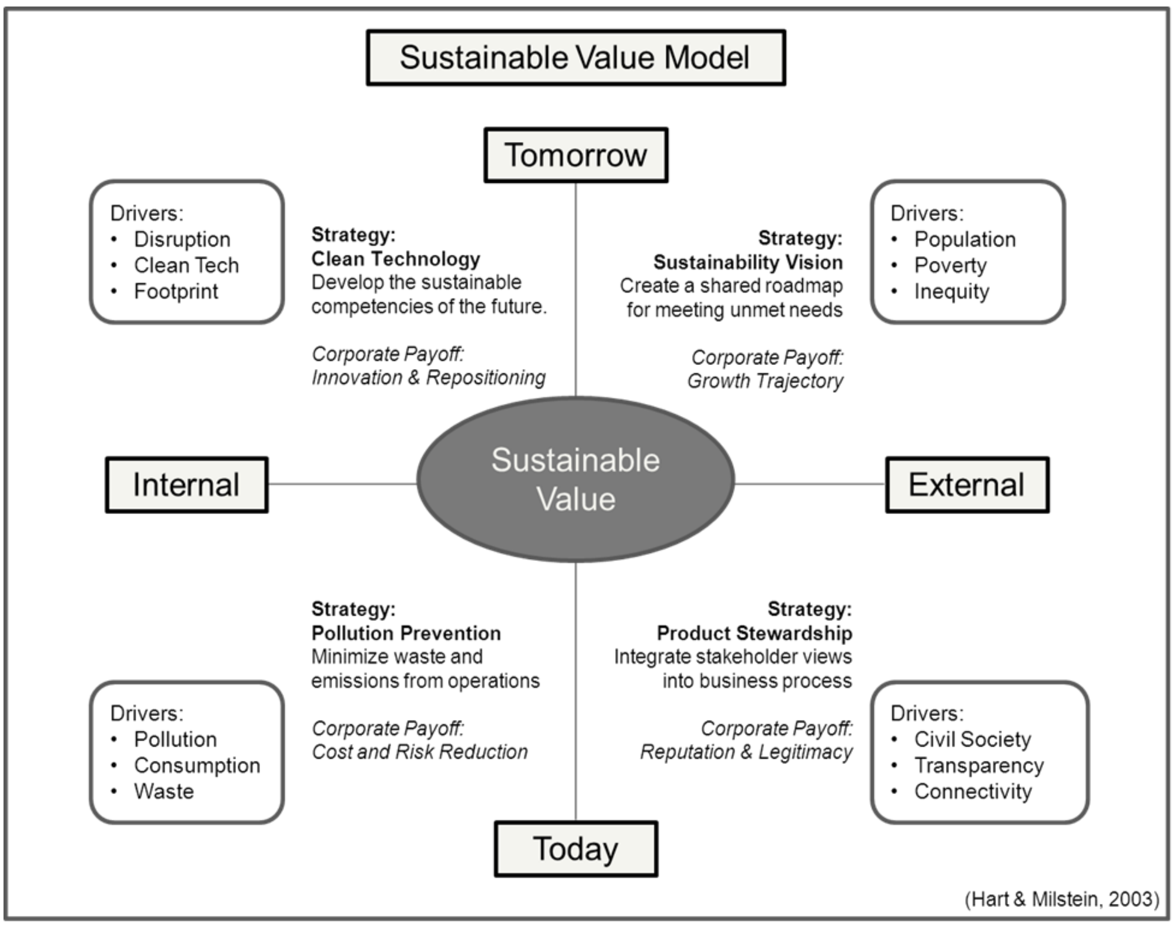

Figure 1. Sustainable Value Model (Hart, Milstein, & Caggiano, 2003)

The first stage of Sustainable Value, *internal/today*, is driven by the need to reduce pollution, consumption, and waste. A strategy of pollution prevention through the minimization of waste and emissions from operations is normally implemented due to possible cost and risk reductions to the company. The main purpose of internal/today is to save money. The second stage, *external/today*, is driven by transparency, connectivity, and civil society. The strategy is to integrate stakeholder views into business processes and to build reputation and legitimacy through product stewardship. The purpose of this stage is to be perceived by consumers as sustainable. These two stages of the Sustainable Value Model, *internal/today* and *external/today,* can be implemented into a company's sustainability strategy immediately, whereas the *internal/tomorrow* and *external/tomorrow* stages require more complex, holistic adoption. (Hart, Milstein, & Caggiano 2003)

During the *external/tomorrow* stage, a company is driven by external factors such as population, poverty, and inequality (Hart, Milstein, & Caggiano 2003). A shared vision and mapped plan is developed during this stage to become a company which is socially as well as environmentally and economically sustainable. During the final stage of the Sustainability Value Model, the *internal/tomorrow* stage, business strategies are innovated and repositioned, resulting in disruption, clean technology, and a smaller footprint (Hart, Milstein, & Caggiano, 2003). See the Figure 1, the Sustainable Value Model, for information about different levels of sustainability.

2.1.5 Obstacles of Sustainable Product Development

Uncertainties regarding the material production, actual product lifecycle, safety, and performance create difficulties in the selection process of sustainable materials, but all are important aspects to take into consideration (Baumgartner & Korhonen, 2010). Among the many obstacles that must be overcome when creating a sustainable product, researchers suggested specific reasons for product and process failure created by upper management and design (Baumgartner & Korhonen, 2010). Multidimensional thought and collaboration were considered essential to the employment of sustainable products. Companies who lacked communication and did not treat sustainability as an interrelated cycle or web of activities lost opportunities for creating sustainable products. Baumgartner and Korhonen (2010) investigated the reasons for failed and slow sustainable development and contribute it largely to the idea of reductionism. Reductionism reflects the idea that all systems are cause-and-effect chains, suggesting that systems must be addressed as a whole rather than by each singular problem. Baumgartner and Korhonen (2010) stated, "Reductionism leads to situations where exiting problems are handled within a certain system while new problems are created elsewhere in this system or in its subsystem or in the future of the same system" (p. 72). Firms which address problems as single issues rather than as a part of a system miss the opportunity for transformation and innovation. Verona (1999) stated that strategic thinking involves using resources to enhance performance, cut out reductionism, and tackle problems through a shared strategic vision and objective.

2.2 Digital Archiving

Implementing systems which facilitate sustainable design decisions is vital to the product development process. Digital archiving was defined by Hodge (2000) as the long-term storage, preservation and access to information that is born digital, created and disseminated primarily in electronic form, or for which the digital form is considered to be the primary archive. A digital archiving system can assist textile and apparel product development by creating a repository of design files which designers can access for inspiration or product information (Glock & Kunz, 2005). As well, digital archiving protects, preserves, and stores designs and intellectual property which are critical assets to textile companies. Through digital archiving of fabric samples, internet access to assets are unbound by geographic location, time zone, or language and are available for use by textile companies – facilitating and expediting communication and collaboration within companies and to clients. As cited in Glock and Kunz (2005), Crawford made the following statement in reference to CAD systems and archiving designs:

> By leveraging an archive of images stored in a central repository, our designers can jump-start the design process using digitally prepared motifs…We have reduced redundant work efforts in scanning, color reduction, and textile art cleanup…By integrating our CAD system to an apparel specifications solution, we have been able to reduce the time an apparel designer needs to have a sketch rendered on CAD. (p. 196)

Requirements for archiving data were identified by Addabbo and Annuziato (2006) in a report summarizing digital archiving. Addabbo and Annuziato (2006) stated that the main needs for archiving in the future are: storage of various file formats and differing types of records, remote access to the database, ability to access and upload information through email, and storage of information on a secure server. The main topics regarding digital information security are: availability – maintaining that data is accessible in good time; integrity – ensuring that data is complete and accurate; and confidentiality – safeguarding that information is only available to authorized users (Addabbo and Annizuiato, 2006). Furthermore, advantages regarding digital archiving were noted by Abelson (1995), including: compactness, portability, durability, rapid accessing of records, minimal storage space required, and ease of information transfer. Various studies have been devoted to the topic of the digital archiving of data however, very little is documented regarding the digital archiving of fabric images. Systems for digital archiving and the use of metadata in digital archiving are topics of further research.

2.2.1 Metadata

Developing metadata is essential to the organization and preservation of data in the TDL System. Metadata is essentially data about other data (Hammer, 1999). Clyde (2002) explained that the purpose of metadata is to describe and index resources in a website in the same manner that cataloging is used in traditional libraries – to have coded or condensed versions of information which represent a greater amount of information. Metadata is also used to describe related data elements within a website or database (Hammer, 1999). Using metadata can assist in the creation of search engines, tracking of information, record keeping, and incorporation of information into an intranet of a company (Clyde, 2002). “Metadata provides an all-encompassing data model and a description of how physical databases and applications relate to that model. Metadata tells you where you have come from, where you have been, how and when you got there, what you did on the way, and what would happen if something changed” (Hammer, 1999, p. 32).

Metadata inputs vary for differing projects and companies, depending on the needs, subject matter, resources, and target market (Hodge, 2000). Though some metadata formats exist, metadata should describe data specific to the company, should be consistent, and should be developed during the creation stage of data or products so as to incorporate the consistent metadata throughout other processes (Hodge, 2000). “Many project managers acknowledged that the best practice would be to create the metadata at the object creation stage, or to create the metadata in stages, with the metadata provided at creation augmented by additional elements during the cataloging/identification stage” (Hodge, 2000, Section 4.1, para. 5)

2.2.2 Digital Image Capture & Image Management

Digital image capture and image management is an important part of digital archiving. Digital images are electronic pictures taken of a scene or scanned from documents (for example: photographs, printed texts, artwork, textiles) in which the image is mapped as a grid of dots or picture elements (Cornell University Library, 2003). The pixels are represented by codes or bits which can then be reduced to a mathematical representation and can be read by a computer (Cornell University Library, 2003). Digitizing assets helps to preserve originals and allows access to assets beyond the physical document or product (Cornell University Library, 2003).

A variety of tools can capture digital images, including a digital camera and a scanner. A study conducted by Cornell University Library (2003) stated that the method in which images are captured should be determined with regard to the product and methods should stay consistent. In addition, the environment in which the images are captured should be controlled (Cornell University Library, 2003). Consistency and controlled environments are important when conducting digital image capture as disparities between real products/documents and digitized images can be vast, depending on the circumstances in which the image was taken. Sachs (1999) stated that the process of making images appear the same between the real image and between two or more computers can be complex and expensive. Some important issues to consider when managing color in digitized images are the hue, saturation, brightness, luminance, and chrominance (Sachs, 1999). Sachs also noted that when viewing digital images, the image viewing conditions should be standardized in addition to the image capturing conditions. Calibrating computers by adjusting the brightness control, the gamma curve, the white point, and using a standard set of phosphors can create almost identical images (Sachs, 1999).

In addition to calibration and consistent processes, the human subject assigned to work with the digital images should remain consistent (Cornell University Library, 2003). They should be trained to interpret color correctly; however, disparities in two peoples vision may cause differences in color perception (Cornell University Library, 2003). A color management system (CMS) could be implemented to decrease issues with color perception (Cornell University Library, 2003).

Furthermore, images can differ depending on the program and the file format used to view the digital images. Some factors affecting the file format used are: bit depths supported, compression techniques supported, color management, proprietary versus standard file format, web browser capabilities, user computer capabilities, and metadata capability (Cornell University Library, 2003). The standard file formats used are TIFF, GIF, and JPEG as these can be viewed in most platforms (Cornell University Library, 2003). Though image management is a complex process and continued research is needed to ensure consistent color and image perception, following these recommendations may create less disparity between digital images, differing computers, and real documents.

2.2.3 Digital Archiving Systems

A wide array of data and image archiving systems exist that offer companies the capability to archive, organize, and search digital assets. The following section will discuss a selection of current image archiving systems. A vast variety of digital archiving systems exist, however, the following six systems were investigated in further detail due to their capability for textile digital archiving. The digital archiving systems include: Canto Cumulus, LUNA Imaging, Microsoft Sharepoint, SeeFile, Mosaic, and Textronics.

2.2.3.1 Canto Cumulus

Canto Cumulus is a digital asset management company that creates software that assists in the organization, search, and sharing of any type of digital files. Started in 1990, the company seeks to improve productivity and workflow, control and standardize branding, track usage of assets, and maximize benefits from intellectual property (Canto Cumulus, 2012). Canto Cumulus digital asset management capabilities include the ability to share specific information and files with clients, crop and edit photos, remote access to files, cross platform support, and security. "Canto Cumulus provides easy, permissions-controlled access for users on both sides of the file sharing equation" (Canto Cumulus, 2012, Partner Portal Two-way Sharing section, para. 4). Furthermore, Canto Cumulus offers technical services and business development services which include installation, configuration, custom development, training, consulting and needs assessment, project management, and change management. Canto Cumulus's software is configured specifically for each individual company's needs and employees are trained on how to use the software. Regular system updates allow Canto Cumulus to be relevant with changing needs. (Canto Cumulus, 2012)

2.2.3.2 LUNA Imaging, Inc.

LUNA Imaging, Inc., a specialist in digital imaging, provides availability of high-resolution images and data from any location. Capabilities of LUNA Imaging include that the program is interoperable (meaning that it has the ability to operate on diverse systems and networks), flexible, efficient, and cross-disciplinary. The program consists of four different components, LUNA, Luna Insight, Insight Studio, and Luna Inscribe. The four parts together allow users to quickly and easily build collections of images and data and further catalogue the images, linking them with data records. With LUNA, users can browse categories, perform simple keyword searches as well as more complex searches, can organize their results as needed (LUNA Imaging, 2010). LUNA has been primarily used in archiving for institutions, such as the North Carolina State University Archive Photograph Collection. In a comparison of LUNA Imaging with other digital archiving software programs, Oblinger (2005) stated, "[LUNA] has well developed image and multimedia indexing and viewing functions but is not a full-fledged DAM (digital asset management) product. [LUNA] does not currently accept Word documents or datasets, for example" (p.20). Although LUNA was perceived not to be a full-fledged DAM product, it was still implemented by NC State University as the other capabilities of the program were suitable for their archiving needs. Differing capabilities of archiving programs could benefit certain institutions or enterprises while being a detriment to others, depending on the needs of the institution or enterprise.

2.2.3.3 Mosaic

Mosaic, a digital archiving company, is a business solution designed to store and categorize digital files (Mosaic, n.d.). Mosaic allows companies to create collections, download images, email collections, customize the site, create user groups and give permissions, and generate reports regarding the information accessed. Though Mosaic is password protected and allows user groups and permissions, it is browser based and files are not stored on an internal repository (Mosaic, n.d.). Mosaic can assist in brand management, marketing management, media management, asset management, and for general photography needs. A customer stated, "[Mosaic] has also proved to be very easy to use. Internally and across our various suppliers we are probably saving ourselves at least five hours of image search time per week" (Mosaic, n.d., Clients section, para. Genesis Energy). By saving time, companies could also save money and become more sustainable – another value of implementing a digital archiving system.

2.2.3.4 Microsoft Sharepoint

Microsoft Sharepoint is a Microsoft application which assists in group collaboration. Within Microsoft Sharepoint, a company can create web sites to share information, search images, manage documents, and publish reports (Sharepoint, 2011). The user builds the site and inputs all content with no outside programming, management, or configuration assistance (Sharepoint, 2011). Microsoft Sharepoint is not web based and cannot be shared with clients (Sharepoint, 2011). In a review of Microsoft Sharepoint, the program was trialed and was found to be easy to install and easy to navigate for users that were familiar with other Microsoft applications, however it required a detailed knowledge of CSS to customize the site (Heck, 2010). The ability of Microsoft Sharepoint to integrate with other Microsoft programs, such as Office and Word, could help further integrate tasks within a company (Heck, 2010).

2.2.3.5 SeeFile

SeeFile is a browser based digital image archiving system. "The main advantage of SeeFile is that it updates continuously from your file system, without requiring uploads at your end. SeeFile lets you make specified areas visible to one or more colleagues, each with their own username and password. The main method of accessing SeeFile is a fixed IP location or URL, which can be linked to your website wherever it is located" (SeeFile, 2010, Product section, para. 2). SeeFile allows uploads and downloads, approvals, previews of images, private folders, and branding. Though SeeFile is password protected, it is browser based and files are not stored on an internal repository (SeeFile, 2012). A review of Seefile found the program to have an easy learning curve and smart filters for searching (PR Newswire, 2011). A client of SeeFile stated, "[SeeFile is] a phenomenal way to handle a range of client communication issues" (Seefile, 2010, Homepage section)

2.2.3.6 Textronics

Textronics is a textile specific design management software. Textronics provides CAD and CAM solutions for textiles and also includes design archiving. "Design Archive is an intelligent design data management system which hosts a comprehensive library created over a period of time. The data can be accessed by various hierarchies/departments of the organization for their specific requirements with predefined rights and permission for design data and corporate security. [A] sales person can communicate design and style requirements while on tour and his request for customer-oriented development."

