ABSTRACT

FIALLOS, MAX. Developing a Cost Model for Sourcing Products for Different Distribution Channels. (Under the direction of Dr. Kristin Thoney and Dr. Jeffrey Joines.)

Apparel sourcing operations are extremely complex due to the intricacies of a global supply chain. Sourcing decisions should not be made without an exhaustive analysis of supply chain cost structures. Landed costs must be analyzed for sourcing decisions, but they must be complemented by information of the effects of supplier lead times and consumer-retail interactions, which are critical to overall supply chain performance. A focus on cost of goods alone gives insufficient importance to the negative effects related to forecast errors when sourcing from regions with long lead times.

A supply chain cost model has been developed in this study. The model looks at cost structures for the entire supply chain from fiber to retail. The cost model shows the accrual of costs throughout each processing step within the textile and apparel industry. It also identifies costs related to international trade, including transportation costs and duties paid upon entry to the United States. The study examines the supply chain processes and costs for producing t-shirts and denim jeans in distinct regions of the world. Trade agreement duty provisions, world cotton market price competitiveness, export tax rebates, and labor rates significantly affect a countries' competitiveness in the textile and apparel industry.

The study helps identify the cost makeup of each process and the resources consumed. This model can assist companies to look outside their area of operation

and have an appreciation of costs related to upstream and/or downstream processes within their supply chain. They can identify broad issues related to their strategic partnerships with suppliers and customers and investigate these in more detail. By combining supply chain costs, transportation time, and manufacturing responsiveness, analyses can be performed to identify scenarios where responsiveness is more critical than cost effectiveness. This study has found that a responsive supply chain can outweigh a lower cost but less responsive supply chain in certain sourcing environments.

Developing a Cost Model for Sourcing Products for Different Distribution Channels

by
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DEDICATION

To my wife, Telma. Your support was essential to my academic success. Thank you for always being there for me when the load seemed overwhelming. This accomplishment is as much yours as it is mine.

BIOGRAPHY

Max Fiallos was born in Tegucigalpa, Honduras. He graduated from Louisiana State University in 2002 with an Industrial and Manufacturing Systems Engineering degree. Upon graduation he returned to Honduras and worked in the apparel industry for five years. He was awarded a Fulbright scholarship and an ITT Fellowship in 2007 to attend North Carolina State University. Max will return to Honduras upon graduation and reintegrate himself within the Honduran textile and apparel industry.

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1 Introduction

As sourcing of textile and apparel products continues to shift toward Asia, retailers are faced with managing an increasingly complex procurement strategy. Sourcing products from Asia requires planning for long lead times and heavy reliance on sales forecast data. The inaccuracies of forecasts can create inventory stockouts or surplus inventory at the end of selling seasons. Both scenarios negatively affect a company's profitability. This research project will compare supply chains with short lead time against supply chains with low cost manufacturing with lengthier lead times and their ability to minimize forecast error effects on retail performance.

1.1 Problem Statement

In some instances, sourcing decisions are based on limited information, primarily focused on labor costs while paying little attention to other critical information. Asia has become the major producer of apparel goods, in part due to their highly competitive labor rates. Sourcing from Asia implies having longer lead times to the United States, compared to the responsiveness of other areas of the world. Given replenishment is not a viable option in some cases when sourcing from Asia, there is an increased reliance on forecast data.

Forecast data for seasonal, fashion, and even basic items is commonly off target. Actual consumer demand for products differs from the total forecasted demand as well as the stock-keeping unit (SKU) mix. Unfortunately, placing replenishment orders to better service true demand is not a viable alternative due to long lead times; there is an imbalance between in-season replenishment requirements and far-east lead times.

In an attempt to have improved consumer service levels, retailers often order above-forecasted quantities of goods. The improved service levels come at the high cost of diminished profit margins given excess inventory has to be marked down, also referred to as discounted or "put on sale", at the end of selling seasons. Not only is it common for retailers to have excess inventory at the end of selling seasons, but often they have inadequate SKU mixes in inventory (i.e., carry the wrong styles, colors, and/or sizes), which ultimately results in stockouts and lower service levels during the selling seasons.

1.2 Research Objectives and Research Value

This research addresses the issues of cost and lead time associated with various textile supply chains. The specific objectives of the research are:

1. to develop a cost model for sourcing apparel goods;
2. to analyze how country trade policies and bilateral trade agreements affect cost structures and related competitiveness;

3. to analyze performance of different global supply chains, as related to landed costs and lead times;
4. to build upon previous research performed by Lisa Hartman (ITT Fellow of 2006) by reducing assumptions and validating the results by using specific data from the new cost model.

The objectives of the research project are beneficial to improving retail sourcing practices and to identify opportunities for textile and apparel production in the western hemisphere. The cost model aims to improve sourcing decisions by including all landed costs associated with an item and avoid focusing excessively on labor costs. Identifying apparel product types that should be sourced within short lead time regions aids justifying producing more textile and apparel products within the western hemisphere.

The latter should be of significant interest to U.S. textile producers. The government of the United States of America has negotiated free trade agreements with Latin America over the past fourteen years that have created new markets for textile producers. The yarn-forward rule of the agreements, and in some cases the fiber-forward rule, ensures that textile producers of the U.S. will have a market to export their products. Increased apparel production in Latin America should result in increased U.S. yarn and fabric consumption allowing the domestic textile complex to survive and flourish.

2 Literature Review

The following sections review supply chain management issues related to the sourcing of products. Different sourcing strategies and their supply chain structure's ability to respond to consumer demand fluctuations are included. Also, an examination of product and sourcing costing practices are presented. Finally, a review of the Sourcing Simulator™ software system and sourcing simulation capabilities is presented.

2.1 Supply Chain Management

According to the Council of Logistics Management the definition of supply chain management is the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company across businesses within the supply chain for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole. Another, more simple, definition of supply chain management is the integration of key business processes from the end user through original supplier that provides products, services, and information that add value for customers and other stakeholders (Long, 2003).

Supply chain management seeks to promote efficiency through supply chain integration. A well-integrated supply chain can increase the value of the whole process for all entities involved and creates value-added products for consumers (Long, 2003). It is of utmost importance for sourcing decisions to include looking into the strengths and weaknesses of complete supply chains as this will have a significant impact on overall sourcing strategy performance.

As an industry example of supply chain leadership, Apparel Magazine documents how J.C. Penney leads the retail industry in best practices and innovation relating to global supply chain management. J.C. Penney has focused on improving speed to market of goods, vendor consolidation, and logistics to gain an edge in the marketplace. The company has developed and implemented factory-to-store supply systems for specific goods. Suppliers reduced shipping lead times within five and seven days of receiving orders and therefore are able to respond to actual consumer demand patterns. By being able to service actual consumer demand, J.C. Penney has been able to reduce stockouts and ultimately increase sales. Direct shipment from factory to stores has helped reduce warehousing costs by simply bypassing warehouses altogether. Another way in which J.C. Penney has improved their supply chain is by accelerating their product development capabilities. The concept-to-consumer cycle has been reduced from two years to forty-five days in some cases. Such reductions in product development time are highly advantageous.

J.C. Penney has adopted several best practices related to logistics. As an importer accredited under the Customs-Trade Partnership Against Terrorism (C-

TPAT) program it can move its goods through customs rapidly. It has decided to diversify the ports it uses to avoid congestion in ports such as Los Angeles, and now it brings some of its shipments from India, Sri Lanka, and other neighboring countries through east coast ports, such as New Jersey, Savannah, and Charleston. J.C. Penney also supports logistics operations with leading edge information technology systems, such as i2, Teradata, ClearTrack, Oracle forecasting engines, and Avery Dennison InfoChain Express. They also benefits from smooth flow of goods from suppliers to stores by collaborating with their partners to ensure products are floor-ready (Atkinson, 2006).

2.2 Sourcing and Supply Chain Responsiveness

Proactive and forward-thinking sourcing managers take into account numerous factors to evaluate for sourcing decisions. In apparel, special attention is placed on supply chain flexibility, product development competencies of manufacturing firms, and other value added services. Examples of how broader service offerings can turn into advantages are found throughout current literature. Pre-production responsiveness leads to improved speed to market advantages over countries within the same geographic region. For example, China does not have the lowest labor rates, CMT, or FOB prices compared to Bangladesh, but it has a much more flexible and complete textile and apparel supply chain (Birnbaum, 2005).

A high level simulation model on outsourcing from Asia developed by Kumar and Arbi (2008) provides insight on how supply chains can be more responsive. The study suggests how IT systems can be leveraged to reduce lead times. One of the supply chain synergies the author recommends is forming long term partnerships. The partnerships can reduce order processing times if both sides agree to a common IT platform.

There are various accounts of the implications and limitations of sourcing offshore as well. A recent study by Lowson (2003) has analyzed hidden costs, also known as costs of inflexibility, related to sourcing offshore. A total acquisition cost model (TACM) related to hidden costs of sourcing offshore had been previously developed. The author executed an empirical study with retail company participation. Relationships, called LIPS interactions, are depicted showing how lead time performance, supplier service level performance, and supplier process time performance relate to retail customer service levels and retail inventory levels. The author's findings are effective as shorter lead times, higher supplier service level, and shorter supplier processing time result in higher customer service levels with lower inventory levels. These findings are illustrated by Figure 2.1, Figure 2.2, and Figure 2.3, respectively.