(Textronics, 2010, Design Management section, para. 1). Because Textronic is specific to textile and apparel archiving, searching categories are preset to color, design type, fabric style, design style, fabric type, weave, yarn type, season, month, and number of colors (Textronics, 2010). Furthermore, Textronics has CAD and 3D design capabilities which can make viewing fabrics and products easier (Textronics, 2010). This capabilities differentiates Textronics from other digital archiving programs.

2.3 Systems Implementation

The implementation of a system is a multilevel, complex process. Bell and Omachonu (2011) stated that when implementing systems, companies should take the following steps: 1) gain management commitment, 2) employ external consultants, 3) conduct an awareness campaign, 4) create an overall quality system manual, 5) develop a documentation system, 6) train employees on the system, 7) create work processes and procedures, 8) conduct system wide reviews, and 9) conduct an audit. Pan, Hackney, and Pan (2008) found in a study regarding the failure of implementation systems that about 70 percent of major systems fail. Failures to successfully implement a system could be caused by unrealistic expectations, a lack of resources, uncooperative customers, and weak management of contractors (Pan, Hackney, and Pan, 2008). To be successful, Barry (2010) suggested the following: 1) project management, 2) process improvement and best-practice implementation, 3) system parameter configuration or modification, 4) successful file conversions, 5) multiple copies of the software and database, 6) software training, and 7) through testing.

Barry (2010) stated, “It can take six to 12 months after implementation to feel comfortable with a new system; training can help shorten the learning curve” (p. 46). Pilot testing can assist employee adoption and training regarding a system. Van Teijlingen and Hundley (2001) stated that conducting pilot testing may reduce the possibility that a system could fail. De Vaus (1993, p. 54) found the following were important reasons for conducting pilot studies when implementing systems:

- Developing and testing adequacy of research instruments
- Assessing the feasibility of a full scale study
- Designing a research protocol
- Assessing whether the research protocol is realistic and workable
- Establishing whether the sampling frame and technique are effective
- Assessing the likely success of proposed recruitment approaches
- Identifying logistical problems which might occur using proposed methods
- Estimating variability in outcomes to help determining sample size
- Collecting preliminary data
- Determining what resources (finance, staff) are needed for a planned study
- Assessing the proposed data analysis techniques to uncover potential problems
- Developing a research question and research plan
- Training a researcher in as many elements of the research process as possible
- Convincing funding bodies that the research team is competent and knowledgeable
- Convincing funding bodies and stake holders that the main study is feasible and worth funding

When implementing systems, these are important factors to consider as pilot testing can help avoid problems and failure during actual implementation (Van Teijlingen and Hundley, 2001). Van Teijlingen and Hundley (2001) suggested that quantitative and qualitative data should be gathered through interviews and survey methodology before pilot testing the system. Though system implementation is a complex process, awareness and adherence to the stated steps and suggestions may assist in successful systems.

2.4 Summary

This review of literature provided a basis of knowledge regarding digital archiving and the methods in which it could facilitate sustainable product development. Furthermore, this research helped identify a need for a Textile Digital Library System. Considerations and issues regarding sustainable product development were reviewed as well as the important factors of digital archiving, including: metadata, digital image capture and management, and an overview of digital archiving programs. Furthermore, systems implementation and case study research were reviewed in order to understand the best methods for performing this research. The next section will provide a detailed methodology, stating the manners in which the Textile Digital Library System was developed, pilot tested, and evaluated.

Chapter 3

3 Methodology

A case study methodology was carried out in order to fulfill the objectives of the research. The following sections explain the methods used in order to develop, pilot test, and evaluate a Textile Digital Library System.

3.1 Research Objectives

The objective of this research was to create a system for the management of fabric samples at a vertical textile mill in order to facilitate the search, view, and retrieval of woven fabrics and provide a guide for implementation of the system. Termed the Textile Digital Library System (TDL System), the sub-objectives were grouped into three parts: development, pilot testing, and evaluation. In order to support the main research objective, the following sub-objectives were established:

Development (Phase 1): Determination of the TDL System Requirements

- **SO1:** Identify the needs for the Textile Digital Library System (TDL System)
    - **SO1A:** Identify the current process of fabric sample organization
    - **SO1B:** Identify search topics and corresponding metadata which will assist product developers in browsing fabric designs.
    - **SO1C:** Identify internal and external needs for the TDL System

Pilot Testing (Phase 2): Initial Testing of Digital Archiving Programs and the TDL System

- **SO2:** Pilot test the digital archiving programs to determine system capabilities and limitations.
    - **SO2A:** Review existing digital archiving programs and supporting software/hardware which fulfill SO1.
    - **SO2B:** Determine initial program requirements for the TDL System
    - **SO2C:** Identify and sample three different digital archiving systems based on observation and secondary research.

Evaluation (Phase 3): Refinement and Evaluation of the TDL System

- **SO3:** Evaluate the digital archiving programs to determine which program is best for the TDL System.
    - **SO3A:** Develop an evaluation tool to rate the different digital archiving systems.
    - **SO3B:** Determine which digital archiving program best suits the needs of Company X.

3.2 Research Design

Based on the objectives of the research, the Principle Investigator (PI) performed a case study to determine the needs of Company X as they relate to a Textile Digital Library System (TDL System). Conducting a case study is one manner in which systems can be implemented. Case study research was defined by Yin (as cited in Woodside, 2010, p. 16) as an empirical inquiry that investigates a contemporary phenomenon within its real life context. This type of research is useful because it allows a deep understanding of processes or thinking which may not be attainable only through surveys or interviews (Woodside, 2010). Eisenhardt (1989) stated that case study research normally consists of combining analysis of archives, interview, questionnaires, and observations and the data gathered may be quantitative or qualitative. Woodside (2010) suggested that in order to obtain a deep understanding of processes or thinking, one should observe the environment directly, ask questions of participants about operational data, and analyze written documents and natural sites. Eisenhardt (1989) noted that case study research involves the constant iteration of backwards and forward steps, even if the researcher is focusing on a single part of the process at one time. Case study research should build a theory which can result in new insights and be can be further tested in future research projects (Eisenhardt, 1989)

The on-site case study data collection period lasted for 30 days and allowed the Principle Investigator (PI) to collect primary and secondary data from Company X. Qualitative and quantitative data collection occurred by 1) observational methods, 2) conducting formal interviews with company personnel, and 3) administering an external survey to industry partners. The survey was approved by the Institutional Review Board. Qualitative data collected consisted of photographs, physical fabric samples, and written descriptions of processes and company requirements. Quantitative data consisted of survey responses and the Functional Requirement Guide – an evaluation tool created by the PI to help determine the best digital archiving system for Company X.

The methodology was composed of three phases; (1) Determination of the Textile Digital Library System Requirements, (2), and (3) Refinement of the TDL System and Evaluation. During Phase 1, a case study was conducted through direct observation of tasks and processes in order to determine the needs and requirements of Company X and its clients for a TDL System. During Phase 2, a review of existing digital archive systems was conducted to determine current programs which could be used for the TDL System and three of those systems were pilot tested. Information regarding each digital archiving software system was gathered through internet queries, informal interviews with personnel of Company X, and informal interviews with industry professionals. Finally, in Phase 3, the PI evaluated three different digital archiving systems in order to suggest a program for use by Company X's TDL System. During Phase 3, the PI created the Functional Requirement Guide to evaluate each program. Figure 2 depicts the three phases of the methodology; development, pilot testing, and evaluation. The methodology was depicted though a Venn diagram to describe the manner in which tasks overlapped and were interrelated, as the case study was iterative.

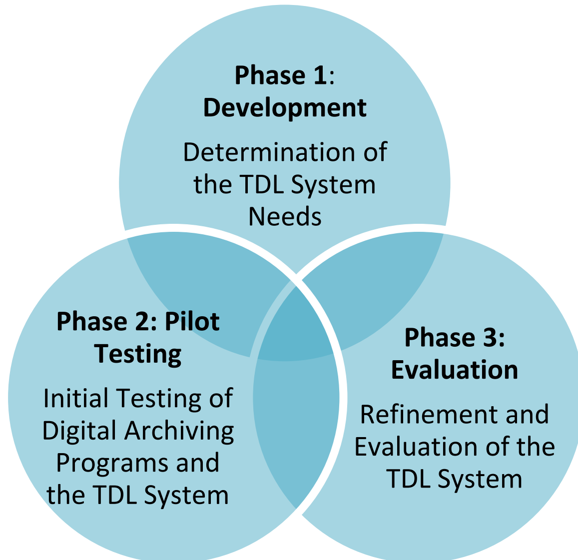

Figure 2. Research Design

Preliminary ideas were collected in Phase 1 through exploratory and observational research by means of a Case Study at Location A, a vertical weaving plant, and Location B, a cut and sew factory. During this phase, the PI conducted informal interviews while observing managers and personnel of the spinning, weaving, dying, finishing, printing, sampling, quality control, inspection, and cut and sew departments of the mill. A survey was also developed during this period to gauge the needs and perceived important search topics of Company X employees, regarding a TDL System (See Appendix A for Survey Instrument). During Phase 2, the PI pilot tested the programs to gain an understanding of the capabilities and limitations of each system and to determine which program was the best for the TDL System. Finally in Phase 3, the requirements for the system were further refined and the Functional Requirement Guide was created. The Functional Requirement

Guide was a tool created by the PI to gauge which digital archiving program was best for the TDL System. Information was gathered pertaining to previously implemented digital archiving systems of other organizations. Next, six digital archiving programs were studied to determine which would fulfill the needs of Company X's Textile Digital Library. Programs were weighed according to the Functional Requirements Guide. Final weighted averages of each program allowed the PI to recommend a program most suitable for the TDL System.

3.3 Phase 1 Development: Determination of Internal and External need of the TDL System

The PI conducted an on-site case study of Company X in order to determine the internal needs which included an overview of the departments within the company related to the TDL System, observation and analysis of the current archival system, and an understanding of the terminology related to the classification of woven fabrics. The case study analysis lasted for a period of seven days, five of which were spent at the Weaving Plant (Location A) and two at the Cut and Sew Plant (Location B). A total of 11 different divisions were observed. The divisions observed the Weaving Plant were: sampling, spinning, weaving, dyeing and finishing, quality control, and inspections. The divisions observed in the Cut and Sew Plant were: product development, cutting, sewing, finishing, and quality control. An assessment of the needs of Company X for a TDL System was conducted through observation and informal interviews and a base for further research was recognized. A survey instrument was developed during the case study in order to obtain information about external, client needs for the TDL System. (See Appendix A for the Survey Instrument)

3.3.1 Observational Tasks

The following tasks were assumed by the PI during Phase 1 in order to obtain a general understanding of mill processes and to identify areas of the Company X which could affect and/or be benefited by a TDL System. As well, observation of departments and processes helped shape the Functional Requirement Guide.

3.3.1.1 Task 1: Observation of Weaving Plant Production Processes

The objective of observing the Weaving Plant was to determine the interrelated divisions and activities of the Sample Department and the other departments in the mill in order to satisfy SO1, SO2, and SO3. During the observation of the Weaving Plant, the PI took notes and asked questions of plant managers and personnel regarding the use of fabric samples and the interaction of each department with the Sampling Department. Topics specific to each division were discussed with the intention of identifying processes which could be affected and possibly benefited by the TDL System. See Table 2 for a description of activities.

Table 2. Task 1 - Weaving Plant Observation

Department	Sub-Objective Fulfilled	Description of Activities	Occupation of Personnel Involved
SPINNING	SO1, SO2, SO3	-Forming the raw material of the yarn -Yarn classification -Technical formation of yarns -Use of yarns -Titration -Torsion -Yarn codification -Production orders and quality control	-Spinning Plant Manager
WEAVING	SO1, SO2, SO3	-Classification of woven fabrics -Woven fabric production phases -Warping -Finishing -Weft insertion -Inspection of greige fabric, types of defects -Order of production and quality control -Explanation of article codes	-Weaving Plant Manager
DYEING AND FINISHING	SO1, SO2, SO3	-Preparation -Mercerizing -Finishing -Laboratory: Formulation of recipes -Laboratory: Color testing, etc. -Order of production and quality control -Forms -Process codes	-Finishing Plant Manager -Dying Plant Manager -Color Laboratory Manager -Color Laboratory Personnel
INSPECTION	SO1, SO2, SO3	-Identification of fabric defects -Four point rating system -Production orders -Forms, recipies, formulas -Labdips, finished color codes -Packaging, packing lists -TIM System	-Inspection Department Manager -Inspection Department personnel
QUALITY CONTROL	SO1, SO2, SO3	-Greige fabric revision -Review of finished fabrics -Revision of finished fabrics -Color control -Codification	-Manager of Quality Control -Quality Control Personnel

3.3.1.2 Task 2: Review of Existing Fabric Archival System

The objective of reviewing the existing fabric archival system in the Sample Department was to obtain an understanding of the 1) fabric sample organization, 2) the work process flow, 3) the activities of employees, and 4) the time spent locating samples. The purpose was to provide a basic understanding of current processes and to determine processes which should be improved, changed, omitted, or included in the TDL System. Table 3 explains the different tasks observed while reviewing the Sample Department.

Table 3. Task 2 - Review of Existing Fabric System

Department	Description of Activities	Occupation of Personnel Involved
SAMPLING	-Sample room observation/tour -Fabric analysis -CAD Sample Analysis -Handloom Sample Process Observation -Codifications and notices -Order tracking	-Sample Department Manager -CAD Designer -Sample Department Personnel -Sample Department Manager -Woven Textile Designer

3.3.1.3 Task 3: Review of Current Fabric Classification and Numerical Coding System

Fabric classification systems through numerical coding provided organizational structure and extensive product information (See Appendix B for the Fabric Codification System Information). Deciphering classifications and codes used at Company X assisted the PI in identifying the current processes of fabric sample organization (SO2). The objectives of reviewing the current fabric classification and numerical coding system were 1) to decipher the meaning of each number in the numerical code, 2) to understand how the coding relates to sample organization, 3) to identify the different designs available, and 4) to distinguish the extent of design information provided by the codes. The PI studied the fabric codification model located in Appendix A.

3.3.1.4 Task 4: Cut and Sew Production Process Observation

The objective of observing the Cut and Sew production process was to obtain an understanding of the final processes of apparel assembly and to determine how the collaboration and communication between the Cut and Sew Plant and the Weaving plant could be facilitated by internet accessible sample archiving. Though the two plants were a part of the same company, they were located in separate facilities. An overview of the entire plant was given by the Chief Operating Officer and time was spent shadowing employees in Product Development. The PI took notes and asked questions of plant managers and personnel regarding the use of fabric samples at the Cut and Sew Plant. Processes observed include: cutting, sewing, finishing, and quality control. Table 4 describes the different tasks assumed, departments observed, activities conducted, and personnel shadowed by the PI during the observation of the Cut and Sew Plant.

Table 4. Cut and Sew Production Process Observation

Task	Objective	Department & Description of Activities	Occupation of Personnel Involved
Task 1	-Cut and sew production process observation	**PLANT OVERVIEW**	Chief Operating Officer
Task 2	-Pre-production process observation	**PRODUCT DEVELOPMENT** -CAD program overview -Sampling	Product Development
Task 3	-Cut and sew production process observation	**CUTTING** -Spreading -Marker layout -Lectra Cutting System	Cutting Manager
Task 4	-Cut and sew production process observation	**SEWING** -Progressive Bundle System	Sewing Floor Manager
Task 5	-Cut and sew production process observation	**FINISHING** -Ironing -Folding -Steaming	Finishing Manager
Task 6	-Cut and sew post-production process observation	**QUALITY CONTROL** -Inspections	Quality Control Manager

3.3.2 Survey Development

The objective of the survey instrument was to assist in determining the external needs for the TDL System and to further communicate those needs to stakeholders through quantifiable information. As well, the survey instrument assisted in satisfying sub-objective three (SO3) by gathering and analyzing data which could be used to frame search classifications. The TDL System – External Survey was founded on observations from the Phase 1 case study, discussions with stakeholders, and information taken from a previously administered survey by Company X. Company X's previously administered survey was sent to employees of Company X to gauge the need for a TDL System. The information from this study shared with the PI assisted in gathering preliminary ideas and determining the needs of employees for a system. The survey generated by the PI was sent to 25 industry partners and clients of Company X with the purpose of further measuring client need for a TDL System, as the internal need was previously realized (See Appendix A for the Survey Instrument). Company X's industry partners and clients consist of North American, South American, and European retailers who rely on Company X to design, develop, and manufacture woven apparel.

Open-ended and closed ended questions were asked in the survey to obtain qualitative and quantitative, descriptive and measurable information. The closed-ended questions consisted of: categorical, multiple choice, and likert-scale to determine information about the respondents and to determine their needs for a TDL System.

The TDL System – External Survey was approved by the Institutional Review Board (IRB) of North Carolina State University. The purpose of being approved by IRB is to protect the rights and welfare of human research subjects, to comply with institutional policy and federal regulations regarding scholarly pursuits, and to educate institutional personnel on the ethical use of human subjects. See Appendix C and Appendix D for Survey Consent Form and Cover Letter.

3.4 Phase 2 Pilot Testing: Initial Development of the TDL System

During Phase 2, the PI refined information gathered in Phase 1 observations to define initial characteristics for the Functional Requirement Guide and further assist in the selection of a digital archiving program for the TDL System. Phase 2 assisted in fulfilling sub-objective two: to review existing digital archive programs and supporting software or hardware which fulfill the needs determined in Phase 1 data collection, to determine initial program requirements for the TDL System, and to identify and sample three different digital archiving systems based on observation and secondary research.

3.4.1 TDL System Pilot Testing

The objective of prototype development and pilot testing was to determine whether each program was feasible in a real world environment and to determine the capabilities and limitations of each program, beyond the information gathered through internet queries and secondary research. The pilot testing would not only assist the PI in determining which program was feasible for the TDL System but would also assist Company X in the final development of the system chosen by creating an outline of processes and issues.

To acquire the demos and being the pilot testing of each program, the PI contacted Canto Cumulus and LUNA Imaging first via email. Company X already had access to Microsoft Sharepoint through the Microsoft suite so the demo acquisition process did not apply to Microsoft Sharepoint. After initial contact with LUNA Imaging and Canto Cumulus via email, the PI scheduled times to speak on the phone with sales representatives to gain a better understanding of each program. The following questions were asked:

- What systems are necessary for Company X to have in order to install the software?
    - What operating system? (eg: Windows, Mac, Linux)

    - RAM?
    - Minimal processor needed?
- What type of files work best with the program? (eg: .tiff, .pdf, .jpeg)
- What is the necessary image resolution?
- How can the program be specialized for textiles?
- How much space is necessary to have in Company X's server?
- Is the program compatible with CAD (Penelope)?

After telephone discussions with representatives of each digital archiving program, the PI was given access to demos which had to be configured into Company X's server. The responsibility of configuring and installing the programs was distributed among IT personnel as it required technical computer expertise outside of the PI's knowledge base. The configuration and instillation of the programs lasted about 3 weeks during which time the PI oversaw processes, developed metadata and search functions, and tested photo capture of the fabric samples.

3.4.2 Fabric Image Capture

The PI ordered a sample book from the sample department which was comprised of a range of fabrics in different colors and designs. The designs consisted of stripes, plaids, checks, and solids and varied in color. In order to determine which manner of acquiring fabric images achieved the most clear and realistic images, the PI used a digital camera, a scanner, and computer aided design (CAD) images. The three manners of fabric image capture were compared and contrasted against real samples and differences in color and detail were noted. Though fabric image capture was initiated by the PI, the process is in continuous development by Company X to determine standards for light source, color calibration, and scale.

3.4.3 Metadata & Search Function Development

The PI combined all previous activities, secondary research, observation, and the survey instrument, to establish search functions and create metadata. Metadata, defined as data that provides information about other data, was assigned for each category in the digital library database. The metadata was based on the search categories designers needed to effectively search for fabric designs and motifs. This information was determined through informal interviews with designers and through the survey instrument results. The metadata and search functions created specifically for Company X were initially written in Spanish and later translated to English to make the information applicable to the audience of this research.

3.5 Phase 3 Evaluation: Prototype Development and Evaluation

After narrowing the digital archiving programs to six, the PI further refined the selection to three programs to further evaluate in the final stage of the methodology. Two rounds of evaluations were created in order to narrow the programs: the initial development of functional requirements and the final Functional Requirement Guide. Requirements were decided upon by collaborations between the PI and the preproduction manager, the woven textile designer, internet technology (IT) personnel, and the chief operating officer of the mill throughout Phase 1 and Phase 2.

3.5.1 Initial Development of Program Requirements

Different methods were used to identify the digital archiving programs and the necessary requirements. Initially, an internet based search was used to narrow the wide array of available digital archiving software and also helped to shape the Functional Requirement Guide. Informal interviews with IT personnel, management, and designers of Company X also assisted in discovering and refining digital archiving programs. Six systems were identified and examined: Canto Cumulus, LUNA Imaging, Mosaic, Microsoft Sharepoint, SeeFile, and Textronics (See the Literature Review section of this report for more information on each program). Canto Cumulus, Textronics, and Microsoft Sharepoint were all recommended by personnel of Company X. Microsoft Sharpoint was previously subscribed to by Company X when the Microsoft suite was purchased. IT personnel identified Microsoft Sharepoint as a possible program for the use by TDL System. Textronics was identified by the Chief Operating Officer while at an international textile exposition and Canto Cumulus was discovered by the woven textile designer at Company X. LUNA Imaging, Mosaic, and SeeFile were found through internet queries by the PI. When conducting the internet queries, search terms such as digital asset management, digital library, digital archiving, and image management were used.

Upon beginning the search for a digital archiving system, many possibilities existed. The act of researching different programs assisted the PI in developing initial requirements. One of the main initial requirements which assisted in greatly narrowing the results was whether the digital archiving programs were password protected, meaning that the program was password protected and not open to the public. Many digital archiving programs were open sourced, with the purpose of sharing information with a mass audience. Limiting requirements to closed-source greatly assisted in narrowing the results.

Once the PI reduced the digital archiving program options to six, topics for further evaluation were established in meetings with IT personnel, the manager of pre-production, the chief operating officer, and woven textile designer. The initial evaluation points consisted of the privacy of the program, whether the program allowed permissions or user groups, and whether a demo was available. By default, the PI also evaluated the program by whether the company was able to be contacted, as some companies did not respond to requests. A password protected, secure program was an important characteristic to the initial evaluation because many digital archive programs are open to the public or the information can easily be found and shared. With an immeasurable amount of proprietary information in the program, Company X requested that the site be private and password protected, with an internal repository for the files. It was also essential that the digital archiving program could be demoed as real demonstration was necessary to obtain more in depth information about each program. Furthermore, Company X needed to be able to share the files with clients, so user groups or permissions to enter specific areas of the site was necessary. Table 5 depicts the initial requirements for each program.

Table 5. Initial Requirements for Digital Archiving Programs

Program	Contact? Y/N/Other	Demo Available? Y/N/Other	Password Protected? Y/N/Other	User Groups & Permissions? Y/N/Other	Notes
Canto Cumulus					
LUNA Imaging					
Mosaic					
Microsoft Sharepoint					
See File					
Textronics					

3.5.2 Development of Functional Requirement Guide

The objective of the Functional Requirement Guide was to give stakeholders measureable, quantifiable results denoting the capabilities and limitations of each digital archiving program. In order to measure which program best fulfilled the needs for the TDL System, an evaluation tool was necessary. Previously determined considerations during Phases 1 and 2 paired with the prototype development and pilot testing in Phase 3 assisted the PI to further refine the Functional Requirements Guide. The process of developing the Functional Requirement guide was iterative as new findings in each phase of the research altered and expanded the requirements.

Informal interviews with stakeholders helped determine the initial requirements noted in Phase 2. The PI combined information from interviews and information gathered from secondary research to expand upon the initial observations and ideas. In the final week of the configuration process, Skype and WebX meetings were held with Canto Cumulus and LUNA Imaging where more specific information was explained to the PI regarding capabilities of the software. Representatives from each company demonstrated the programs in real time using WebX and Skype. This allowed the PI to obtain a better understanding of each program's potential before the configuration was complete. The PI uploaded images and metadata into the different programs and noted the Results. During pilot testing the PI was able to gather a considerable amount of information regarding the needs for the Textile Digital Library Program and the coinciding necessary categories for the Functional Requirement Guide. Pilot testing indicated problems and successes and helped the PI recognize necessary additions and constraints.

3.6 Summary

The case study research methodology consisted of observation, development, pilot testing, and evaluation. The process was iterative and information gathered in each part of the research helped shape the results. The following Result section will discuss the outcomes of the methodology.

Chapter 4

4 Results

The results of this research were grouped into three parts; 1) development, 2) pilot testing, and 3) evaluation. Within the three main categories, eight results were found. Those results were: the determination of needs for a Textile Digital Library System, the identification of current fabric sample organization, the development of a survey measuring client needs, the identification of search topics and metadata, the identification of six digital archiving programs, the pilot testing of three digital archiving programs, the initial development of system requirements, and the final development of the Functional Requirement Guide.

4.1 Development

The development of the Textile Digital Library System (TDL System) resulted in the 1) determination of the needs for TDL System, 2) identification of the current process of fabric sample organization, and 3) the development of a survey to gauge client needs for a TDL System. Sub-objective 1 was addressed in the Development section of the Results.

4.1.1 Result 1: Determination of Needs for a TDL System

In order to determine the needs for a TDL System at Company X, the PI preformed an initial needs assessment by observing processes of the vertical textile mill, holding informal interviews with employees, and sending out a survey to clients. The needs of the vertical textile mill for a TDL System were determined to be:

- Rapid access to samples
- Reduced time for product development
- Remote access through a web-based tool
- User groups and permissions which make the tool accessible to clients
- Search and browse functions organized by fabric design related topics
- Secure archiving system
- Best fabrics section denoting specific fabrics which are efficient to produce
- Onsite pricing and sales (or future possibility for onsite pricing and sales)
- Re-design and organization of sample room

4.1.2 Result 2: Identification of Current Fabric Sample Organization

Company X currently houses their physical samples, the only documentation of thousands of designs, in boxes in a room where one employee has memorized the location of each sample. Employees in need of fabric samples and designers in need of inspiration must rely on the memory of one person to access physical samples and information about each design. Samples are organized by numerical codes which explain technical fabric information and minimal descriptions regarding design or aesthetic qualities. Fabrics codifications are stored in a computer program called Fichas Technicas, or Technical Specifications in English, where technical information, production information, and general fabric information can be found. Samples are not organized in a manner appropriate for product developers to search for patterns, colors, or any design specific information. The current process of searching for and acquiring fabrics is inefficient, time consuming, and counterproductive to the design and sales processes.

Each fabric has a code denoting the type of material, design (yarn dyed or printed), weave, and color code. The organization and fabric coding does not assist in finding specific designs or motifs, only technical information. Furthermore, no pictures of fabrics are included in the Fichas Technicas. Company X uses the Fichas Technicas to store large amounts of technical information and create reports. These reports record detailed fabric specifications and assistsin finding errors and inefficiencies during production. Company X is in the process of designating certain fabrics as those which produce the best without problems based on reports. The following are the main findings regarding fabric sample organization at Company X:

- Fabrics are organized in boxes according to the numerical code associated with the fabric (See Appendix E for the Fabric Codification System)
- Samples are not organized by design specific information, therefore locating specific fabric designs is hindered
- Coding of fabrics does not offer detailed information about fabric design
- Only one employee knows the location of each sample

4.1.2.1 Mill Workflow

Understanding the workflow of Company X was vital to assessing the needs of the program. Through an internship, the PI observed each process of Company X, including spinning, weaving, dying, finishing, printing, samples, inspections, quality control, and assembly. The following topics were taken into consideration while developing the TDL System: organization of workflow, user activities, fabric organization, important fabric information, reporting needs, requirements for search a retrieval, knowledge and understanding of users, and security.

Company X exported and profited from yarn, greige fabric, dyed and printed fabric, as well as final garments which were sold locally and throughout South America. Seasonal collections were created by in-house designers, however, clients often requested specific designs or color schemes which were not included in the existing collections. Rather than finding similar, previously designed fabrics, designers often completely remade the sample because sorting through old samples was time consuming and often unfruitful. The newly designed fabric would then be developed, tested, and produced. Clients were consulted by sales personnel to ensure the fabric was correct and modifications were made throughout the development. Fast access to specific designs through a TDL System could decrease the reproduction of fabric, essentially decreasing waste and lead time for the client.

Decreasing lead time was a major initiative of Company X. Sample books, comprised of specific samples requested by the client, took about 1.5 months to assemble, adding a considerable amount of lead time to the product development process. This period includes the time taken to search for fabrics and assemble books and does not include shipping or handlooms. Handlooms are samples produced in short runs by hand in order to create a small sample for clients. Handlooms are created because either the design does not exist in Company X's fabric collections or the design exists but the sample could not be found in Company X's sample room. Lead time for handlooms is normally 3 months. During busy times where many clients need samples, lead time increased by one month. For an internal employee of Company X to acquire 30 samples, it takes about three days, if and only if the employee has all of the fabric codes. Without fabric codes, time taken to receive samples for employees of Company X grows to about two weeks.

A TDL System could decrease lead time by assisting the sample department and designers in finding fabrics. In addition, the TDL System would need advanced securities as the program would house a large portion of Company X's intellectual property and assets. As security is extremely important with the site containing proprietary design information, clients should still be able to access the site through user groups and permissions. Only certain areas should be available for clients to view and these areas should be designated through permissions by Company X. The users of this library within Company X include designers, management, sales personnel, and employees of the sample department. Only specified users can add and change data. Clients with permission can also view the library, but cannot make changes to it.

Figure 4 depicts the process flow of ordering fabrics, denoting the current steps necessary to receive fabrics. Extended time and waste are created by the inability to quickly locate samples. Fabric which can be located can be quickly put into use by designers or clients. With a TDL System, time, money, and waste can be further reduced by allowing clients and designers to rapidly find specific fabrics.

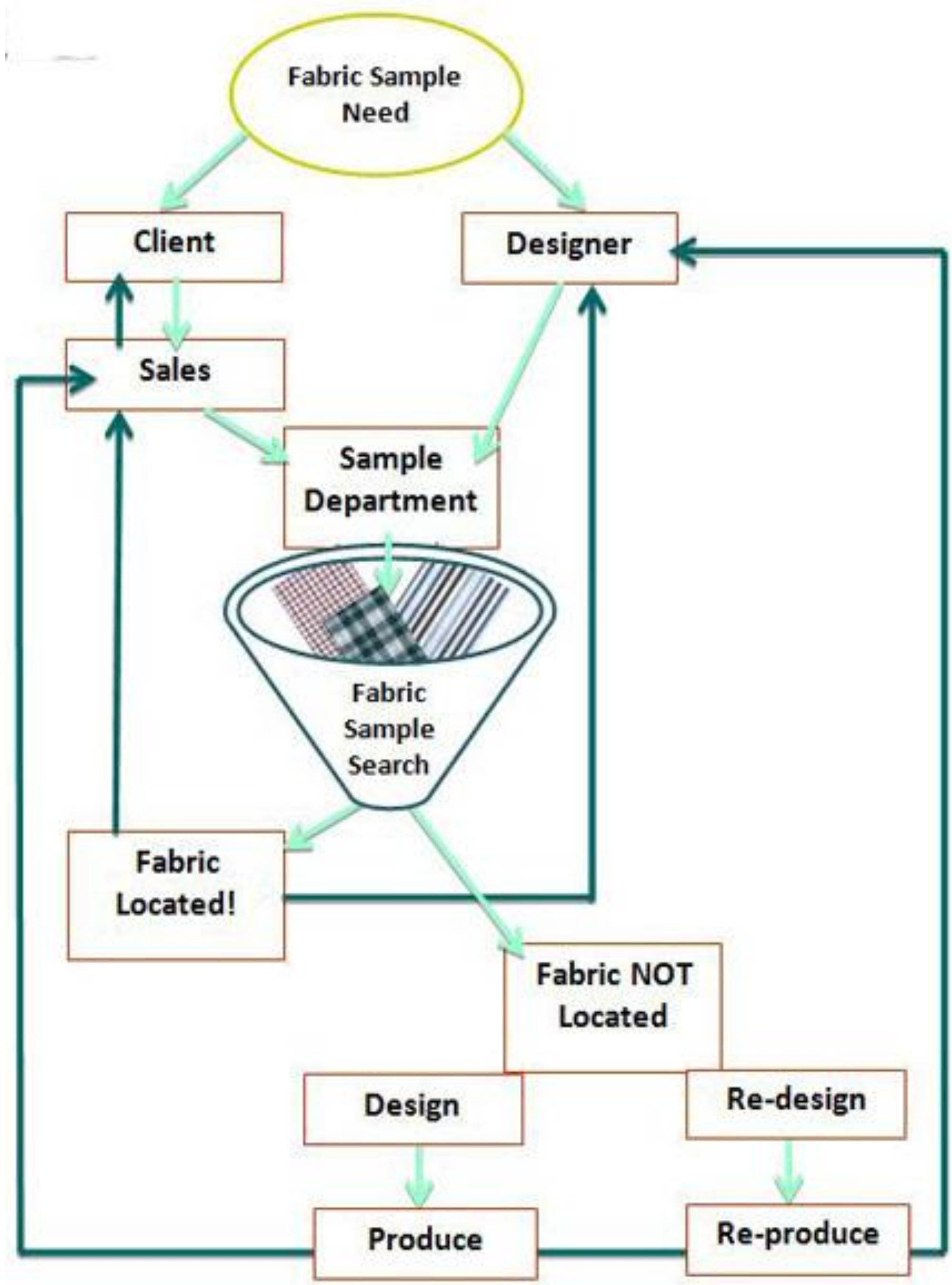

Figure 3. Fabric Sample Acquisition Process Flow

4.1.3 Result 3: Survey Measuring Client Needs for a TDL System

The following survey was created to obtain information from clients regarding their need for a TDL System. As well, the survey assisted in gathering information about search topics which were deemed most important for finding specific fabric designs. Company X sent the survey out to 25 clients and industry partners and a total of 11 companies responded – generating a 44 percent response rate. Company X's entire client base and industry partners equaled approximately 50 companies signifying that the results represented the opinions of about one fourth (1/4) of Company X's external stakeholders. The survey provided descriptive information and allowed the PI to identify problems and gather initial ideas pertaining to the structure of the TDL System.