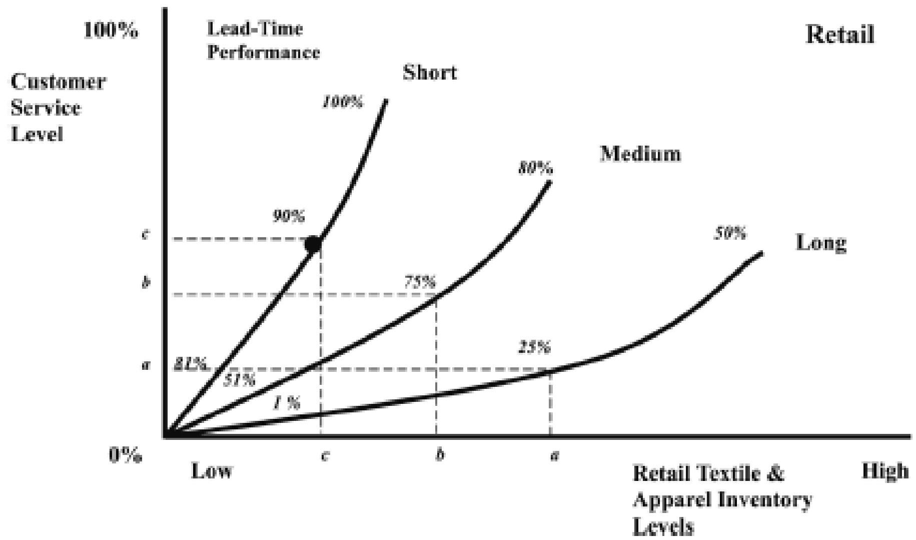

Figure 2.1: Customer Service Levels Affect Re-Order Lead Times (Lowson, 2003)

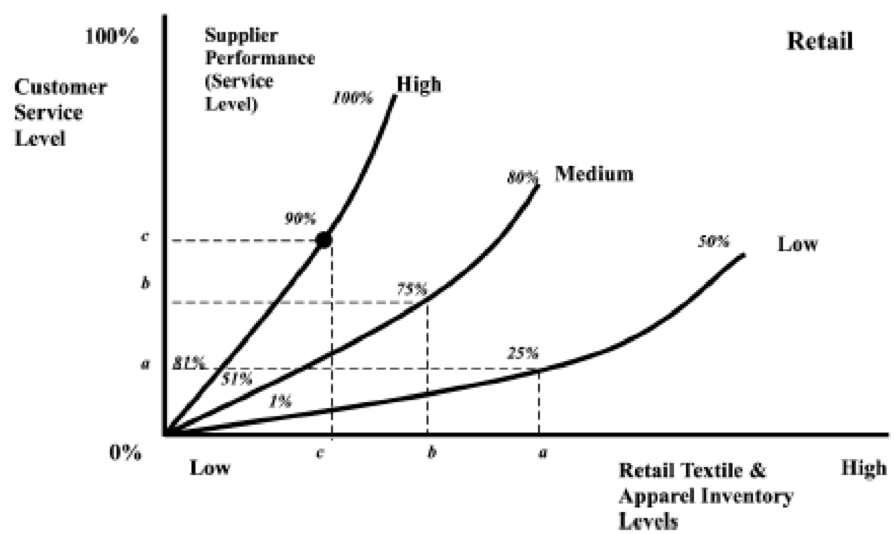

Figure 2.2: Customer Service Levels Affect Supplier Performance (Lowson, 2003)

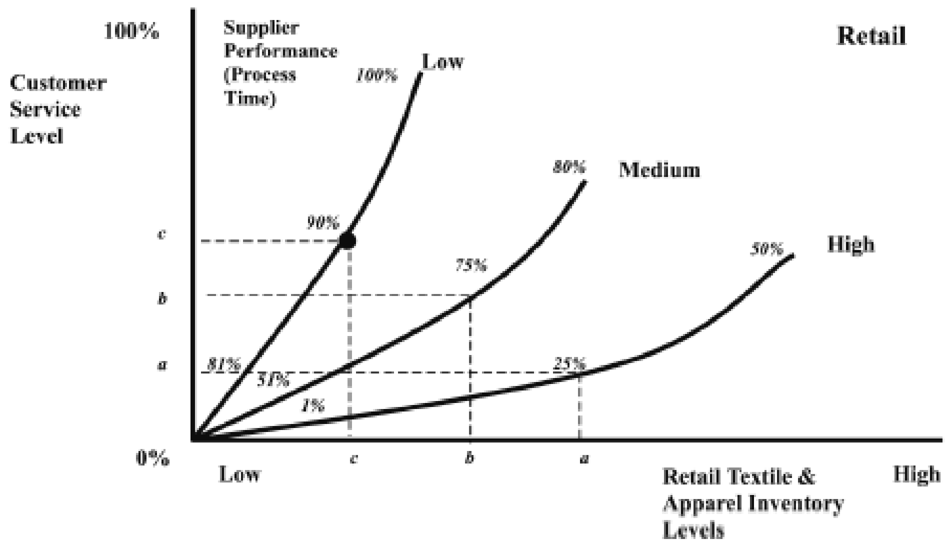

Figure 2.3: Customer Service Levels Affects Inventory (Lowson, 2003)

2.2.1 Traditional Sourcing

Traditional sourcing is a procurement method which aims to have all goods forecasted to sell available before an actual selling season begins. This strategy has no in-season reorders and cannot respond to actual demand fluctuations (Hartman, 2006). This type of practice is becoming less commonly used by some importing countries. For example, the United Kingdom has reduced their traditional sourcing of seasonal products from 67% in 1997 to 15% in 2008 (Butler, 2008).

2.2.2 Quick Response (QR)

Quick response manufacturing and sourcing is a practice which can significantly improve retail performance for seasonal and fashion items. Quick response, as its name implies, supplies products with quick turn times. This enables orders to be placed more closely to and within selling seasons and therefore have better product offering accuracy. QR can improve returns, flexibility, and customer service levels (Hunter, 2002). This practice has been increasingly adopted for sourcing seasonal products in recent years in the United Kingdom. In-season buying and replenishments, which are related to quick response, has also become more widely used (Butler, 2008). Figure 2.4 depicts the changes the UK has adopted for seasonal product sourcing.

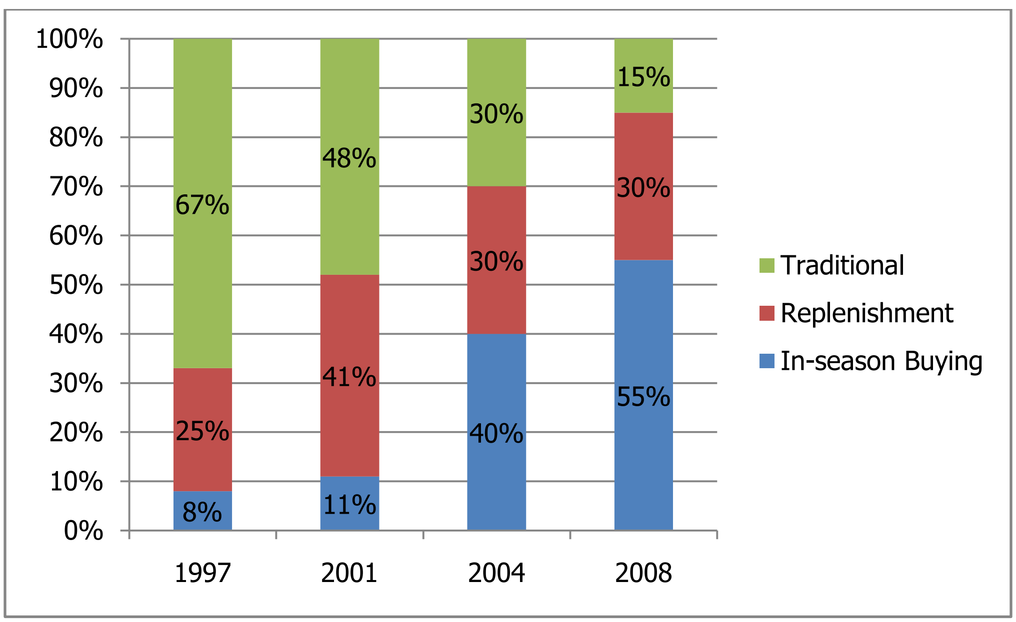

Figure 2.4: Changes in Sourcing Practices for Seasonal Products in the UK (adapted from Butler, 2008)

Consumer satisfaction is a key performance indicator of retail operations, as repeated patronage is linked with customer satisfaction. A study by Ko (2007) recently focused on examining how quick response techniques (QRT) by retailers affect customer satisfaction. The study divided store attributes into QRT-related and non-QRT attributes. Some of the QRT-related retail store attributes were availability of advertised products, accuracy of advertised products, price for value, new/fresh merchandise, and checkout time, among others. Some non-QRT store attributes were after-sale service, location of store, parking facilities, store hours, and others.

The study analyzed three types of shopping orientations of customers: fashion focused, economy focused, and shopping time focused. The 232 women study found that QRT practices yield great customer satisfaction to fashion focused and economy focused customers. This is due to low levels of stockouts, quick merchandise turnaround, and high value service for reasonable pricing (Ko, 2007).

Western hemisphere apparel executives feel that sourcing is returning to the region from the Far East. During a panel discussion at Material World in April 2008, Brian Meck of Fessler USA, a knitting-forward company located in Pennsylvania, alluded to the fact that innovative and fashion-forward companies are seeking their services in part because of their ability to respond with quick turn times to product sell-through at retail.