Survey question one denotes the different job duties of the survey respondents. It was important that a majority of respondents worked in design and sales related fields as the purpose of the TDL System was to assist product development, specifically design, rather than manufacturing. A total of 11 companies responded to the question, "What is your area of work?". Of the 11 respondents, 7 worked in design related fields. The second largest respondent group, totaling 18.2 percent (2 of 11 respondents), worked in sales. The other professions represented were material sourcing, totaling 9.1 percent (1 of 11 respondents), and management which equaled 9.1 percent also (1 of 11 respondents). Figure 4 depicts the different respondent professions.

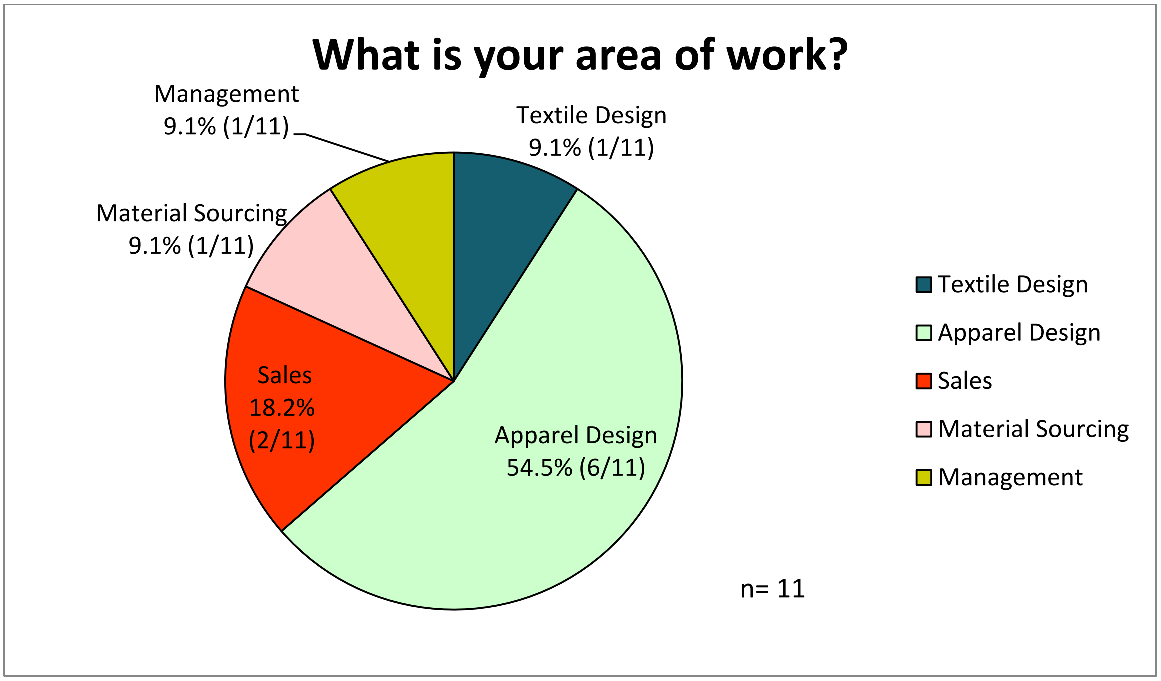

Figure 4. Survey Question 1

The second survey question stating, "How frequently do you need access to samples?" allowed the PI to gauge how often clients ordered samples from Company X. Of the 11 respondents, 45.5 percent (5 of 11 respondents) of clients needed samples once a week and 36.4 percent needed samples once a month. Only 9.1 percent of clients, or 1 of 11 respondents, actually needed samples two times a day. Other respondents needed samples once every two weeks. This information demonstrates the need clients have for fabric samples. Figure 5 summarizes the frequency of sample accessed needed by clients.

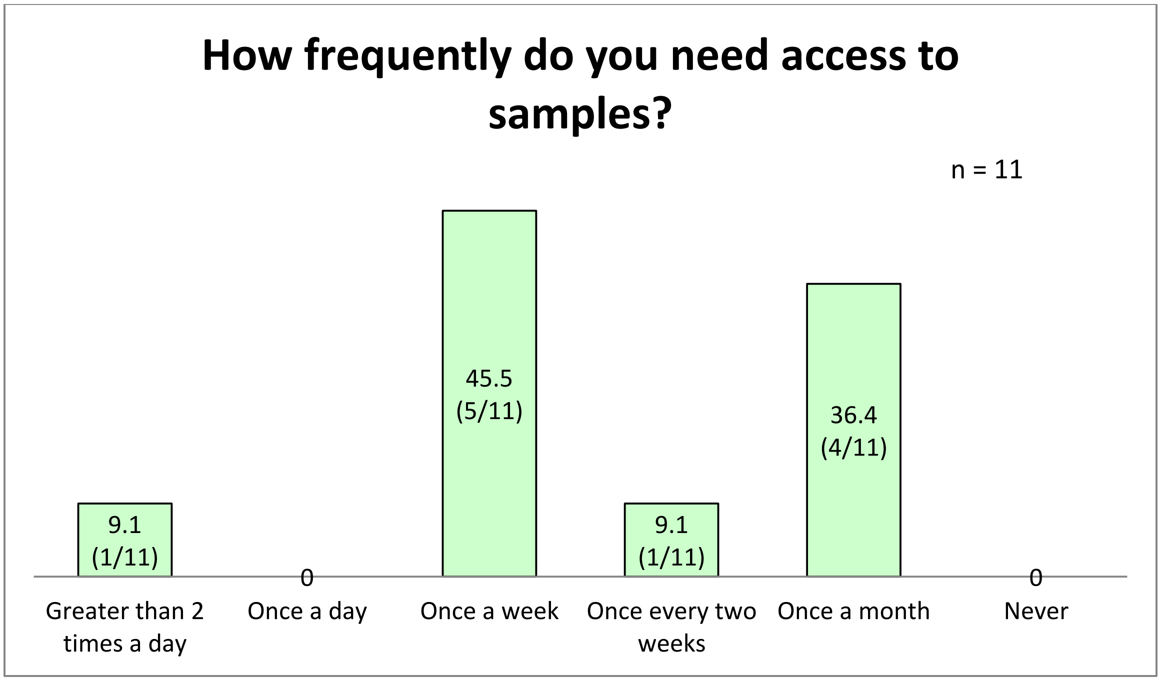

Figure 5. Survey Question 2

Survey question three states, "About how long does it take to receive physical samples?" Of the 11 respondents, 36.4 percent (4 of 11 respondents) of clients do not receive samples until 1.5 months or later. The majority of respondents, 63.6 percent (7 of 11 respondents), receive samples in one month. One respondent commented, "At the moment, we are not having the final product on time, around 30-60 days *delay of our expectations* and market needs, because we have to wait [for] the samples or swatches." The following percentages in Figure 6 as well as this comment further support the need for systems which speed up the sampling process.

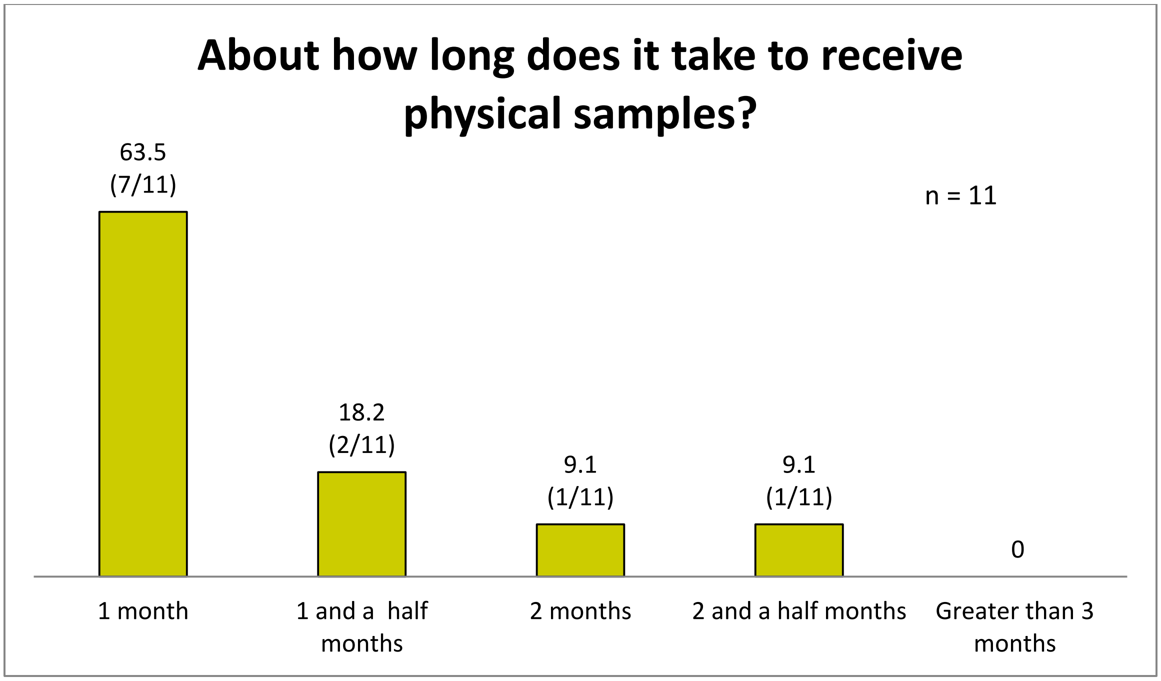

Figure 6. Survey Question 3

The following question, survey question four (Figure 7), assisted the PI in identifying possible issues of the TDL System which may hinder acceptance of the program on behalf of clients. The question asked, "How do you feel the following factors would be impacted when using a TDL System?" Those issues included the ability to perceive scale, the ability to perceive quality, the ability to differentiate coloration, and the ability to evaluate hand. The respondent could choose whether each issue had a negative impact, no impact, or positive impact. The survey showed that a majority of respondents, 63.6 percent (7 of 11 respondents), felt the ability to differentiate coloration would be largely impacted by the TDL System. The majority also believed that the ability to perceive quality and the ability to evaluate hand would be largely impacted by a Textile Digital Fabric Library. About half of respondents, 54.5 percent (6 of 11 respondents), perceived scale to be unaffected by the TDL System. One respondent commented, “Decision makers require a touch [and] feel approach and therefore a digital library would not work for our business.” Overall, the answers to survey question four lead the PI to believe that all issues are topics of importance and should be further addressed when creating a TDL System, as the answers reveal that each factor is largely impacted.

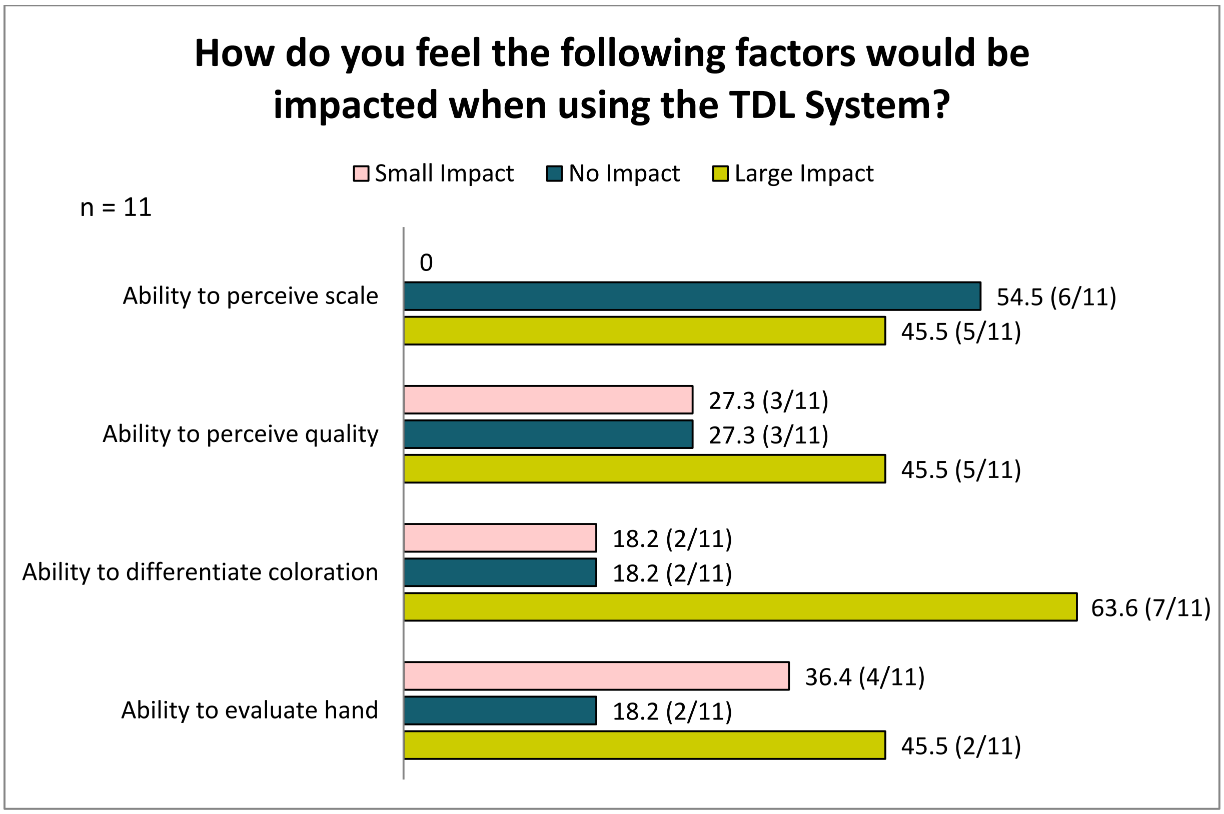

Figure 7. Survey Question 4

Survey question five addressed the subject of CAD images asking, “Do you consider CAD images of fabric samples an acceptable manner of reviewing fabrics as opposed to actual physical samples?” A majority of 72.7 percent (8 of 11 respondents) of respondents believed that CAD images were not an acceptable manner to review fabric samples. One respondent said, “Depending on the fabric we are requiring, in some cases it can work (for trims and basic pattern/styles), in others, no…It will definitely help to improve lead time on development of handlooms.” In congruence, another respondent said, “[CAD images are] okay for initially viewing samples, but before I place a final order I would need to see actual fabric samples.” These responses show that CAD images are acceptable for initial fabric viewing, however, final approvals of fabrics must be based on actual fabric samples.

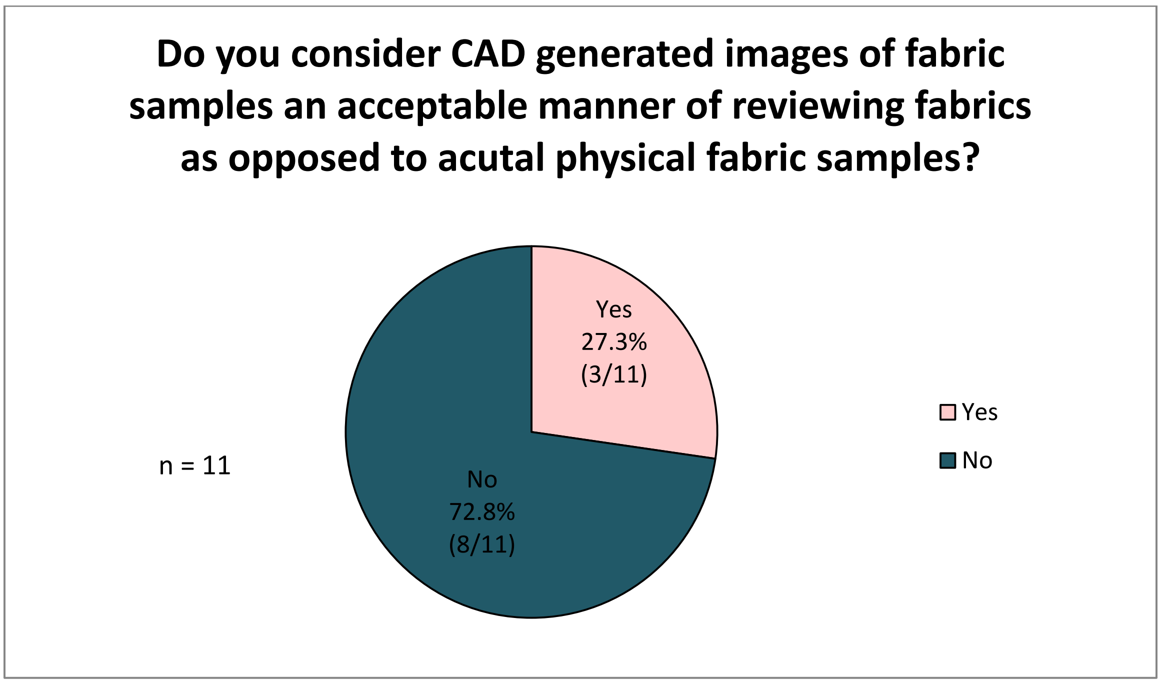

Figure 8. Survey Question 5

Survey question six discusses which topics were important when searching for specific fabrics. The question asks, “When searching for digital fabric images, what do you perceive to be the most important search categories?” The categories were price, article number, size of repeat, yarn count, fabric weight, weft thread, warp thread, fabric material, weave type, color, and pattern. The respondents could choose whether the category was very important, somewhat important, or not important. The most important categories were price, fabric material, color, and pattern. The categories of article number and repeat size were perceived as not important by the majority of respondents. The answers assisted the PI in determining which topics to use as main search categories to best assist designer in finding fabrics through the TDL System. It also helped demonstrate which topics were unnecessary for use in the TDL System.

Figure 9 summarizes the different search topics perceived to be *very important*. Color was chosen by 90.9 percent (10 of 11 respondents) as a very important. Other important topics were price, fabric material*, and pattern. Search categories which were considered not important include article number, size of repeat, warp thread, and weft thread. (*The term *fabric material* was directly translated from Spanish. The standard term used is *fiber type,* for example: cotton or polyester)

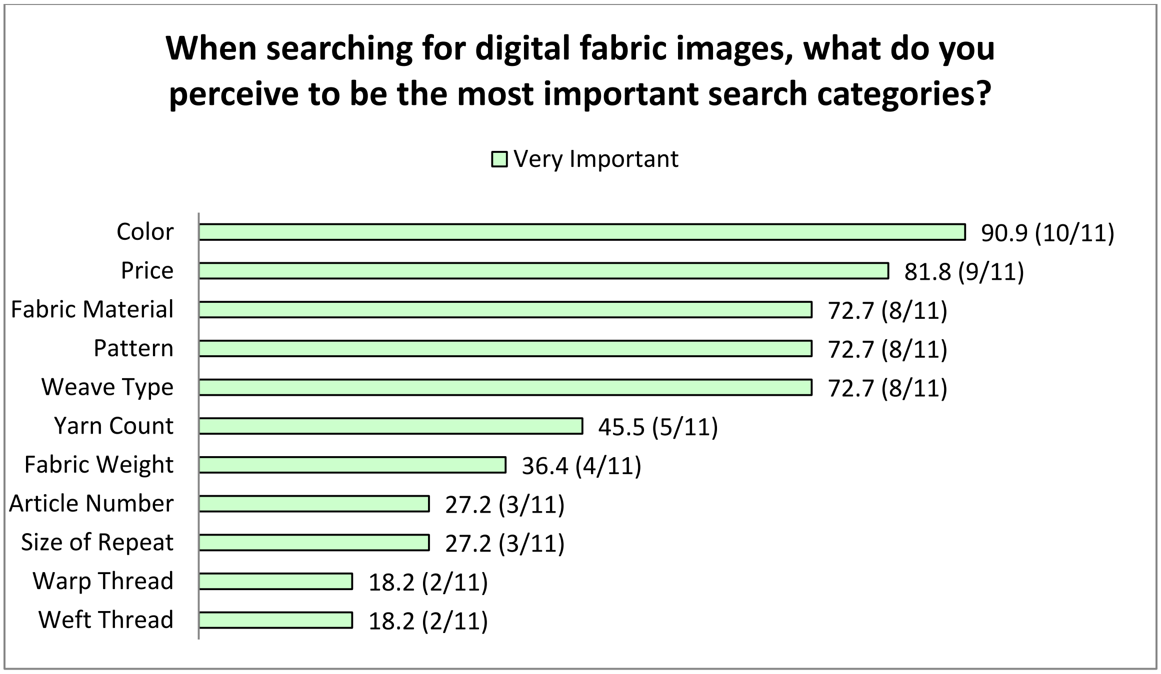

Figure 9. Survey Question 6 - Response of Very Important

Overall, the survey respondents had differing views concerning the TDL System. Some believed that a TDL System would be a beneficial tool to decrease time to receive samples, to improve pattern developments, to assist in research for collections, to better understand what the factory can produce, to use for continuous classic collections, and to conduct trend research. Others believed that the inability to touch and feel the fabric would inhibit the TDL System from being successful.

4.1.4 Result 4: Metadata and Search Topic Identification

Based upon the understanding of the mill workflow and processes, the PI determined initial characteristics for search functions. Information search and retrieval in the TDL System needed to be based around factors of design. As defined in Table 7, Table 8, and Table 9 and information gathered from the survey, the search categories are pattern, type of weave, colors, material, article number, warp yarn, weft yarn, and size of the design. In the future, price and type of garment, such as women's blouses, were requested by stakeholders to be added to the library. The difference between these categories and the categories of Fichas Technicas include that the labels and names are categorized based on design and aesthetic information which can easily and quickly be found by designers or clients who do not understand or need more technical information. Information from the survey assisted in designating the most important topics for search and retrieval of specific fabrics and designs. Fabrics can be searched simultaneously by multiple topics, for example blue stripes, rather than by a numerical code which is only understood by informed employees. The following information in Table 6 and Table 7 demonstrates the Metadata categorization. See Appendix E for the version of the Metadata developed at Company X which was written in Spanish.

Table 6. Metadata

Metadata		
Principle Category	**Subcategory**	**Code**
Color (C)	Red	CR10
	Orange	CN11
	Yellow	CA12
	Green	CV13
	Celeste	CT14
	Blue	CZ15
	Indigo	CI 16
	Purple	CM17
	Pink	CP18
	Black	CB19
	White	CW20
	Grey	CG21
	Creme	CC22
	Beige	CE23
	Brown	CO24
	Crude/Greige	CD25
Pattern (P)	Stripe	P100
	Formal	P101
	Casual	P102
	Jeanswear	P103
	Plaid	P200
	Dotted	P300
	Checked	P400
	Formal	P401
	Casual	P402
	Jeanswear	P403
	Solid	P500
	Fil a Fil	P600
	Chambray	P700
	Vichy	P800
	Herringbone	P900
	Pied di Poule	P1000

Table 7. Metadata Continued

Metadata Continued		
Principle Category	**Subcategory**	**Code**
Fabric Material (M)	Pima Cotton	M70
	Tanguis Cotton	M60
	Upland Cotton	M50
	Hybrid	M40
	Cero Cotton	M20
Weave Type (TT)	Plain	TT1
	Twill 2/1	TT2
	Twill 3/1	TT3
	Twill 2/2	TT4
	Saten 5	TT5
	Oxford	TT6
	Dobby	TT7 / TT8
	Other	TT0
Article Number (A)	70707040	A70707949
Price (D) (Per yard)	$0-3	D1
	$4-6	D2
	$7-9	D3
	$10-12	D4
	$13-15	D5
Type of Garment (R)	Shirts	R1
	Women	R1W
	Men	R1H
	Pants	R2
	Women	R2M
	Men	R2H
	Pajamas	R3

4.2 Pilot Testing

The pilot testing of the TDL System resulted in the 1) initial identification of six digital archiving systems, 2) piloting of three digital archiving systems for use in the TDL System, and 3) the determination of methods for capturing fabric images which best represent actual fabric samples. Sub-objective 2 was fulfilled during this portion of the study. Figure 11 shows the manner in which programs were narrowed to determine the program for the Textile Digital Library System. Beginning with many digital archiving programs to choose from, the PI narrowed them to six through discussions with stake holders and internet queries. The initial six programs were decided upon because they were all password protected systems and they were recommended through discussions with IT personnel, designers, and managers of Company X. Those programs were then narrowed to three by developing initial requirements of the system. Then the three programs which best fulfilled the initial requirements were evaluated with the final Functional Requirement guide. The digital archiving system which best fulfilled the Funcational Requirement Guide was chosen for the TDL System. The following sections will discuss how the programs were narrowed and how the process of narrowing the programs through the creation of system requirements helped to develop the TDL System.

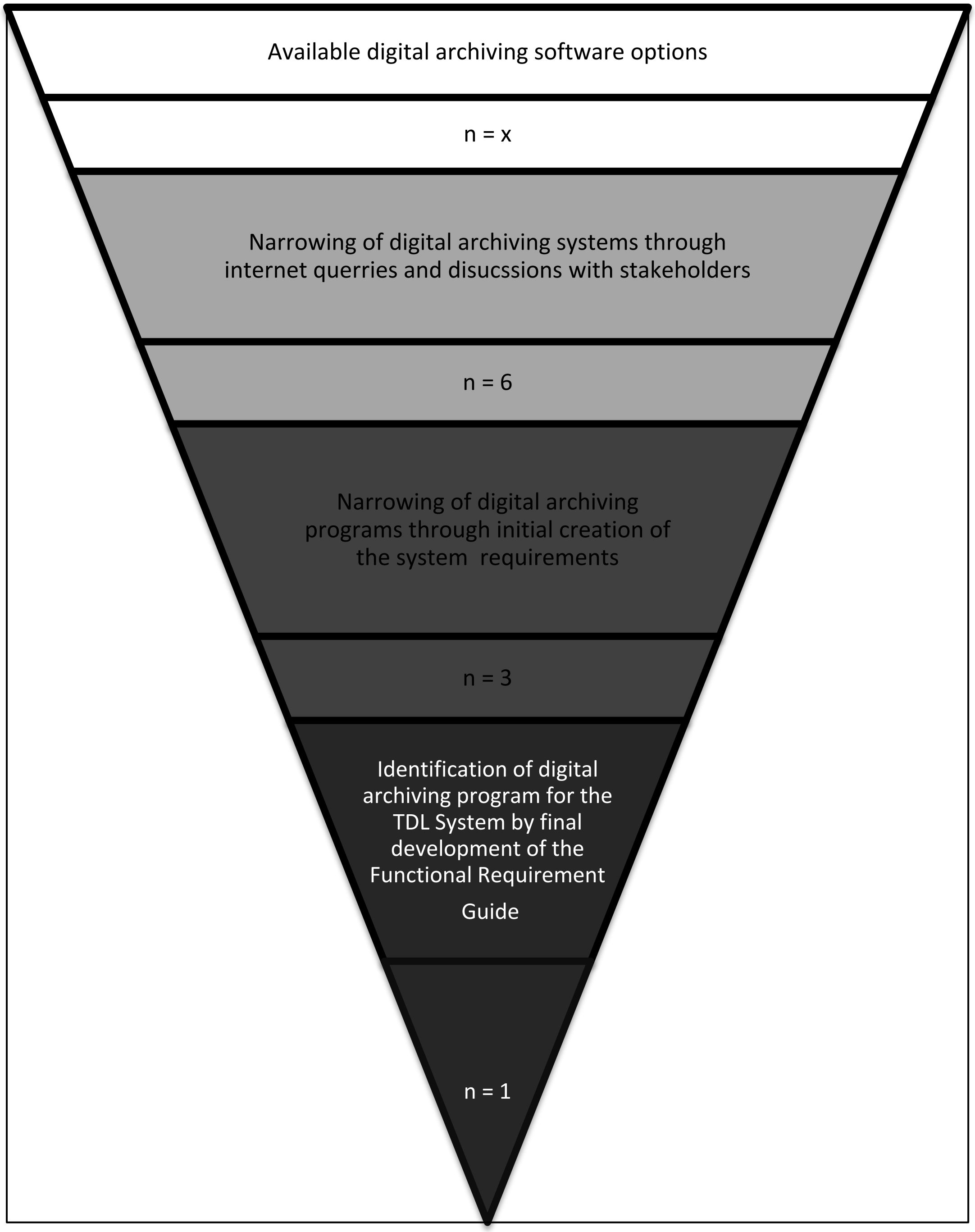

Figure 10. Narrowing of Programs

4.2.1 Result 5: Initial Identification of Six Digital Archiving Programs

The PI identified, researched, and reviewed five digital archiving programs. Those included Canto Cumulus, LUNA Imaging, Microsoft Sharepoint, Seefile, Mosaic, and Textronic. Each program was a possible candidate for use as a TDL System by Company X. Understanding the capabilities and limitations of each company allowed the PI to further refine the Functional Requirement Guide and gain a better understanding of what functions were necessary for Company X.

The programs were chosen by input from stakeholders of Company X, through internet searches, and through the PI's knowledge from previous internships. The internet search used terms such as, digital archiving, digital asset management, and digital libraries. The different search quarries were cross referenced and frequent companies were researched in further depth.

4.2.2 Result 6: Pilot Testing of Three Digital Archiving Systems

Three programs, Canto Cumulus, LUNA Imaging, and Microsoft Sharepoint were identified to demo and evaluate. Development of the initial requirements allowed the PI to narrow the program selections but requirements were further refined in the final stage. After the identification of three digital archiving programs which would be suitable for use by the TDL System, the PI piloted demos of each program in order to text the strengths, weaknesses, and overall conformity to Company X's needs. The following explains the positive and negative aspects of each program identified in Stage 3 of the methodology.

With Canto Cumulus, organizing, finding, and sharing of any type of digital file was fast and easy. The IT team encountered no difficulties when configuring Canto Cumulus as the program was compatible with Company X's platform. The strengths included; simple and advanced search capabilities which allowed users to quickly find exact images; image management which permitted cropping, scaling, color correction, detailed zooming, and watermarking; security as well as client access and permission; a web interface for remote access to files; compatibility with Company X's systems; compatibility with CAD systems; and potential for future growth with the option for edition updates as necessary to Company X. Canto Cumulus set standards for the Digital Library of Fabrics with advanced capabilities and a user friendly interface.

Luna Imaging, Inc. claimed to be easily integrated with all operating systems, however, the program did not configure correctly with Company X's platform due to differing languages of the systems. The codes of Company X's platform were written in Spanish while LUNA Imaging was only compatible with English computer codes. Some issues which differentiated LUNA Imaging from Canto Cumulus, as shown in the Functional Requirement Guide, were; image management as LUNA Imaging did not have editing capabilities; no availability of user groups and permissions, and decreased potential for future growth as the .

Although Sharepoint allows users to structure the site in accordance with their needs, the demo proved that the program did not have advanced search capabilities necessary for Company X's needs. As well, the program did not have a web interface which could be available for client interaction and sharing. The program had an overall low potential for future growth and did not fully satisfy the needs of Company X.

4.2.2.1 Photo Capture

During the piloting process, the PI took photos of fabrics and uploaded them into each program to provide examples in the pilot tests of the digital archiving programs. The PI attempted to find the method of digital image capture best for Company X's TDL System exclusively for the purpose of piloting the program, however, image capture research is a continuing development at Company X. When capturing images of fabrics, many aspects can cause disparities between the actual fabric and the final digital image. In order to find the best manner of capturing realistic photos, three methods of image capture were tested; photos of fabrics from a digital camera, scanned fabrics, and CAD simulated images drawn in Penelope (computer aided design software). Problems encountered include the perception of true color, scale, and lack of detail. Different computer calibrations proved to distort fabric colors. Exact fabric scale was difficult to represent as the images in the TDL System were much smaller than actual samples. Scale could be represented by mapping the fabrics onto an item of clothing, a process which can be done through specific CAD programs such as Penelope or Adobe Photoshop. Photos taken via digital camera yielded the best detail and were the most realistic, whereas scanned images lacked detail and CAD simulated images looked unrealistic in detailed zoom versions.

Figure 11 below is a fabric photo in normal scale captured by means of a digital camera. Figure 11 shows the same image captured by a digital camera but zoomed in 150 percent. In the zoomed image, individual yarns are visible. The next image, Figure 12, demonstrates the same fabric however the image is captured through a scanner. The scanned image is lighter in color and not as vibrant as the imaged captured with a digital camera. The zoomed image of the scanned fabric, Figure 12, shows that scanning does not produce a detailed image. The fabric in Figure 12 is blurred and each individual yarn cannot be distinguished. The final image, Figure 13, was a simulated image created through CAD of the same fabric which demonstrates the color disparity between all three images. In conclusion, the digital camera was chosen as the best manner for capturing images of fabrics. To improve detail, a camera with a higher resolution can be used. The following are the main findings regarding digital image capture of fabrics:

- Capturing images by means of a digital camera produced the best digital replication of fabric samples
- Digital cameras elicited the most detailed zoom capabilities, showing each individual yarn.
- CAD Images were not considered by clients to be an accepted manner of viewing fabrics

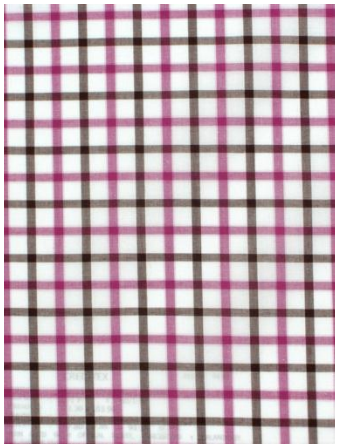

Figure 11. Digital Camera - Regular Scale

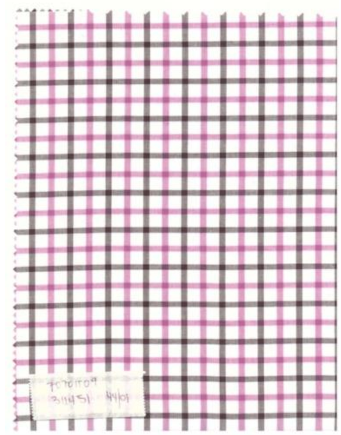

Figure 12. Scanner - Regular Scale

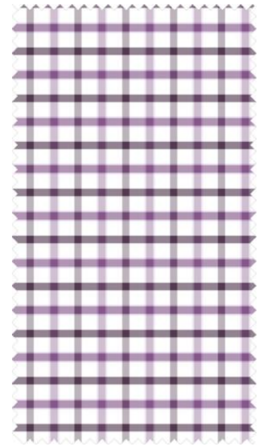

Figure 13. CAD Simulated Image - Regular Scale

Zoomed images of the fabrics allowed the PI to view the quality and detail of each method for capturing photos. Figure 15 is a fabric image captured by means of a digital camera and shows each actual yarn and color shades.