2.2.3 Collaborative Planning, Forecasting and Replenishment (CPFR®)

A concept very similar to quick response, and one of the latest developments in supply chain optimization, comes from collaborative efforts and partnership ideologies. Collaborative Planning, Forecasting and Replenishment (CPFR®) is a business practice which aims to combine the intelligence of all supply chain participants in the planning and fulfillment of customer demand, specifically by making consumer demand intelligence available to all partners. By linking all processes, CPFR® aims to improve the availability of goods to consumers, reduce inventory, transportation and logistics costs. Case studies of CPFR® projects have shown improvements of in-stock percentage of up to 8% and a total supply chain inventory reduction of 10 to 40% (Voluntary Interindustry Commerce Solutions, 2008).

2.3 Consumer Demand Forecasting, Stockouts and Markdowns

A core component of sourcing success or failure is the ability to respond to forecast error. Forecasting is a quantitative prediction of future events. In apparel sourcing it is often difficult to predict consumer behavior and its related fluctuations. Consumer demand for apparel can vary from forecasted total demand, SKU mix, drift, demand seasonality, and others (Lowson, 2003). Some apparel producers counteract demand uncertainty by delaying the dyeing process after garments have been sewn to allow consumer color preference data to be more accurate, but this approach is limited in application (Yeh, 2003).

Research finds that apparel retailers in the United States lose $64 billion per year due to markdowns. Some of the retailers allocate half of their planning resources to managing markdowns. About five percent of excess product inventory is pushed to off-price retail channels (Kurt Salmon Associates, 2008). Leading sourcing consultant, David Birnbaum, has been quoted saying "retailers can no longer bear the burden of the markdown epidemic. Going forward factories will be forced either to participate in the markdown loss (which will eventually bankrupt them) or work to solve the problem once and for all" (Nichols, 2008).

Recent benchmark studies performed by Retail Systems Research further detail how common forecasting error affects business performance. More than fifty percent of respondents admit to struggling with excessive promotional discounts and markdowns pricing of seasonal goods. While those actions are related to sell-through of on-hand inventory, retailers significantly struggle with out of stock items as well. Roughly forty percent of respondents consider out of stocks to be a persistent problem for basic products, and thirty percent believe the same is true of seasonal products (Rosenblum, 2008).

Fashion markets are characterized by products with short life cycles, high demand volatility, low forecast accuracy, and high consumer impulse purchasing.

Players, like Zara, are rotating their product much more frequently and have increased their seasons per year up to twenty in some product categories. Traditional forecasting methods for fashion markets have resulted in overstocks or stockouts. Reliance on forecasts to meet consumer demand must be reduced and in its place should be reduction of lead times (Christopher, 2004).

Three distinct lead times that are essential for competing effectively in fashion markets are time-to-market, time-to-serve, and time-to-react. Agile supply chains should be information centered, focusing on consumer trends, sharing information virtually, and having supply chain linkages working together and flexible by using player strengths. The latter characteristic is exemplified by Zara and Benetton in that they source certain operations to specialized and often small, manufacturers. While speed and flexibility are important, the required levels of both are determined by consumer demand unpredictability (Christopher, 2004).

2.4 Costing

The approaches to developing cost calculations can vary significantly from one industry to the next. Some companies use straight cost accounting methods, others activity based costing, and more recently time-driven activity based costing has become more common. General manufacturing industry cost calculations are relevant to this study, and therefore included in this section.

2.4.1 Manufacturing Cost Models

A study on inter-country pooled data illustrates that costs for the paper, iron and steel, and aggregate manufacturing industries are driven by capital, labor, energy, and material inputs (Roy, 2006). The electronics assembly industry's cost structure is formed by factory time, human resources, setup times, processing times, materials and overhead (Locascio, 2000). The costs for pultrusion processes (Creese, 2000), general job-shop assembly operations (Aderoba, 1997), injection molding process (Shehab, 2002), and ethanol production processes (Kwiatkowski, 2006) share the same cost drivers: materials, labor, energy, overhead, and cost of capital. Studies on cost drivers and cost accounting are less readily available than studies on economic order quantity (EOQ).

2.4.2 Apparel Costing

Techniques for costing apparel are seemingly infinite, as different companies pursue different methods. Costing documents are great tools for comparing time periods, vendors, and countries. The apparel and textile manufacturing industries share the same cost drivers as the industries listed previously. Studies on textiles and apparel point to labor, materials, capital, and energy as the drivers of costs (Datta, 2005). A case study on a knitwear company points out that labor, materials, and overhead drives its production cost structure (Zhuang, 1990), while the costs of preparing an apparel collection are summarized into labor, materials, and overhead (Aktuglu, 2001).

In parts of the world, the availability of working capital can be a limiting factor to a company's competitiveness. During a panel discussion at Material World in April 2008 for example, Jim Chestnut of National Textiles, expressed that working capital in Central America is in short supply and needs to improve in order to keep the area competitive. He also described difficulties of obtaining capital investment financing for projects in that area.

A simulation model for textile supply chains, COSTEX, simulated the performance of a Belgian supply chain. The model simulates the performance of a traditional supply chain versus an improved version of the supply chain with quick response capability. A supply chain qualifies for quick response capability by using best practices such as information systems (EDIs, integrated information systems platforms), and management concepts (Just In Time, Total Quality Management, Vendor Managed Inventory). Each best practice has qualitative effects on performance. Depending on the use of best practices, lead times, inventory levels and capacities change. The costs related to labor, material, capital, overhead, and operations are reevaluated with improved supply chain performance metrics which yield improved performance (Belpaire, 2000).

One costing method that stands out, Full Value Cost Analysis is a comprehensive tool which aids industry professionals to consider, and include, often-missed components of costing (Birnbaum, 2000). Costing items fall under the following three categories: direct costs, indirect costs, and macro costs. Macro costs are related to specific countries and their infrastructure, financial institutions, corruption, communications, bureaucratic inefficiencies, tariffs, safeguard impositions, and similar factors. While these costs are very important, they are extremely difficult to quantify and use in costing analyses.

Indirect costs are related to services offered by factories required by customers. Indirect costs include many pre-production tasks such as pattern making, lab dip submission, screen print strike-offs, procurement of trims, and more. If factories perform any of the services then the indirect costs are included in the product price, but if the sourcing agent or customer performs these tasks then the indirect costs are allocated within their respective overhead structure. It is evident that sourcing decision makers value this concept. At OTEXA's "Americas Textile and Apparel Competitiveness Forum" John Strasburger, Vice-President and Managing Director of VF Americas Sourcing, stated that factories need to offer product development, pricing, sampling, and prototyping services to stay competitive.

Direct costs are, as its name implies, costs which are directly related to the actual garments. The operations and inputs included in direct costs are cut and make labor, trims, fabric, and others. Direct costs are the one variable in the cost equation which can be negotiated by buyers, as a buyer's reach will not be able to modify indirect or macro costs (Birnbaum, 2000).

2.5 Logistics

The previous section discussed manufacturing costs, but a very important support structure and indirect cost of production to take into account is logistics. Numerous textbooks on logistics and supply chain management define logistics using the Council of Logistics Management's definition. Logistics is "that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption in order to meet customer requirements" as defined by the Council of Logistics Management (Long, 2003). Logistics operations are charged with the obligation of having products at the right place at the right time. Therefore an extremely important consideration when deciding on the appropriate logistics infrastructure to employ is lead times.

The textile and apparel industry has an international logistics network, which adds complexity to operations. Each country has a set of customs paperwork, requirements, and procedures which must be followed as well as port congestion and charges, which are among other factors that affect lead times and costs. Shipping routes have different frequency of service departures and transportation times. Access from western South America to the US east coast requires use of the Panama Canal, as does in many cases from the Far East. Shipments from India to the US east coast commonly require transit through the Suez Canal. Insurance for goods shipped, bunker surcharges, and overall cost structures also vary from one shipping route to another. These and many other factors must be evaluated when making sourcing decisions.

2.6 Global Trade

In a post-quota world and where free trade agreements by the United States have been signed it is extremely important to understand the implications. Free trade agreements lower trade barriers such as tariffs and allow for reciprocal market access between trading partners. Textile businesses that are well informed of the implications of free trade agreements can leverage their knowledge to gain advantages.

A study in 2005 carried out at the David F. Miller Center for Retail Education and Research addresses the opportunities the US textile industry has related to apparel producers in the DR-CAFTA region. As more and more retailers are sourcing products from China, the US textile industry must reinvent itself. China has become the dominant supplier of apparel products because it has a very complete supply chain with efficient product development services. However, China's lengthy lead times cannot respond to fluctuations in consumer demand as effectively. The US textile and apparel industry has become more complex due to shorter product life cycles, volatile and unpredictable demands, and high product variety, otherwise known as SKUs.

In order to counteract the variation of demand, retail firms are pursuing different supply chain strategies that meet the following requirements:

- Delayed production close to selling seasons for improved forecasting accuracy,
- short turn-around time,
- high product variety in small order size, and
- flexibility to handle volatile consumer demands for short life cycle products.

The current state of sourcing practices shows that DR-CAFTA countries are supplying basic goods, which do not have significant fluctuations in consumer demand. This can greatly reduce the advantage of speed-to-market. Asian suppliers pose a threat to DR-CAFTA apparel suppliers of basic goods, and in turn pose a threat to US textile firms as the DR-CAFTA region is the largest consumer of US yarn and fabric. Supply chains in DR-CAFTA need to focus on value-added fashion apparel instead of basic apparel and make geographic proximity advantages relevant. However, in order to be able to source these products from the area, the textile industry must invest in the area and form long term relationships. It is also necessary that pre-production services be established and offered within DR-CAFTA regions.

Retailers should realize that profitability improvements should focus on maximizing revenue and not cost of goods reductions. This can only occur if retailers sell what is actually demanded by consumers. In order to have a successful strategy it is important to have retailers, apparel and textile firms cooperating. Not only is speed-to-market needed, but also insight into consumer demand trends and behavior (Oh, 2007).

2.7 Sourcing Simulator™

The Sourcing Simulator™ software system is a tool which enables simulating retailing scenarios for a product line; it also has the capability to model relationships between selected operational parameters related to sourcing and environmental factors and retail performance. The tool is designed to aid users to evaluate retail and manufacturing performance under specific sets of conditions; it also serves as a training tool for retail buyers and managers.

The actual simulation is dependent on the information users input. User inputs include settings related to the buyer's plan, markdowns and promotions, sourcing strategy, cost, consumer demand, and vendor specification. Under the before mentioned tabs the software user can specify the item selling season duration, total units forecasted to sell, style/color/size mix, specify promotion periods and its related details, supplier performance, lead times, cost of goods, among many other parameters.

Once all parameters are set to specifications, the system is ready to simulate the scenario. The system begins by generating random arrival of customers to the retail setting and assigns an SKU to the customer randomly. The SKU is related to a specific style, color and size garment. The system then checks if the SKU is in-stock on the retail shelves. If the SKU is available then a sale is recorded. If the SKU is out-of-stock, the customer may choose an alternate SKU or leave without making a purchase.

From this simulation, the system records a large amount of performance data. The performance metrics collected are related to revenues, costs, inventory, and customer service on a weekly or complete season basis. Users can then vary simulation inputs and compare the performance of different scenarios. These metrics are a powerful tool for training of buyers and for actual sourcing decision processes.

Industry case studies illustrate the practical applications of the Sourcing Simulator™ software. King and Maddalena (1998) performed a replenishment strategy analysis in cooperation with two companies: Dillard's' and clothing manufacturer Warren Featherbone Co. Both retailer and manufacturer were interested in implementing replenishment scenarios for children's apparel. The participants used the Sourcing Simulator™ software to analyze several strategies prior to making a commitment. The simulations run showed that gross margin performance was improved significantly with the adoption of single in-season reorder with a 50% initial inventory delivery, compared to a traditional sourcing approach with 100% initial inventory delivery. The single in-season replenishment also had improved metrics in service levels and inventory turns. The study also investigated initial inventory stocking percentages and its effect on revenue, forecast error effects on gross margin, and the number of reorders and its effects on gross margin. Based on the scenario analyses the two companies were able to adopt a trial strategy.

The previous project was executed by the retailer and manufacturer. The adoption of the replenishment strategy yielded improved performance versus a traditional strategy. Significantly higher sell-through ratios were observed in the styles that were sourced using a replenishment strategy, compared to styles sourced with a traditional strategy. The results suggest that the replenishment strategy helps move merchandise more effectively. The authors conclude that apparel suppliers with replenishment capabilities have much to offer their retail customers (King and Maddalena, 1999).

King and Moon (1999) employed the Sourcing Simulator™ to analyze different replenishment strategies for a vertically integrated manufacturer who had recently expanded their operations along the textile and apparel supply chain. By systematically changing simulation parameters relevant to the manufacturer, including initial inventory shipment quantities, number of reorder and frequency, lead times and costs associated with different raw material stocking policies, the users were able to obtain performance metric outputs for each scenario. The performance metrics detail retailer (brand) performance, as well as manufacturer performance, including gross margins, service levels, and on-time shipments, among others.

Lisa Hartman (2005) employed the Sourcing Simulator™ software system for an exhaustive analysis of several sourcing scenarios. Hartman focused on how supply chain speed in sourcing impacted retail performance. In her study, she analyzed the performance of a great number of sourcing strategies for basic goods.

For basic goods, she designed numerous sourcing scenarios by changing supplier lead times, demand patterns, forecast error, and demand drift. For each of the combinations possible, Hartman determined the lowest possible levels of initial weeks of inventory and reorder target weeks of supply needed to yield a given target service level at retail. Performance metrics were collected (e.g. related to inventory levels, service levels, ROI, etc.) once the optimal solution was found for each scenario.

By analyzing the inventory levels required for each scenario, Hartman was able to make several inferences on sourcing strategies performance. Her analysis identified many instances where retailers can work with shorter lead time suppliers and afford to pay higher wholesale prices to those suppliers (up to a given percentage), without seeing their performance suffer (Hartman, 2006). Similarly, retailers can improve their performance by sourcing the same product at the same price from shorter lead time suppliers. This decreased the amounts of inventory within the supply chain and decreased inventory holding costs, obsolescence, and markdowns, among other performance improvements.

3 Methodology

The review of literature showed there is a need for additional costing tools for a largely international textile and apparel supply chain complex. The initial objective of the research project is to develop a cost model for sourcing apparel products. Seasonal as well as basic apparel items produced in different supply chain routes where products could be sourced are included in the study. A list of yarn-forward cost categories will be developed and collected. Once the cost model has been completed, costs associated to specific products from each supply chain route will be fed to simulation scenarios in the Sourcing Simulator™. Analyses on supply chain impacts on retail performance will then be performed.

3.1 Product Selection

The product categories selected for the study are products that are sourced from a large base of textile and apparel producing countries. The product categories will be selected based on trade data from OTEXA (Office of Textile and Apparel, 2008); specifically on major U.S. imports. Multi-Fiber Arrangement (MFA) categories were analyzed, along with Harmonized Tariff Schedule (HTS) subcategories. HTS products are more specific categories compared to MFA categories, but they can include basic goods as well as seasonal or fashion. The products eventually selected for the study included denim bottoms and knit tops. As mentioned previously, these products are sourced from all over the world including many Far East and Western Hemisphere countries. The wide sourcing base provides for a variety of scenarios with a set of diverse costs and lead times.

3.2 Supply Chain Routes

The following supply chains will be analyzed in the research project.

1. U.S. Yarn → U.S. Fabric → U.S. Cut/Sew/Finishing → U.S. Retail
2. U.S. Yarn → U.S./CAFTA-DR Fabric → CAFTA-DR Cut/Sew/Finishing → U.S. Retail
3. U.S. Yarn → U.S./ANDEAN Fabric → ANDEAN Cut/Sew/Finishing → U.S. Retail
4. China Yarn → China Fabric → China Cut/Sew/Finishing → U.S. Retail
5. China Yarn → China Fabric → Vietnam Cut/Sew/Finishing → U.S. Retail
6. India Yarn → India Fabric → India Cut/Sew/Finishing → U.S. Retail

3.3 Landed Cost Components

To compare the various supply chains, landed costs of the goods needs to be established. Cost analysis will begin from fiber input costs through inbound U.S. logistics. The major cost components to that will be included in the cost model for the two products and the different supply chain regions/routes are:

- Fabric, trim and other raw material inputs,

- textile wet processing,
- cutting and sewing operational activities and their related labor costs,
- finishing (denim washing, floor-ready packing, etc.),
- raw material outbound logistics,
- port of export charges,
- U.S. rates of duty, and
- inbound logistics.

3.4 Sourcing Simulator™

Once the costing model and data collection for the different supply chains are complete, the data will be used to drive scenarios for the Sourcing Simulator™. The simulations will give information on how the different supply chains affect overall retail performance. The final retail performance outputs will determine the sourcing recommendations.

4 Sourcing Cost Model

The cost model developed in this study focuses on direct costs in relation to where a product is made. The model is different from others in that it goes further into detail, encompasses supply chain costs from fiber to end-consumer, and provides comparisons of multiple countries for sourcing apparel goods, while being relevant to the textile, apparel, and retail supply chain. The cost model helps identify the overall makeup of costs for the procurement of goods. The breakdown of the many cost elements allows for an improved appreciation of the importance of each element. All of the cost data and related cost calculations have been entered into a spreadsheet for interested parties.

The cost model literature available provides insight into large scale costs of doing business. These models, such as Full Value Costing (Birnbaum, 2000), list cost components which can be difficult to quantify, including the costs of doing business in specific countries and supporting services related to the development of new products. Other literature sources focus on specific industries and provide a list of broad operational cost drivers related to that industry. The level of detail in the literature is limited and little information is available on international supply chains and their respective cost implications.

4.1 The Textile, Apparel, and Retail Supply Chain

By definition, a supply chain is the system which connects end consumers with raw materials via many value added transformations. A supply chain does not end with goods being delivered at a company's warehouse or store, but instead at the moment of sale to the end consumer. This seemingly simple concept is very important to the cost model developed within this study. The health of an entire supply chain is heavily impacted by the final link in which the end consumer interacts with retail, as retail can incur significant profitability erosion due to markdowns. As previously mentioned in the sourcing practices literature review, markdowns can result in part due to sourcing from suppliers with lengthy lead times.

Two products were analyzed in this study, including knit t-shirts and denim jeans. The supply chain for a t-shirt, in simplified terms, begins with fiber being spun into yarn, followed by yarn being knit into fabric. The fabric is subsequently dyed and finished for further apparel conversion steps. The apparel operations begin with the cutting room, and end with sewing and packaging operations. Denim jeans follow a similar route, except that dyeing is performed in the yarn form compared to knits which are typically dyed in fabric form. Denim jeans also have additional processing after sewing and before packaging. In garment form, jeans are subject to different sanding and grinding operations, called dry processing, to achieve worn-out looks. This operation is followed by garment washing steps with desizing agents, surfactants, enzymes, and softeners that give the jean desired hand and visual properties. Figure 4.1 illustrates a typical apparel supply chain for the production of a t-shirt, while Figure 4.2 shows a denim bottoms supply chain. Costing of the two products will be carried out throughout this chapter. The following sections describe the core cost drivers of each sub-industry of the supply chain.