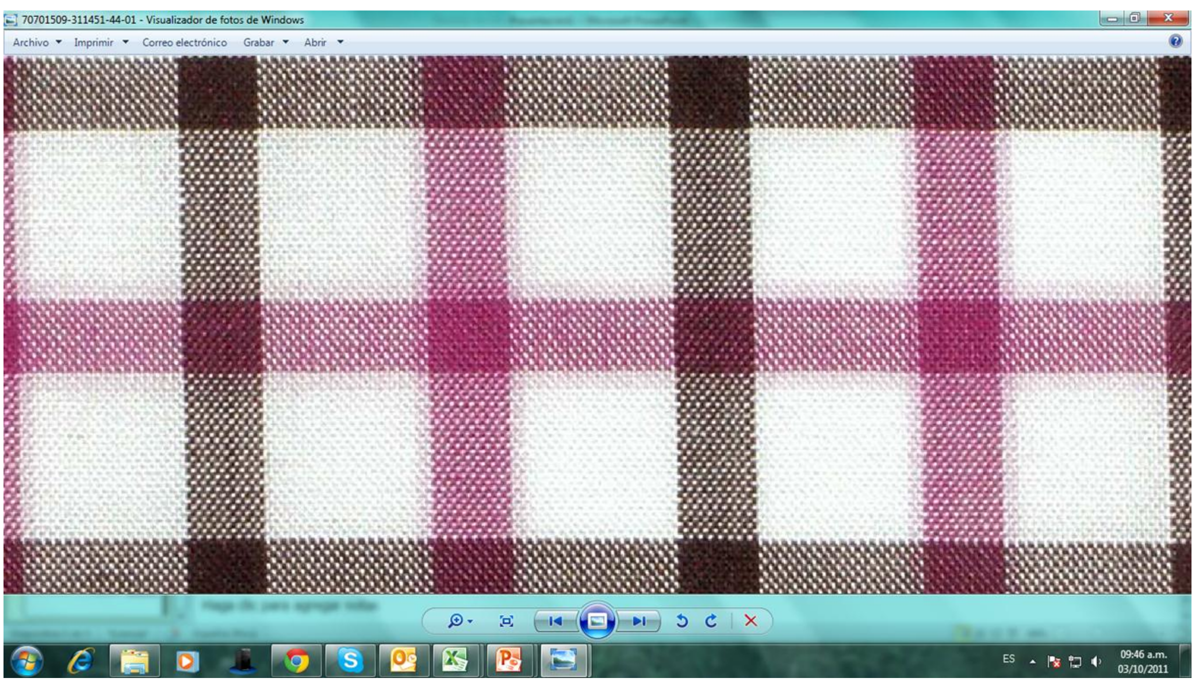

Figure 14. Digital Camera - Zoom

Figure 16 was captured using a scanner. The scanner provides less detail and creates a blurred image. The color of the image captured by the scanner is not as vibrant as the image captured by the digital camera. A higher quality scanner may provide a better image; however, Company X did not have access to a scanner with more detailed image processing qualities.

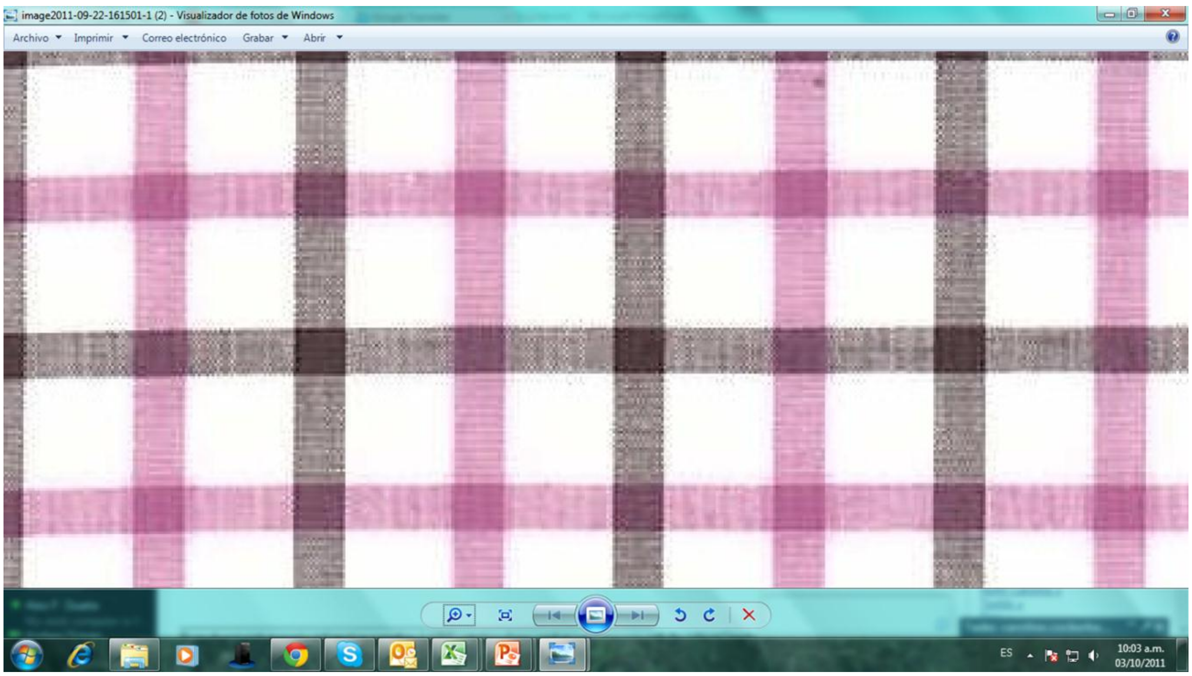

Figure 15. Scanner - Zoom

Figure 17 shows the results of using Computer Aided Design (CAD) to generate images. The zoomed images shows the details in the color shading as well as actual yarns. However, when zoomed the CAD simulated image does not look like a real fabric.

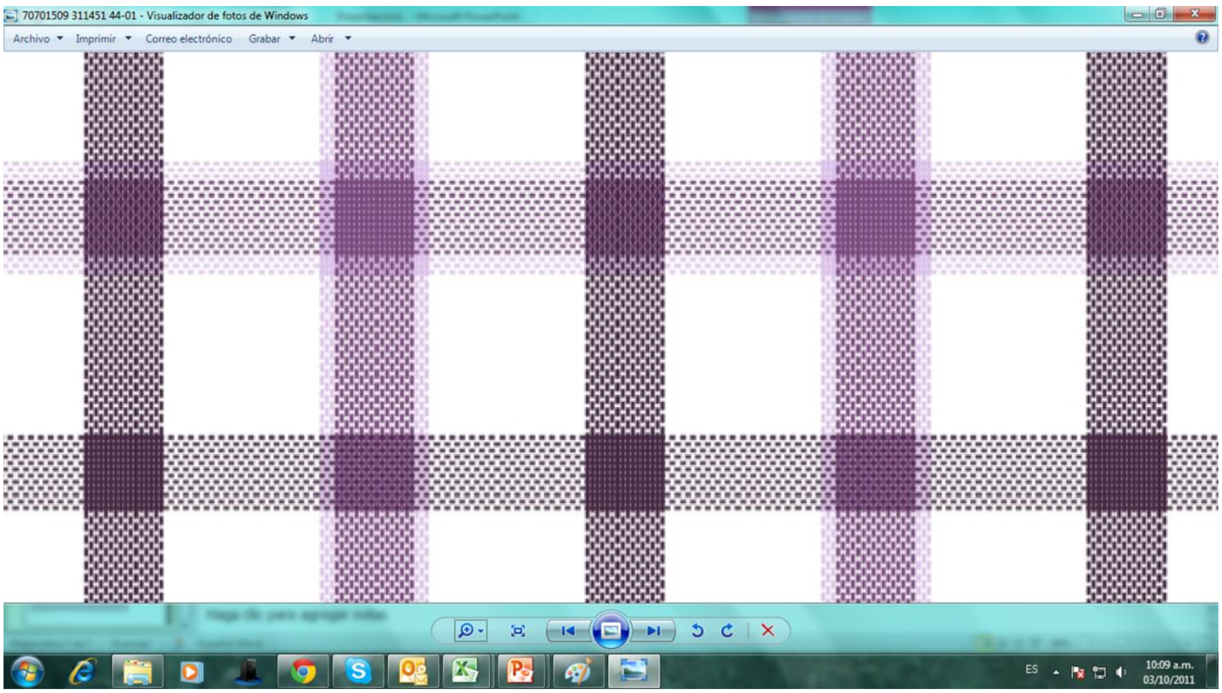

Figure 16. CAD Simulated Image - Zoom

4.3 Evaluation

The evaluation of the TDL System resulted in the 1) development of initial requirements for the Functional Requirement Guide and the 2) development of the final TDL System - Functional Requirement Guide. Sub-objective 3 was addressed in the Evaluation section of the results.

4.3.1 Result 7: Initial Development of System Requirements

Results gathered from observations and informal interviews gave a basis of information for the PI to develop the initial requirement for the TDL System – Functional Requirements Guide. The following table describes whether or whether not each company complied with the initial constraints. The requirements included whether the company could be contacted, if a demo was available, if the program was password protected, and whether the program had the option to create user groups and specific permissions. These questions were vital as the research could not move forward without contact with the company or availability to demonstrate the program. Likewise, a password protected program was necessary as the information was not open to the public. Many digital archiving programs differentiated themselves upon whether they were private, password protected or public and as information within private systems needs to be confined to a certain user group and publically available systems are normally used to share and disseminate information with large or infinite groups of people. Furthermore, user groups or permissions within the password protected digital archiving program would allow clients authorization to enter specific areas of the site. All of these factors were fixed requirements agreed upon by stakeholders.

Email correspondence was used to determine if the company would respond to requests and if demos could be acquired. Further information pertaining to privacy and user groups and permissions was acquired through secondary research. Responses of *no* or *other* are briefly explained in the far right column. Responses from the initial requirements allowed the PI to determine which programs to examine in further detail for consideration of use by the TDL System. Table 8 depicts the initial fulfillment of the TDL System Functional Requirements.

Table 8. Initial TDL System Functional Requirements

Program	Contact? Y/N/Other	Demo Available? Y/N/Other	Password Protected? Y/N/Other	User Groups & Permissions? Y/N/Other	Notes
Canto Cumulus	Yes	Yes	Yes	Yes	Complies with all initial requirements
LUNA Imaging	Yes	Yes	Yes	Other	User Groups not available but possibility to create Permissions in product configuration
Mosaic	No	No	Yes	Yes	Browser based – no software installation Unresponsive to request for Demo
Microsoft Sharepoint	Yes	Yes	Yes	Other	Microsoft Application – Only internal company access, but permissions and limited access can be given within company.
See File	No	Yes	Yes	Yes	Browser Based – no software installation Unresponsive to contact
Textronics	No	No	Yes	Yes	Unresponsive to inquiries or requests for Demo's – Information was unable to be attained. Only textile specific program found

4.3.2 Result 8: Development of Functional Requirement Guide

Through a six week, exploratory case study, the PI piloted a TDL System and developed a corresponding evaluation tool – the TDL System Functional Requirement Guide – to gauge which program was most suitable for Company X's TDL System (See Figure 17 below for detailed information regarding the Functional Requirement Guide). Canto Cumulus ranked the highest in the Functional Requirement Guide, scoring 439 out of 445 total points and was the chosen program for the TDL System (see Figure 20). The Functional Requirement Guide was arranged based on necessary requirements decided through interviews with stakeholders, observations, secondary research, and results from the survey.

The initial foundation for the Functional Requirement Guide (Figure 17) was established in Stage 1 of the methodology, then refined in Stage 2, and further refined and developed in Stage 3. The final resulting Functional Requirement Guide was comprised of five main topics; (1) Search and Explore, (2) Image Management, (3) Security, (4) Compatibility, and (5) Future Growth. Each topic contained subcategories which further described requirements of each category. The main categories, Search and Explore, Image Management, Security, Compatibility, and Future Growth, did not receive weights however their subordinate categories did receive weights from one to five points, depending on importance. A subcategory with a weight of one implied that it was of very low importance while a weight of five meant that the subcategory was very important. A weight of four meant high importance, three meant medium importance, and two meant low importance.

None of the subcategories actually weighed lower than a two in importance as each category was considered to be essential or else it would not have been included in the guide.

As weights were consistent throughout each evaluation, the fulfillment differed for each program. Under the fulfillment heading, a program could receive zero to five points depending on the extent to which the subcategory was satisfied. Zero points implied that the program did not fulfill the requirement at all while five points indicated that the program fully fulfilled the requirement. Four points denoted that the program had high fulfillment, three points were given for medium fulfillment, two points were given for low fulfillment, and one point was given for very low fulfillment.

Finally, once fulfillment for each program was multiplied against the weights of the corresponding subcategory, totals were determined and each program received a grade. A perfect score was denoted by 445 points. To receive an *A*, programs could score 445 to 400 points, for the grade of *B*, 399 to 356 points, for the grade of a *C*, 355 to 311 points, for the grade of a *D*, 310 to 267 points, and for the grade of an *F*, 266 points and below. The PI determined the grading scale by multiplying 445 by percent's of 90, 80, 70, 60, and 50. See the following Table 9 for a detailed explanation of how each grade was determined. The following are the main findings and results of the Functional Requirement Guide:

- Canto Cumulus was chosen as the best program for Company X's TDL System.
- Microsoft Sharepoint scored 221 points out of 445, raking an F in the Functional Requirement Guide (see Figure 18)

- LUNA Imaging scored 347 points out of 445, ranking a C in the Functional Requirement Guide (see Figure 19)
- Canto Cumulus scored 439 points out of 445, ranking an A in the Functional Requirement Guide (see Figure 20)

Table 9. Functional Requirements Guide - Grading Scale

Functional Requirements Guide - Grading Scale				
Grade	Total Points		Multiplied By Percentile	Points for each Grade (Rounded Down)
A	445	x	.90	400
B	445	x	.80	356
C	445	x	.70	311
D	445	x	.60	267
F	445	x	.50	222

Creditex Digital Library - Functional Requirements (60%)				
MASTER				
	Weight	Fulfillment	Points Available	Points Received
Search & Explore				
Search Specific to Textiles	5		25	-
Ability to input metadata	5		25	-
Ability to structure search to make relevant to Creditex	5		25	-
User Friendly Search Function	4		20	-
Advanced Search Capability	5		25	-
Google Style (Quick Search) Capability	3		15	-
Heirarchy Style Search Capability	3		15	-
Both	4		20	-
Image Managment				-
No Maximum Limit	3		15	-
Fast Upload Speed of Images	4		20	-
Fast Image View (< 3 Seconds)	4		20	-
Capacity to import and export multiple types of files	4		20	-
Image Administation by Client	4		20	-
Security & Access				-
Closed source (password entry)	5		25	-
Secure from leaking information/designs	5		25	-
Client Access	5		25	-
Ability to restrict access to certain information (via password)	5		25	-
Site available in different languages	2		10	-
Compatibility				-
Compatible with Penelope Design Software	5		25	-
Future Growth				-
On site costing for clients	3		15	-
Abitliy to alter, exchange, and approve samples	3		15	-
Fabrics of Excellence Section	3		15	-
Total Points			445	-
GRADE				

CODE	
Weight	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
Fulfillment	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
0	No Fulfillment
Grade	Range
A	445 - 400
B	399 - 356
C	355 - 311
D	310 - 267
F	266 & below