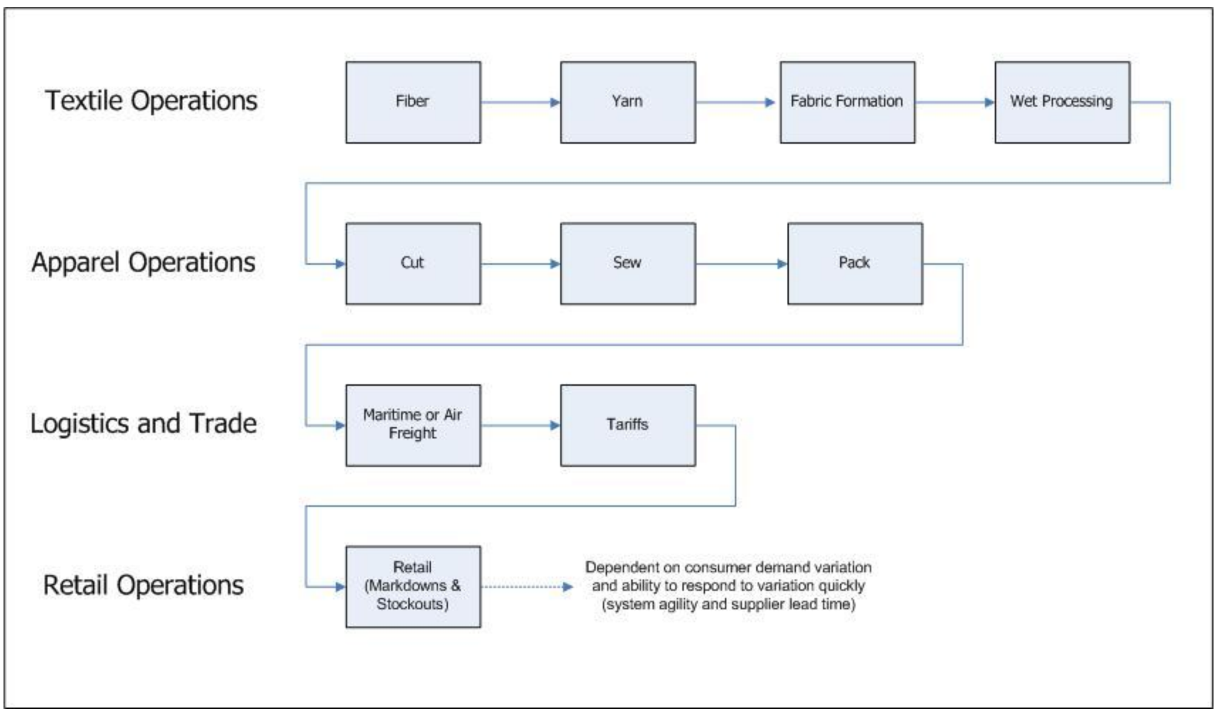

Figure 4.1 - Textile, Apparel, Retail Supply Chain for T-Shirts

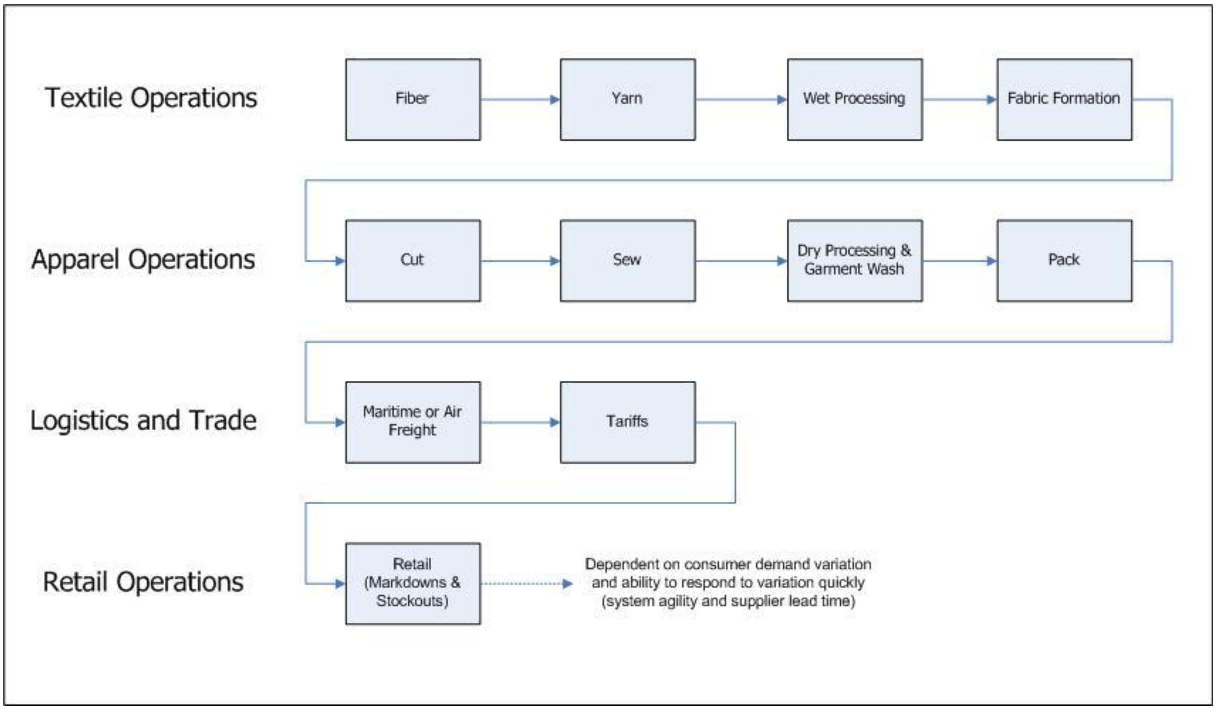

Figure 4.2 - Textile, Apparel, Retail Supply Chain for Denim Bottoms

4.2 Manufacturing Inputs

The distinct operations along the supply chain have very unique processes and resource consumption levels. Textile and apparel manufacturing however, share common resource requirements, including energy, labor, water and steam. The following sections illustrate where information can be obtained for these resources for different countries.

4.2.1 Labor

The most comprehensive publisher of labor wages is the International Labor Office, a branch of the United Nations. Their wages are reported by economic activity in manufacturing, or more generally by manufacturing industries as a whole. Rates for specific industries, including textiles and apparel, are limited in availability for certain countries. The ILO report has reporting gaps as not all countries have data reported for every time period or every economic activity (International Labor Organization, 2009).

Private companies, such as Werner International or Jassin-O'Rourke consulting firms, publish information as well. Their data is specifically related to the textile and apparel industries, respectively, and have no data gaps for key producing countries. The reliability of accuracy and coverage of both organizations' data are highly rated, as the United States International Trade Commission has published studies on competitiveness in the apparel and textile sector using labor rates from both Jassin-O'Rourke and Werner International (United States International Trade Commission, 2004). The labor costs for apparel manufacturing were taken from the 2008 report by Jassin-O'Rourke Group (O'Rourke, 2008), while the labor rates for the United States were taken from ITMF's IPCC 2008 report as illustrated by Table 4.1.

Table 4.1 - Fully Loaded Hourly Labor Rates

	$/hr	Source
China	1.08	O'Rourke
Colombia	1.42	O'Rourke
Guatemala	1.65	O'Rourke
India	0.51	O'Rourke
United States	14.10	ITMF IPCC 2008
Vietnam	0.38	O'Rourke

4.2.2 Energy

Information on energy rates is readily available for Organization of Economic Cooperation and Development (OECD) states. The International Energy Agency publishes a great amount of reports related to all energy industries, including electricity prices for industrial consumption. Data for developing countries, which are often major participants of the apparel industry, is available in a much more fragmented manner. Information on Latin America can be obtained through the Latin American Energy Organization, OLADE (Segura, 2008). Information was also gathered through online newspaper articles on industrial energy costs (The Associated Press, 2008) and governmental agencies (ENEE, 2008). ITMF's IPCC report proved to be a valuable source of information for energy costs as well (ITMF, 2008). Electrical energy rates for all countries in this study are summarized in Table 4.2.

Table 4.2 - Electrical Energy Rates

	$/kWh	Source
China	0.1000	ITMF
Colombia	0.1070	OLADE
Guatemala	0.1600	ENEE
India	0.1120	ITMF
United States	0.0630	ITMF
Vietnam	0.0550	The Associated Press

Energy generation infrastructures vary significantly from country to country. Some countries have been myopic in their decisions and eventually become vulnerable to macroeconomic conditions. Some Central American countries have supported recent increases in demand for energy by adding thermal energy stations that run on residual fuel oils to their grid. As a consequence, those countries are now susceptible to surges in world oil prices, which can make their energy more expensive to produce.

Vietnam also seems to have issues with their energy markets. They have enjoyed relatively low energy rates recently through price controls executed by the government, but those prices will most likely increase. Vietnam needs to expand their energy supply and infrastructure to meet increased demand, but this market is keeping investors away. Unless the retail prices become favorable for energy suppliers, companies will not invest in power plant projects (The Associated Press, 2008). There are price increases scheduled for residential consumption, but this could spill over into industrial markets as well.

4.2.3 Water

Information on water rates was obtained from ITMF IPCC 2008 report, municipal water agencies (EPM, 2009), web resources (Look at Vietnam, 2009), as well as from operating data from companies with operations in the countries of interest. Information on water costs are found in Table 4.3.

Table 4.3 - Water Rates

	$\$/m^3$	$/ gal	Source
China	0.3600	0.0014	ITMF
Colombia	0.4099	0.0016	EPM
Guatemala	0.2496	0.0009	Industry data
India	0.3200	0.0012	ITMF
United States	0.3389	0.0013	Industry data
Vietnam	0.4588	0.0017	Look at Vietnam

4.2.4 Steam

The cost of steam was determined using calculations employed in a consulting project executed by Mr. Chris Moses (2006), as noted in Equation 4.1 using energy and residual fuel oil prices from Table 4.2 and Table 4.4, respectively. It is followed by an example calculation for steam generation costs in China. Table 4.5 shows the cost per pound and kilogram of steam generated in each country.

Table 4.4 - No. 6 Residual Fuel Oil Rates

	$/gal	Source
China	0.9648	Energy Information Administration
Colombia	1.1198	Energy Information Administration
Guatemala	1.1198	Energy Information Administration
India	0.9648	Energy Information Administration
United States	0.9079	Energy Information Administration
Vietnam	0.9648	Energy Information Administration

Equation 4.1 – Cost of Steam in $ per kilogram of steam

$$\frac{\$}{kg_{steam}}$$

$$= \left(\frac{Enthalpy_{steam}}{Heat\ Combustion_{No.6\ Fuel\ Oil}}\ x\ \frac{1}{Heating\ Efficiency_{Boiler}}\ x\ \frac{\$}{gln_{No.6\ Fuel\ Oil}}\right)$$

$$+ \left(\frac{Power\ Use_{Boiler}}{Steam\ Throughput_{Boiler}}\ x\ \frac{\$}{kWh}\right)$$

$$Ex.)\ \frac{\$}{kg_{steam}} = \left(\frac{2326000\,\frac{J}{kg}}{159600000\,\frac{J}{gln}}\ x\ \frac{1}{0.833}\ x\ \frac{\$0.9648}{gln}\right) + \left(\frac{100\ kWh}{4650\ kg}\ x\ \frac{\$0.1000}{kWh}\right)$$

$$= \frac{\$0.0190}{kg_{steam}}$$

Table 4.5 - Steam Rates

	$/kg	$/lb
China	0.0190	0.0086
Colombia	0.0219	0.0099
Guatemala	0.0230	0.0104
India	0.0193	0.0087
United States	0.0172	0.0078
Vietnam	0.0181	0.0082

4.3 Textile Operations

The textile industry requires large investments in facilities, equipment, and machinery. Reports and analyses have shown capital related expenses can represent as much as thirty seven percent of United States ring spinning manufacturing costs, excluding raw material costs, and as much as twenty three percent of costs when raw materials are taken into account (International Textile Manufacturers Federation, 2008). Other textile operations, such as knitting and weaving follow similar trends in capital intensity. Despite the capital intensiveness of the textile industry and its role as a barrier to entry, textile operations can be found in developed and developing countries as well. Some countries have textile infrastructures and market participation to lesser degrees, but it is clear that textile operations have participants from all parts of the world.

4.3.1 International Production Cost Comparison

Given the international landscape of textiles, it is important to understand the strengths and limitations of key players. One of the associations related to the textile industry is the International Textile Manufacturers Federation (ITMF). The Zurich-based organization aims to serve as an international association for the world's textile industries. One of its many efforts is to disseminate information to its membership. ITMF has been a leader in publishing reports which compare textile operating costs of leading textile producing nations.

ITMF began publishing the International Production Cost Comparison (IPCC) report in 1979. The publication seeks to enable understanding of the capital intensity of the textile industry and to provide a detailed review of all manufacturing costs. The study, developed through cooperation with original equipment manufacturers (OEMs), individual textile companies, and several countries' textile associations, breaks down the major manufacturing costs and total product costs of major operations. The areas of textile operations included in the report are spinning, texturing, knitting, and weaving. ITMF's publication provides key textile cost data used as a base for inputting fabric raw material costs to the sourcing cost model developed in the research.

The IPCC report establishes baselines and assumptions in order to calculate costs. It assumes that all companies use the latest technology and equipment available, and that all companies have a common plant size, equipment, and layout. It is important to consider the assumptions, as this makes a portion of the cost component calculations, such as machinery depreciation, irrelevant to companies which use outdated and second hand machinery. Its scope of costs is limited to direct manufacturing costs and does not include sales incentive offers, transportation, insurance, and other similar costs. The study does not take into account service levels or broader business strategy as factors for competitiveness. In summary, it includes direct costs of manufacturing exclusively.

The countries included in the study are Egypt, Brazil, Italy, Korea, Turkey, China, India, and the United States, with the latter three countries being of most relevance and importance to the sourcing cost model research. The study assumes that output is the same for all countries, and compensates for this by varying the amount of labor required in each country to obtain the established output levels. Although the report does not analyze a vast range of yarn counts and types, woven or knitted fabric weights, the report does provide a vast amount of information on common product types. Albeit limited in product scope, the structure of the cost data can be used as a base to scale for cost approximations of similar fabrics. Each manufacturing process cost is apportioned into waste, labor, power, auxiliary materials, capital, packing (in texturing), and raw materials. By taking average currency exchange rates of the first quarter of 2008, costs are presented in US Dollars.

4.3.1.1 Spinning

Spinning operations are subject to several cost factors, but the prices of cotton are the main driver for 100% cotton yarns. They can easily represent forty percent of total yarn costs, as detailed in the next few paragraphs. Figure 4.3 lists the prices of cotton of each country within the IPCC report. The prices of cotton staple used for raw material costs in spinning are those prevalent during the last week of May 2008.

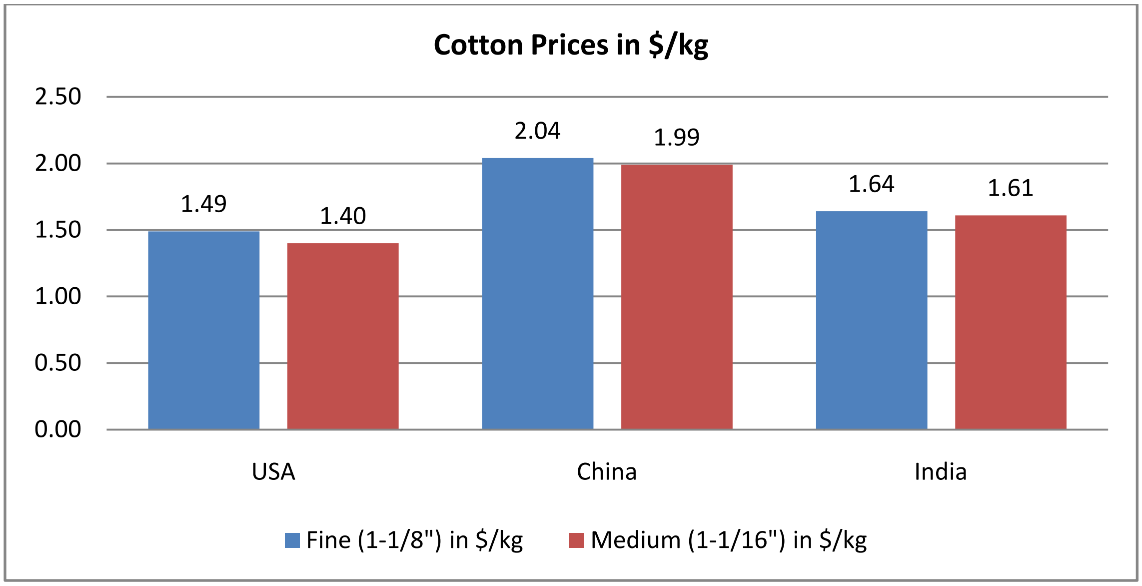

Figure 4.3 - Cotton Prices (ITMF, 2008)

There are two types of yarns included in the IPCC report. The first yarn analyzed is a combed ring spun yarn, Ne 30, using 1-1/8 inch cotton staple. The areas of operation analyzed include winding and assume a rate of output of 400 kilograms per hour on Rieter equipment. The second yarn analyzed is a carded open-end spun yarn, Ne 20, using 1-1/16 inch cotton staple. The output rate is the same 400 kilograms per hour on Rieter equipment as well. Table 4.6 and Figure 4.4 show the manufacturing costs related to the production of ring spun yarn, while Table 4.7 and Figure 4.5 illustrate total product cost including raw material costs. The manufacturing costs of rotor spun yarn can be seen in Table 4.8 and Figure 4.6, while the total product cost including raw material is shown in Table 4.9 and Figure 4.7.