Figure 17. Functional Requirement Guide - Master

Creditex Digital Library - Functional Requirements (60%)				
SHAREPOINT				
	Weight	Fulfillment	Points Available	Points Received
Search & Explore				
Search Specific to Textiles	5	2	25	10
Ability to input metadata	5	5	25	25
Ability to structure search to make relevant to Creditex	5	5	25	25
User Friendly Search Function	4	3	20	12
Advanced Search Capability	5	0	25	-
Google Style (Quick Search) Capability	3	0	15	-
Heirarchy Style Search Capability	3	0	15	-
Both	4	0	20	-
Image Managment				-
No Maximum Limit	3	3	15	9
Fast Upload Speed of Images	4	3	20	12
Fast Image View (< 3 Seconds)	4	4	20	16
Capacity to import and export multiple types of files	4	3	20	12
Image Administation by Client	4	1	20	4
Security & Access				-
Closed source (password entry)	5	5	25	25
Secure from leaking information/designs	5	3	25	15
Client Access	5	1	25	5
Ability to restrict access to certain information (via password)	5	1	25	5
Site available in different languages	2	0	10	-
Compatibility				-
Compatible with Penelope Design Software	5	5	25	25
Future Growth				-
On site costing for clients	3	1	15	3
Abitliy to alter, exchange, and approve samples	3	1	15	3
Fabrics of Excellence Section	3	5	15	15
Total Points			445	221
Grade				F

CODE	
Weight	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
Fulfillment	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
0	No Fulfillment
Grade	Range
A	445 - 400
B	399 - 356
C	355 - 311
D	310 - 267
F	266 & below

Figure 18. Functional Requirement Guide - Microsoft Sharepoint

Creditex Digital Library - Functional Requirements (60%)				
LUNA				
	Weight	Fulfillment	Points Available	Points Received
Search & Explore				
Search Specific to Textiles	5	5	25	25
Ability to input metadata	5	5	25	25
Ability to structure search to make relevant to Creditex	5	5	25	25
User Friendly Search Function	4	4	20	16
Advanced Search Capability	5	5	25	25
Google Style (Quick Search) Capability	3	5	15	15
Heirarchy Style Search Capability	3	5	15	15
Both	4	5	20	20
Image Managment				-
No Maximum Limit	3	2	15	6
Fast Upload Speed of Images	4	2	20	8
Fast Image View (< 3 Seconds)	4	4	20	16
Capacity to import and export multiple types of files	4	5	20	20
Image Administation by Client	4	2	20	8
Security & Access				-
Closed source (password entry)	5	5	25	25
Secure from leaking information/designs	5	5	25	25
Client Access	5	3	25	15
Ability to restrict access to certain information (via password)	5	3	25	15
Site available in different languages	2	0	10	-
Compatibility				-
Compatible with Penelope Design Software	5	5	25	25
Future Growth				-
On site costing for clients	3	1	15	3
Abitliy to alter, exchange, and approve samples	3	0	15	-
Fabrics of Excellence Section	3	5	15	15
Total Points			445	347
GRADE				**C**

CODE	
Weight	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
Fulfillment	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
0	No Fulfillment
Grade	Range
A	445 - 400
B	399 - 356
C	355 - 311
D	310 - 267
F	266 & below

Figure 19. Functional Requirement Guide - LUNA Imaging

Creditex Digital Library - Functional Requirements (60%)				
CANTO CUMULUS				
	Weight	Fulfillment	Points Available	Points Received
Search & Explore				
Search Specific to Textiles	5	5	25	25
Ability to input metadata	5	5	25	25
Ability to structure search to make relevant to Creditex	5	5	25	25
User Friendly Search Function	4	5	20	20
Advanced Search Capability	5	5	25	25
Google Style (Quick Search) Capability	3	5	15	15
Heirarchy Style Search Capability	3	5	15	15
Both	4	5	20	20
Image Managment				-
No Maximum Limit	3	5	15	15
Fast Upload Speed of Images	4	5	20	20
Fast Image View (< 3 Seconds)	4	5	20	20
Capacity to import and export multiple types of files	4	5	20	20
Image Administation by Client	4	5	20	20
Security & Access				-
Closed source (password entry)	5	5	25	25
Secure from leaking information/designs	5	5	25	25
Client Access	5	5	25	25
Ability to restrict access to certain information (via password)	5	5	25	25
Site available in different languages	2	5	10	10
Compatibility				-
Compatible with Penelope Design Software	5	5	25	25
Future Growth				-
On site costing for clients	3	3	15	9
Abitliy to alter, exchange, and approve samples	3	5	15	15
Fabrics of Excellence Section	3	5	15	15
Total Points			445	439
GRADE				**A**

CODE	
Weight	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
Fulfillment	Meaning
5	Very High
4	High
3	Medium
2	Low
1	Very Low
0	No Fulfillment
Grade	Range
A	445 - 400
B	399 - 356
C	355 - 311
D	310 - 267
F	266 & below

Figure 20. Functional Requirement Guide - Canto Cumulus

4.4 Summary

The results section of this study stated the outcomes of this case study research and. The Textile Digital Library System was successfully developed, pilot tested, and evaluated and new insights were found regarding needs for TDL systems, client perception of TDL Systems, search functions and metadata for digital archiving of fabrics, and digital archiving program capabilities/limitations. In the *Conclusions* section, the implications of the results will be further discussed.

Chapter 5

5 Conclusions

In conclusion, this research can be deemed successful in that the objective to create a system for the management of fabric samples at a vertical textile mill in order to facilitate the search, view, and retrieval of woven fabrics and provide a guide for implementation of the Textile Digital Library System (TDL System) for product development was met. The major findings of this research were:

- Organization and search functions for the TDL System
- Client and industry partner perceptions and needs for a TDL System
- Requirements for a TDL System
- Functional Requirement Guide - Evaluation tool for TDL Systems
- Adoption of Canto Cumulus for Company X's TDL System

The research provided a foundation for the formation of a TDL System at Company X and would be significant to other companies wishing to implement a TDL System. Sustainable product development, as investigated in the literature review, requires fluid communication and integration of tasks, design support tools, understanding and consideration for major topics regarding sustainability, integration of sustainable ideals throughout the entire business structure, and strategies for sustainable growth. A TDL System gives designers more power to affect the sustainability of product development and also benefits all interrelated departments of the mill by providing a tool for communication and collaboration. Considerations investigated in the literature review, including: reduction of waste, recycling and reuse, reduction of processes, materials choices, and product lifetimes were addressed by the TDL system. Figure 22 depicts the capabilities of the TDL System to reduce the time, waste, processes, and departments involved in sampling fabrics.

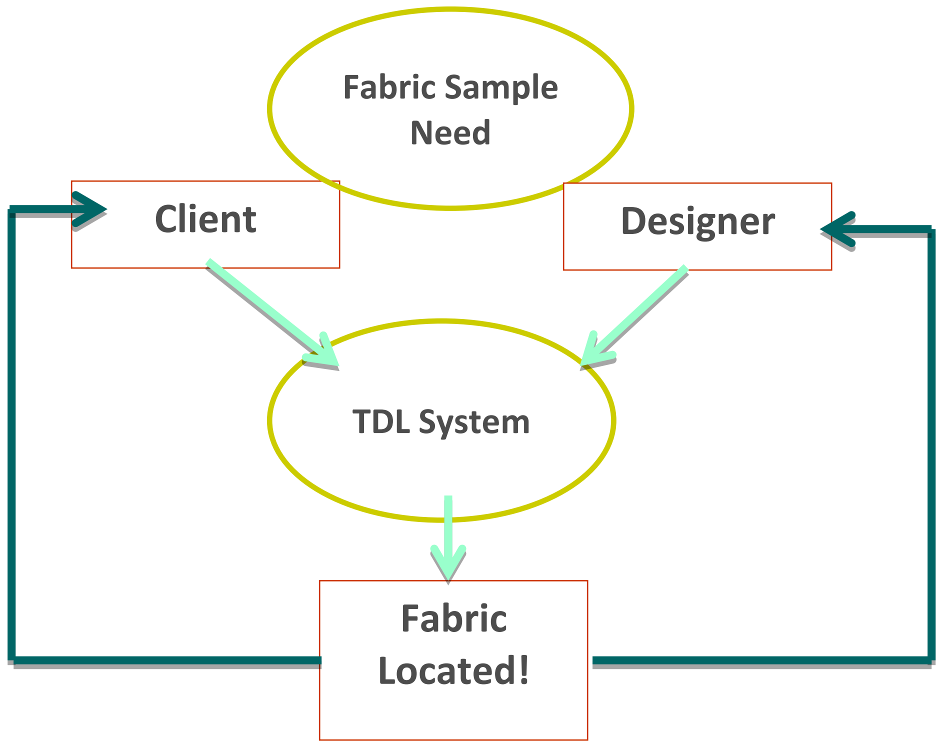

Figure 21. Fabric Sample Acquisition Process with TDL System

Results concluded that Canto Cumulus was the most suitable program for the needs of Company X and was adopted for the TDL System. Scoring an A with a point value of 439 out of 445 on the TDL System – Functional Requirements Guide, Canto Cumulus is an intuitive program which will grow with Company X and correspond to their changing needs as they increase future capabilities, such as inclusion of costing on the site or further integration of CAD systems. Employing Canto Cumulus for the TDL system will support the efforts of Company X to become a more sustainable enterprise by promoting communication, organization, and collaboration amongst interrelated departments within the company and with clients. The implementation of the TDL system greatly contributes to adopting a visionary sustainability strategy, repositioning companies, reducing footprint, and creating disruptive, positive change in the textile and apparel industry. Figure 23 depicts the stage at which the TDL System is involved in the Sustainable Value Model (Hart, Milstein, and Caggiano 2003).

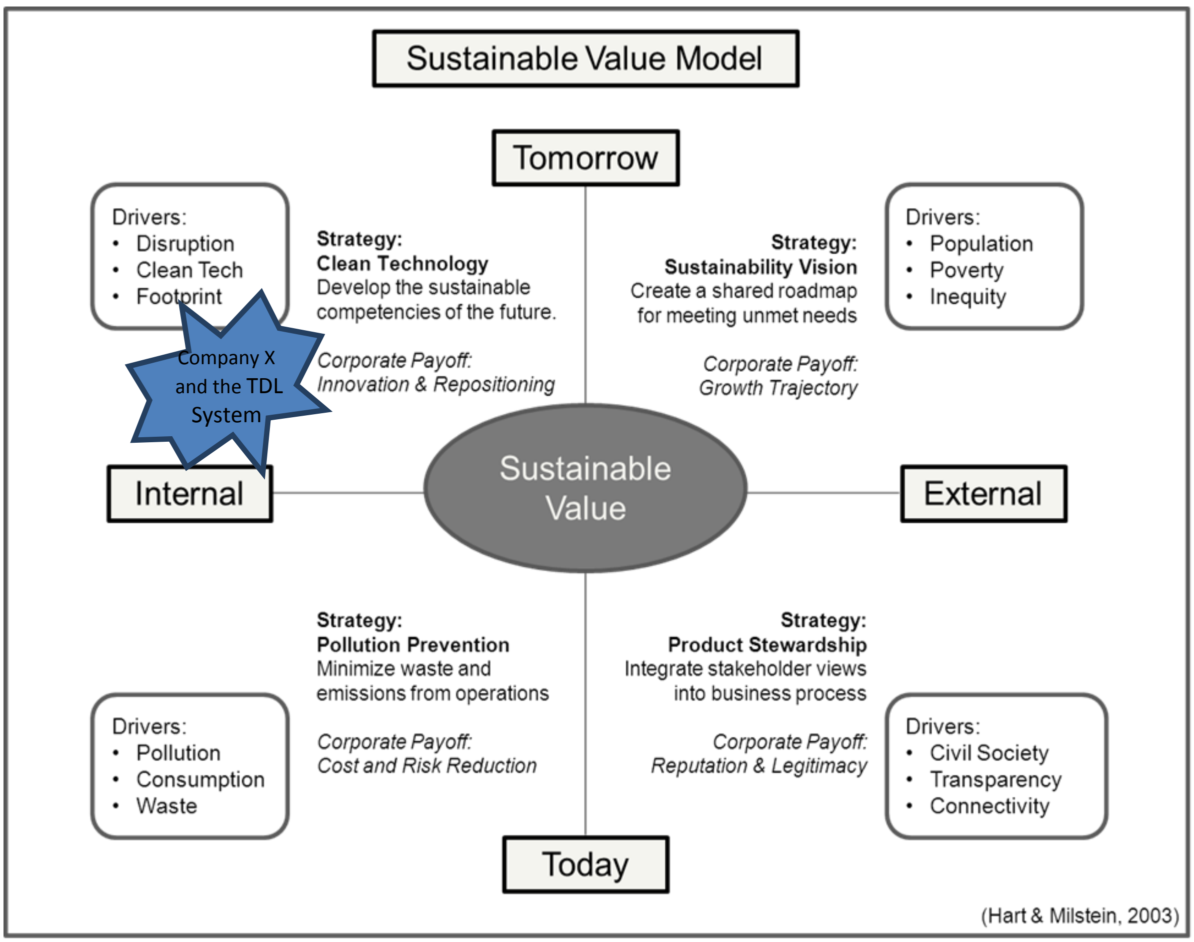

Figure 22. Sustainable Value Model (Hart, Milstein, & Caggiano, 2003)

5.1 Benefits

The Textile Digital Library System has many benefits to employees, clients, and industry partners of Company X and also benefits other textile companies. This exploratory research will assist other textile companies who wish to implement a TDL System in the future by:

- Providing information about current digital archiving programs
- Explaining the structure and needs of the system
- Identifying the important search functions and metadata related to design archiving
- Improving processes and future system configuration
- Supplying the Functional Requirement Guide to help companies choose the program correct for their needs
- Reducing risk of implementation failure to Company X
- Discovery of potential outputs
- Refinement of the design, performance and integration of the TDL System

When fully implemented into a company's process, TDL system has the capability to leverage sustainability by providing designers with fast access to information about fabric designs –helping designers to make informed decisions during product development. The TDL system facilitates the reduction of waste and reduction of processes through decreasing the re-design and re-production of existing fabrics. Product developers can quickly locate specific designs and fabrics, obtain the production and/or construction information, and modify or reuse designs – without starting from scratch, searching through boxes of fabrics, or waiting for weeks for fabrics to be located. Additionally, Company X can reduce risk by implementing the TDL system as proprietary designs and information are protected and stored electronically.

Information regarding material contents of fabrics included in the TDL system can also support design decisions. Fabrics can be deliberately chosen based on their material content and recyclability – refraining from choosing fabric blends containing multiple types of fibers which are difficult to separate during recycling. As well, waste can be minimized through the optimization of fabric by choosing fabrics with non-directional repeats. Images stored on the TDL system will allow designers to choose fabrics containing design repeats which enable an optimized marker layout.

Integration of the TDL system with CAD systems will assist in the communication and collaboration between divisions of the mill and with clients. As gathered from the survey, approximately 45 percent of clients need to view samples weekly. Using the TDL system to communicate designs to clients will allow fast review of samples and avoid the time-consuming, energy intensive, and expensive process of mailing samples. In return, the mill will then be able to spend less time assembling sample books and producing fabrics for sampling and more time producing fabric yardage for exports and profit.

By giving clients permissions on the site, they can browse samples, create collections, and can better communicate desired changes to fabric designs. With the ability to browse designs in the TDL system, clients can select or reject specific samples and limit the number of physical samples ordered. This will reduce the amount of physical samples produced and shipped to clients – reducing processes, reducing waste, and reducing material use. The TDL system will also allow consumer preferences to be tracked and reported allowing product developers to gather information about trends and popular fabrics. This information can be used as a basis for new designs, decreasing waste by reducing fabric production of unsuccessful designs.

5.2 Limitations

Due to limited time, money, and resources, findings are limited to capabilities recognized by pilot testing the software as the research did not test the fully implemented system. Though information from actual use by employees and clients of the fully configured TDL System may provide further understanding of program capabilities and limitations, it was important to first determine the needs, structure, requirements, and program capabilities for the TDL System. A future study could assess the acceptance, issues, benefits, and effects of the TDL system on the sustainability of the mill.

As discovered in the survey, touching fabrics is an important aspect of fabric selection and clients expressed this as a need. Though the TDL System does not incorporate the ability to touch fabrics, the purpose of the system is to assist in sample acquisition. Companies should use the TDL system as a tool to view and narrow the range of fabric samples ordered, communicate design requirements, and to accept or reject certain designs. Final selections of the specifically chosen, physical fabric samples can then be sent to the client, reducing the creation and shipment of many, irrelevant samples. Consumer education of the benefits of the TDL System would help clients learn how to use the program, to fully profit from its capabilities. Also, Company X could send clients a sample book encompassing of the different fabrics, giving clients examples of the hand, weight, and overall feel of the fabric and they could further choose the design using the TDL System.

Adopting three-dimensional (3D) digital imaging software is another method to better represent digital images of fabric and facilitate rapid prototyping. Three-D software options for fashion are offered by Lectra, Gerber Browzwear, Optitex, My Virtual Model, and Tukateck. As stated in the literature review, 3D CAD systems can reduce and shorten design processes, facilitate communication, and minimize physical prototyping resulting in reduced waste, reduced material use, and overall more sustainable product development (Glock & Kunz, 2005). With the integration of a 3D digital imaging into the TDL system, the scale and drape of fabrics can be more realistically represented. Three-D digital imaging programs are consistently improving in technology, making avatars and fabric look more authentic and assisting to innovate design processes. With this software, a designer no longer has to transfer a 2D pattern into a 3D garment. The design work is done in 3D where shapes, angles, and curves of the body can be correctly modeled and patterns can be correctly represented. Three-D software will improve the TDL system in the arenas of design, production, and rapid prototyping and further research regarding the integration of these two systems is recommended.

Disparity of color between differing computers is also an issue of TDL Systems which calls for further attention. The PI was unable to completely address this issue as color calibration is complex and requires specific expertise. However to resolve this issue, several steps can be taken. Firstly, computer screens should be calibrated regularly. Although it does not ensure the exact perception of color from one computer screen to another and from one person to another, calibration will warrant more true colors on the computer screen. Also, the creation of an annual or seasonal color blanket would give clients a better indication of true color. The colors in each pattern, for example, could be labeled with a code corresponding to its matching swatch on the color blanket. Clients could adapt designs found in the TDL system using the yearly or seasonal colors. Another option for reducing color disparities is to adopt an intuitive, consistent, and globally accepted color labeling system, such as Pantone. It is recommended that Company X further team with North Carolina State University color specialists to research and pilot a solution for color constancy.

In order to resolve some of these limitations, Company X should begin to incorporate fabric production and efficiency information in the TDL system. Designers need to consider all aspects affecting the sustainability of product development and make sustainable decisions. Information regarding the production efficiency, water use, energy use, waste creation, chemical composition, material content, and expected lifetime should be included in the TDL system. Furthermore, a section should be incorporated into the TDL system which houses the most efficient fabrics of Company X's collection. This will allow designers to effortlessly choose fabrics which are faster, easier, and more efficient to produce – reducing cost, time, production problems, and creating an overall more sustainable process. To further expedite sample acquisition, Company X should consider including the option to directly order samples through the TDL System. This would bypass sales and create a faster, more efficient process. Company X can continue to improve the TDL System with enhancements such as this by collaborating with Canto Cumulus.

5.3 Future Recommendations

After researching, pilot testing, and evaluating a Textile Digital Library System and considering the current benefits and limitations, future research should be conducted to continue the development of TDL Systems. Recommendations for future research include: research to test client and employee adoption of the TDL System, research substantiating the actual effects of a TDL System on sustainability, further exploration of color disparities, research regarding sustainability of fabrics, and research regarding the most efficient fabrics at Company X.

Once the TDL System is completely adopted into Company X's workflow, research regarding client and employee adoption of the system would be beneficial. This would show Company X what aspects need further development and also point out areas which have become more sustainable by using the system. A quantitative analysis of the sustainable effects of TDL Systems may help other companies to adopt similar systems.

The conducted research identified characteristics needed to configure a TDL System for a vertical textile mill, including: the internal and external needs, fabric organization, process flow, metadata and search topics, and functional requirements. Based on this research, a future research project could measure the actual amount of time and waste decreased by employing a TDL System. This would provide Company X and other companies wishing to adopt a similar system, quantifiable data regarding the benefits, limitations, and need for TDL Systems.

Further research regarding sustainable fabrics would be beneficial to TDL Systems. Indicators of fabric sustainability within TDL Systems would allow designers to easily choose fabrics based on factors of design as well as sustainability. Researchers should consider aspects of production efficiency, waste, material inputs, and consumer use. Research of these topics would assist the scientific community in gathering information about TDL Systems, assist companies wishing to implement TDL Systems, and further build the sustainability of textiles and apparel through Textile Digital Library Systems.

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7 Appendices

Appendix A. Survey

About: Creditex is in the process of creating a Digital Fabric Library with the intent of making fabric viewing and retrieval easy, fast, and efficient. The following survey will assist us in creating a database which best suits your needs. Please help us by filling out this survey to the best of your ability.

1. *Please denote the name of your company in the box below:*
2. *What is your area of work*
    - *Textile Design*
    - *Apparel Design*
    - *Sales*
    - *Materials Sourcing*
    - *Management*
    - *Other ____*
3. *How frequently do you need access to fabric samples?*
    - *Greater than two times a day*
    - *Once a day*
    - *Once a week*
    - *Once every 2 weeks*
    - *Once a month*
    - *Never*
    - *Other ____*
4. *About how long does it take to receive physical samples?*
    - *One month*
    - *One and half months*
    - *Two months*
    - *Two and half months*
    - *Greater than 3 months*
    - *Other ____*
5. *Do you consider CAD generated images of fabrics samples an acceptable manner of reviewing fabrics as opposed to viewing actual physical samples?*
    - *Yes*
    - *No*
    - *Other ____*
6. *When searching for digital fabric images, what do you perceive to be the most important categories?*

	Very Important	***Somewhat Important***	***Not Important***
Pattern			
Color			
Weave Type			
Fabric Material			
Warp Thread			
Weft Thread			

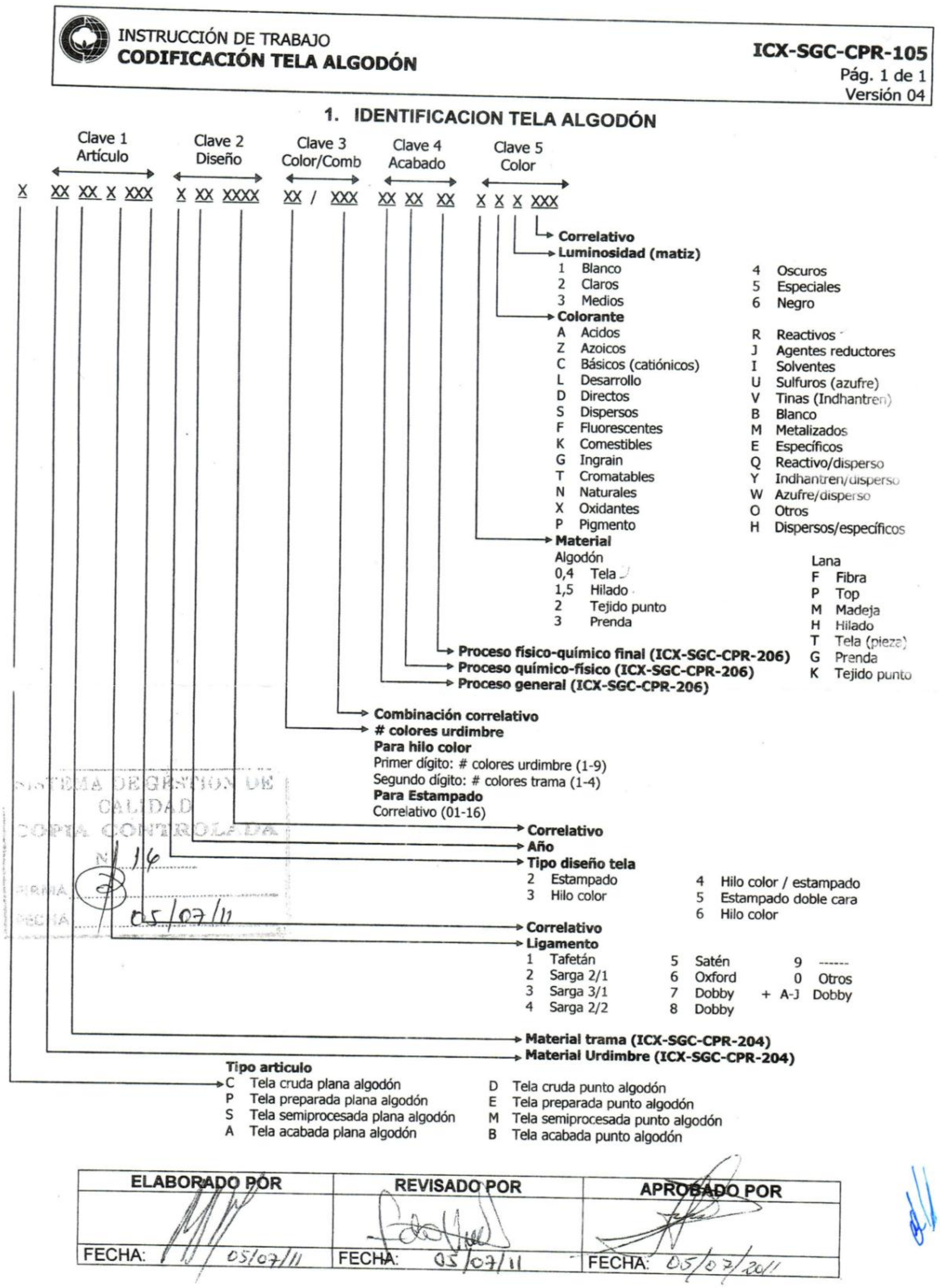
Fabric Weight	
Yarn Count	
Size of Repeat	
Article Number	
Price	
Other ?	

7. *How do you feel the following factors would be impacted when using a digital library?*

	Positive Impact	***No Impact***	***Negative Impact***
Ability to evaluate hand			
Ability to choose coloration			
Ability to perceive quality			
Ability to perceive scale			
Other ?			

8. *In your own words, please indicate why or why not a digital library would be beneficial to your line of work.*

Appendix B. Fabric Codification System



INSTRUCCIÓN DE TRABAJO
CODIFICACIÓN TELA ALGODÓN

ICX-SGC-CPR-105
Pág. 1 de 1
Versión 04

1. IDENTIFICACION TELA ALGODÓN

Clave 1 Artículo	Clave 2 Diseño	Clave 3 Color/Comb	Clave 4 Acabado	Clave 5 Color
X XX XX X XXX	X XX XXXX	XX / XXX	XX XX XX	X X X XXX

Correlativo

Luminosidad (matiz)
1 Blanco
2 Claros
3 Medios
4 Oscuros
5 Especiales
6 Negro

Colorante
A Acidos
Z Azoicos
C Básicos (catiónicos)
L Desarrollo
D Directos
S Dispersos
F Fluorescentes
K Comestibles
G Ingrain
T Cromatables
N Naturales
X Oxidantes
P Pigmento
R Reactivos
J Agentes reductores
I Solventes
U Sulfuros (azufre)
V Tinas (Indhantren)
B Blanco
M Metalizados
E Específicos
Q Reactivo/disperso
Y Indhantren/disperso
W Azufre/disperso
O Otros
H Dispersos/específicos

Material
Algodón
0,4 Tela
1,5 Hilado
2 Tejido punto
3 Prenda

Lana
F Fibra
P Top
M Madeja
H Hilado
T Tela (pieza)
G Prenda
K Tejido punto

Proceso físico-químico final (ICX-SGC-CPR-206)
Proceso químico-físico (ICX-SGC-CPR-206)
Proceso general (ICX-SGC-CPR-206)

Combinación correlativo
 # colores urdimbre
Para hilo color
Primer dígito: # colores urdimbre (1-9)
Segundo dígito: # colores trama (1-4)
Para Estampado
Correlativo (01-16)

Correlativo
Año
Tipo diseño tela
2 Estampado
3 Hilo color
4 Hilo color / estampado
5 Estampado doble cara
6 Hilo color

Correlativo
Ligamento
1 Tafetán
2 Sarga 2/1
3 Sarga 3/1
4 Sarga 2/2
5 Satén
6 Oxford
7 Dobby
8 Dobby
9 ------
0 Otros
+ A-J Dobby

Material trama (ICX-SGC-CPR-204)
Material Urdimbre (ICX-SGC-CPR-204)

Tipo articulo
C Tela cruda plana algodón
P Tela preparada plana algodón
S Tela semiprocesada plana algodón
A Tela acabada plana algodón
D Tela cruda punto algodón
E Tela preparada punto algodón
M Tela semiprocesada punto algodón
B Tela acabada punto algodón

SISTEMA DE GESTION DE CALIDAD
COPIA CONTROLADA
Nº 16
FIRMA
FECHA 05/07/11

ELABORADO POR	REVISADO POR	APROBADO POR
FECHA: 05/07/11	FECHA: 05/07/11	FECHA: 05/07/2011

Appendix C. Survey Consent Form

Attachment B
Consent Form

North Carolina State University
INFORMED CONSENT FORM for RESEARCH
Title of Study: Digital Fabric Libraries and Sustainable Product Development: Identifying, evaluating, and piloting a program to increase preproduction efficiency in a vertical textile mill.

Principal Investigator: Caroline Cockerham Faculty Sponsor: Lisa Parrillo-Chapman

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. The purpose of research studies is to gain a better understanding of a certain topic or issue. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. If at any time you have questions about your participation, do not hesitate to contact the researcher Caroline Cockerham or Lisa Parrillo-Chapman.

The purpose of this study is to improve preproduction sustainability and efficiency by creating a digital fabric library. The survey results will become part of the published master's research conducted by Caroline Cockerham. If you agree to participate in this study, you will be asked to complete the following questions.

The information in the study records will be kept strictly confidential. Data will be stored securely on a password protected server accessible only by the principal investigators. SLL encryption will be used for transmitting survey results. No reference will be made in oral or written reports which could link you to the study.

There is no monetary compensation. You will not receive anything for participating and the knowledge that you are contributing to building a greater body of work about digital fabric libraries. There are no foreseeable risks associated with completing this survey or participating in the case study.

If you have questions at any time about the study or the procedures, you may contact the researcher, Caroline Cockerham or Lisa Parrillo-Chapman, (919-513-4020) at the College of Textiles, NCSU, Raleigh NC 27695-8301. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Arnold Bell, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/515-4420).

By checking the "I accept" box I acknowledge I have read and understand the above information and am over the age of 18. I may print a copy of this agreement for my records. I agree to participate in this study with the understanding that I may withdraw at any time.

I accept ☐

I do not accept ☐

Appendix D. Survey Cover Letter

Attachment A
Cover Letter

R. Caroline Cockerham
North Carolina State University
Textile and Apparel Technology Management

Dear Creditex Client,
Creditex is conducting a study in collaboration with the College of Textiles at NC State University to create a digital fabric library for the purpose of facilitating design, communication, preproduction processes. Your participation in this study is voluntary and any data that you provide will be held in the strictest confidence where the identity of yourself or your company will not be associated with any data elements in my Master's Thesis or subsequent presentation or publications.

A digital fabric library is a searchable, browsable database of fabric images and information. The goal of this project is to improve preproduction sustainability and efficiency by creating a digital fabric library. The library will allow rapid and easy selection and acquisition of fabrics; facilitating product development by reducing replications of designs, decreasing sample creation, expediting client access to samples, and improving communication, both internally and externally.

To participate in this study, please click on the linked survey.
https://www.surveymonkey.com/s/LLJ9TVL

Your cooperation is greatly appreciated. If you have any questions concerning this study, please contact me at caroline.cockerham@gmail.com.

Sincerely,

Caroline Cockerham
Graduate Student
North Carolina State University
MS Textiles program, Textile and Apparel Technology and Management

Lisa Parrillo-Chapman, Ph. D.
Professor—NCSU
North Carolina State University
MS Textiles program, Textile and Apparel Technology and Management

Appendix E. Metadata – Spanish

Metadata		
Categoria Principal	**Subcategoria**	**Codigo**
Patron (P)		
	Raya	P100
	Formal	P101
	Casual	P102
	Jeanswear	P103
	Esocesa	P200
	Punteado	P300
	Cuadros	P400
	Formal	P401
	Casual	P402
	Jeanswear	P403
	Solido	P500
	Fil a Fil	P600
	Chambray	P700
	Vichy	P800
	Herringbone	P900
	Pied di Poule	P1000
Tipo de Tejido (TT)		
	Tafetan	TT1
	Sarga 2/1	TT2
	Sarga 3/1	TT3
	Sarga 2/2	TT4
	Saten 5	TT5
	Oxford	TT6
	Dobby	TT7 / TT8
	Otros	TT0
Colores (C)		
	Rojo	CR10
	Naranaja	CN11
	Amarillo	CA12
	Verde	CV13
	Celeste	CT14
	Azul	CZ15
	Indigo	CI 16
	Morado	CM17

	Rosado	CP18
	Negro	CB19
	Blanco	CW20
	Gris	CG21
	Crema	CC22
	Beige	CE23
	Moreno	CO24
	Crudo	CD25
Tela Material (M)		
	Algodon Pima	M70
	Algodon Tanguis	M60
	Algodon Upland	M50
	Hybrid	M40
	Algodon Cero	M20
Peso del Tela (PS)		
Hilo Material Urdimbre (U)		
	Algodon Pima	U70
	Algodon Tanguis	U60
	Algodon Upland	U50
	Hybrid	U40
	Algodon Cero	U20
Numero de Articulo (A)		
	Algodon Pima	T70
	Algodon Tanguis	T60
	Algodon Upland	T50
	Hybrid	T40
	Algodon Cero	T20
Tamano de Diseno (S)		
	Pequeno	SP
	Medio	SM
	Grande	SG
Numero de Articulo (A)		
	70707040	A70707949
Precio (D) (Per yard?)		
	$0-3	D1

	$4-6	D2
	$7-9	D3
	$10-12	D4
	$13-15	D5
Tipo de Confeccion (R)		
	Camisa	R1
	Mujeres	R1W
	Hombres	R1H
	Pantalones	R2
	Mujeres	R2M
	Hombres	R2H
	Pijamas	R3