Table 4.6 - Ring Yarn Manufacturing Costs in $/kg (adapted from ITMF, 2008)

	USA	China	India
Waste	0.240	0.328	0.263
Labor	0.503	0.033	0.043
Power	0.216	0.343	0.384
Auxiliary Material	0.132	0.118	0.118
Depreciation	0.470	0.364	0.354
Interest	0.173	0.113	0.155
TOTAL (USD per kg of yarn)	1.734	1.299	1.317

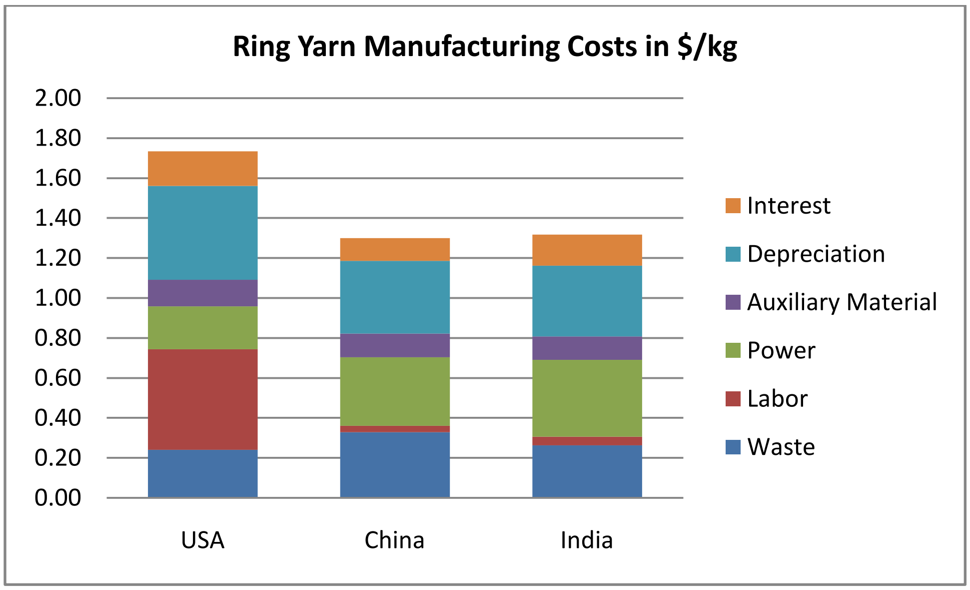

Figure 4.4 - Ring Yarn Manufacturing Costs in $/kg (adapted from ITMF, 2008)

Table 4.7 - Ring Yarn Total Cost in $/kg (adapted from ITMF, 2008)

	USA	China	India
Waste	0.240	0.328	0.263
Labor	0.503	0.033	0.043
Power	0.216	0.343	0.384
Auxiliary Material	0.132	0.118	0.118
Depreciation	0.470	0.364	0.354
Interest	0.173	0.113	0.155
Raw Material	1.490	2.040	1.640
TOTAL (USD per kg of yarn)	3.224	3.339	2.957

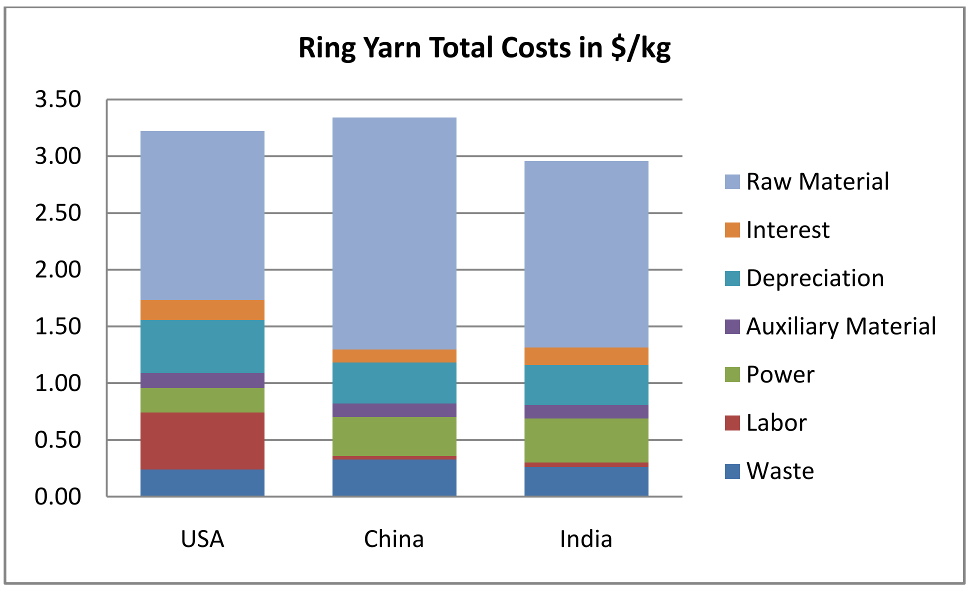

Figure 4.5 - Ring Yarn Total Costs in $/kg (adapted from ITMF, 2008)

Table 4.8 - Open-End Yarn Manufacturing Costs in $/kg (adapted from ITMF, 2008)

	USA	China	India
Waste	0.105	0.148	0.121
Labor	0.120	0.008	0.010
Power	0.090	0.142	0.159
Auxiliary Material	0.090	0.084	0.084
Depreciation	0.195	0.150	0.147
Interest	0.075	0.046	0.063
TOTAL (USD per kg of yarn)	0.675	0.578	0.584

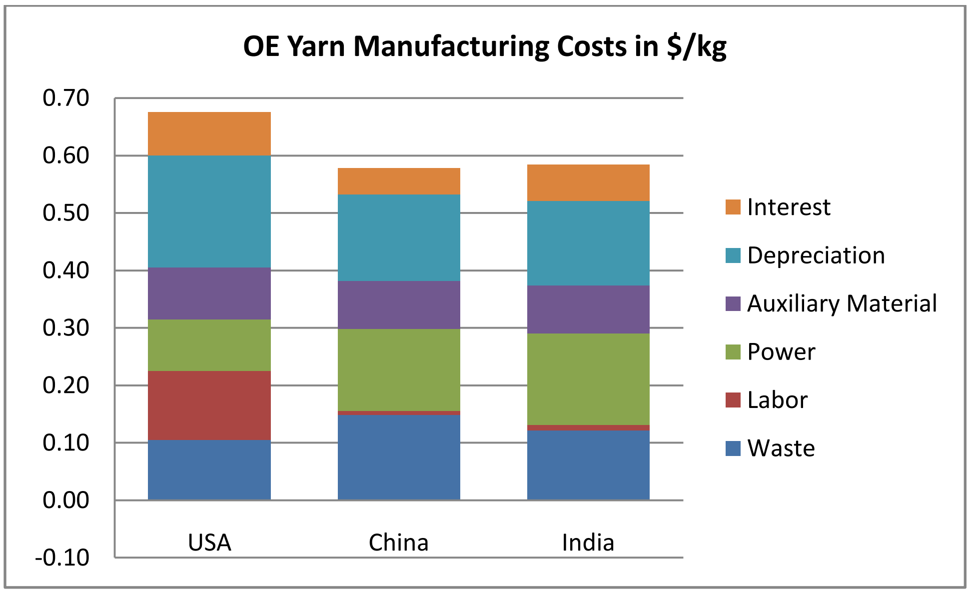

Figure 4.6 – Open-End Yarn Manufacturing Costs in $/kg (adapted from ITMF, 2008)

Table 4.9 - Open-End Yarn Total Costs in $/kg (adapted from ITMF, 2008)

	USA	China	India
Waste	0.105	0.148	0.121
Labor	0.120	0.008	0.010
Power	0.090	0.142	0.159
Auxiliary Material	0.090	0.084	0.084
Depreciation	0.195	0.150	0.147
Interest	0.075	0.046	0.063
Raw Material	1.400	1.990	1.610
TOTAL (USD per kg of yarn)	2.075	2.568	2.194

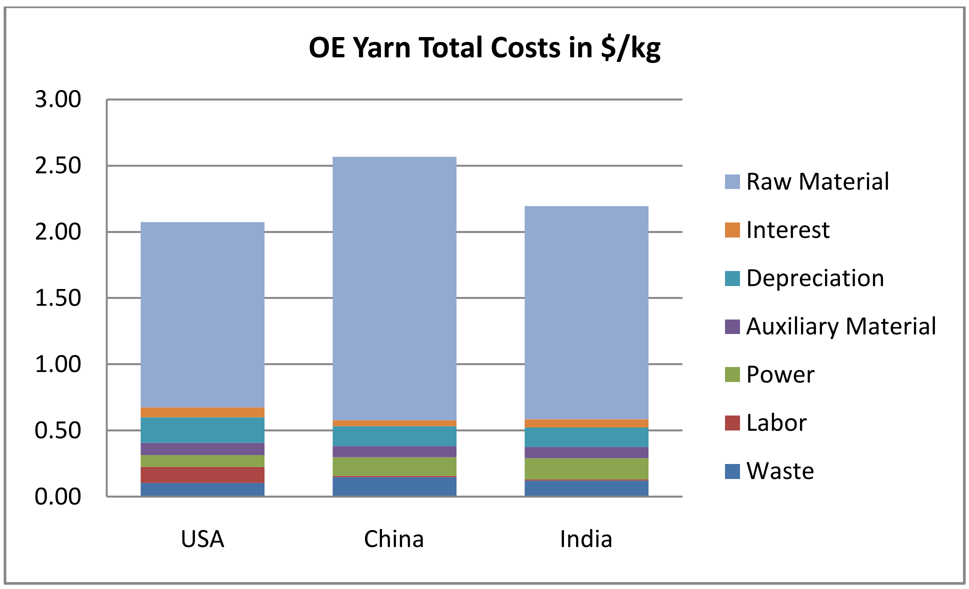

Figure 4.7 – Open-End Yarn Total Costs in $/kg (adapted from ITMF, 2008)

4.3.1.2 Knitting

ITMF's International Production Country Cost report covers three knitted fabric structures: single jersey, lapique, and interlock. The single jersey fabric, which is relevant to this cost model, is knitted with 100% cotton, combed, Ne 30, ring spun yarn. The fabric has a weight of 230 grams per meter and an open-width of 1.92 meters and is manufactured on Karl Mayer Relanit 3.2 II knitting machines, with 30 inch diameter, 24 gauge, and 96 feeders with side creel. The cost calculations are based on a mill with seventeen machines with an output per machine of 25.3 kilograms per hour. Table 4.10 and Figure 4.8 provide a detail of the costs of producing the knitted fabric, while Table 4.11 and Figure 4.9 include raw material costs of Ne 30 CPRS yarn as shown in Table 4.7.

Table 4.10 - Single Jersey Knitting Manufacturing Costs in $/m (adapted from ITMF, 2008)

	USA	China	India
Labor	0.025	0.001	0.002
Power	0.003	0.005	0.005
Auxiliary Material	0.007	0.006	0.006
Depreciation	0.011	0.012	0.009
Interest	0.004	0.003	0.003
TOTAL (USD per m of fabric)	0.050	0.027	0.025

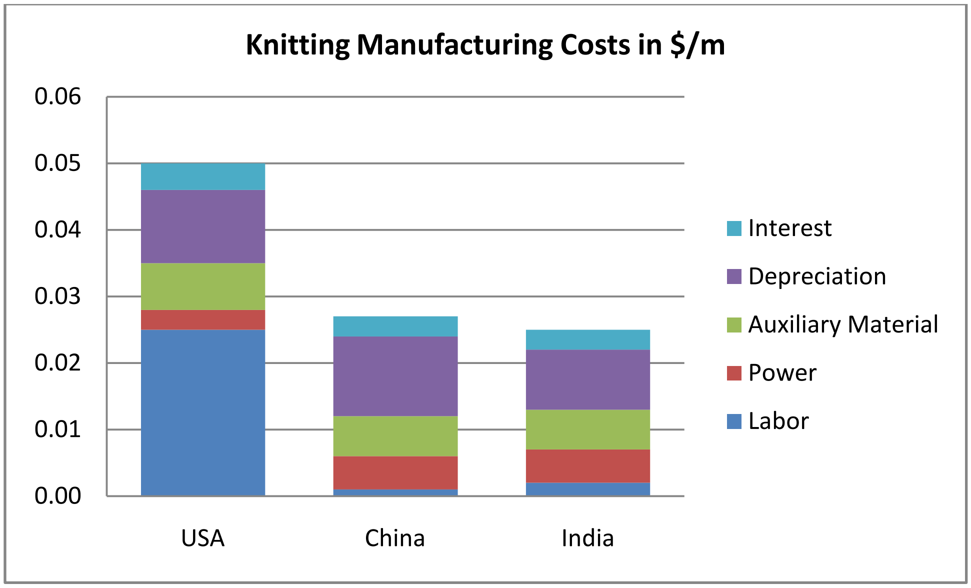

Figure 4.8 – Single Jersey Knitting Manufacturing Costs in $/m (adapted from ITMF, 2008)

Table 4.11 - Single Jersey Fabric Total Costs in $/m (adapted from ITMF, 2008)

	USA	China	India
Labor	0.025	0.001	0.002
Power	0.003	0.005	0.005
Auxiliary Material	0.007	0.006	0.006
Depreciation	0.011	0.012	0.009
Interest	0.004	0.003	0.003
Raw Material (CPRS Ne 30 Yarn)	0.742	0.768	0.680
TOTAL (USD per m of fabric)	0.792	0.795	0.705

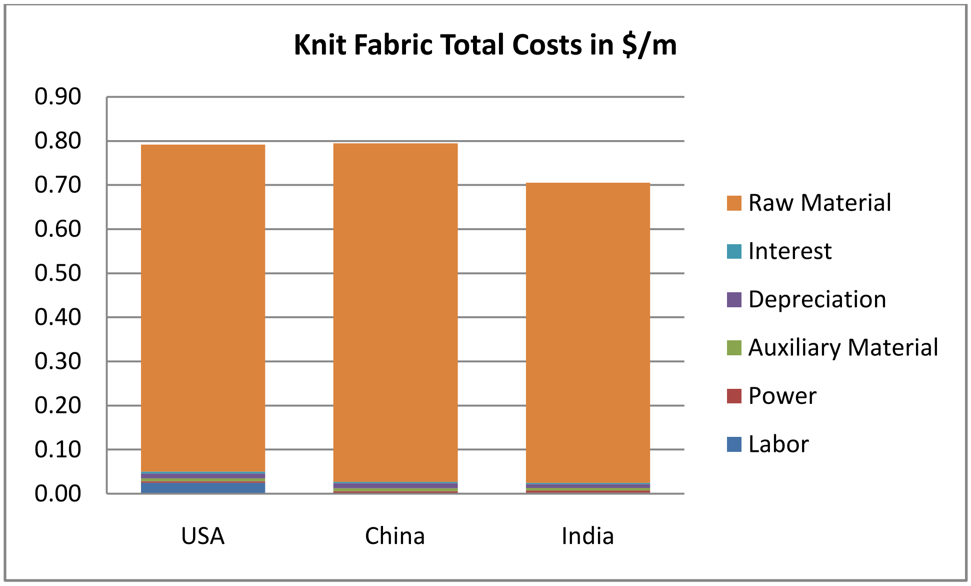

Figure 4.9 - Single Jersey Fabric Total Costs in $/m (adapted from ITMF, 2008)

The information and cost structure found in Table 4.11 was taken as a base for calculating knitted fabric costs for countries not included in the ITMF report, including Guatemala, Vietnam and Colombia. Raw material costs for Guatemala and Colombia were set equal to US yarn cost plus maritime transportation costs to the respective country. Vietnam's raw material costs were set to China's yarn costs plus maritime transportation costs from China. Container shipping rates were obtained through Seaboard Marine (2008) and Orient Overseas Container Line (2008). Consultation with yarn manufacturers exporting their products provided container stuffing data. For yarn shipping cost calculations, it was assumed that up to 16,646.84 kilograms of yarn can be shipped in a forty foot container and that a 1.87% insurance charge is applied to the cost of yarn. Equation 4.2 accounts for raw material cost calculations for non-ITMF countries including the cost of shipping yarn, followed by an example calculation for using yarn shipped from the US to Guatemala, using the shipping rates shown in Table 4.12.

Table 4.12 - Forty-foot Container Shipping Rates

	$/40ft
US to Colombia	3660
US to Guatemala	2851
China to Vietnam	1788

Equation 4.2 – Cost of Yarn including Shipping Costs in $ per Meter of Knit Fabric

$$\frac{\$}{m_{fabric}} = \left(\frac{container}{kg_{yarn}} x \frac{\$}{container} x \frac{kg_{yarn}}{m_{fabric}}\right) + \left(\frac{\$_{yarn}}{kg} x \frac{kg_{yarn}}{m_{fabric}} x \left(1 + Insurance\ Rate_{shipping}\right)\right)$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \left(\frac{container}{16{,}646.84\ kg} x \frac{\$2851}{container} x \frac{0.2300\ kg}{m_{fabric}}\right) + \left(\frac{\$3.224}{kg} x \frac{0.2300\ kg}{m_{fabric}} x\ 1.0187\right) = \frac{\$0.7948}{m_{fabric}}$$

Auxiliary materials and capital costs (interest and depreciation) for countries not included in the ITMF report were assumed to be equal to the average of those for the US, China and India. The labor and power cost components were scaled against every ITMF country, using each country's labor and power rates, in dollars per hour and dollars per kWh, respectively. Guatemala, Vietnam, and Colombia were assigned values equal to the average of the scaled values against the United States, China, and India. The calculations for labor and power costs for non-ITMF countries can be calculated using Equation 4.3; labor costs for Colombia are shown as an example. Table 4.13, Figure 4.10, and Figure 4.11 show greige fabric costs for all countries.

Equation 4.3 – Cost Calculations for non-ITMF Countries

$$\frac{\$_{cost\ component}}{m} = \left(\sum \frac{labor\ rate_{non-ITMF\ country}}{labor\ rate_{ITMF\ country\ i}}\ x\ \frac{\$_{cost\ component}}{m_{ITMF\ country}}\right) \div 3\ , for\ all\ countries\ i$$

$$Ex.)\ \frac{\$_{labor\ Colombia}}{m} = \left[\left(\frac{\$1.42_{Colombia}}{\$1.08_{China}}\ x\ \frac{\$0.0010_{China}}{m}\right) + \left(\frac{\$1.42_{Colombia}}{\$0.51_{India}}\ x\ \frac{\$0.0020_{India}}{m}\right) + \left(\frac{\$1.42_{Colombia}}{\$14.10_{US}}\ x\ \frac{\$0.0250_{US}}{m}\right)\right] \div 3 = \frac{\$0.0031_{Colombia}}{m}$$

Table 4.13 - Greige Knit Fabric Costs in $/m for all Countries

	Labor	Power	Aux. Material	Capital	Raw Material	Greige Total
	$/m	$/m	$/m	$/m	$/m	$/m
China	0.0010	0.0050	0.0060	0.0150	0.7680	0.7950
Colombia	0.0031	0.0051	0.0063	0.0140	0.8060	0.8345
Guatemala	0.0036	0.0076	0.0063	0.0140	0.7948	0.8263
India	0.0020	0.0050	0.0060	0.0120	0.6801	0.7051
United States	0.0250	0.0030	0.0070	0.0150	0.7415	0.7915
Vietnam	0.0008	0.0026	0.0063	0.0140	0.8070	0.8308

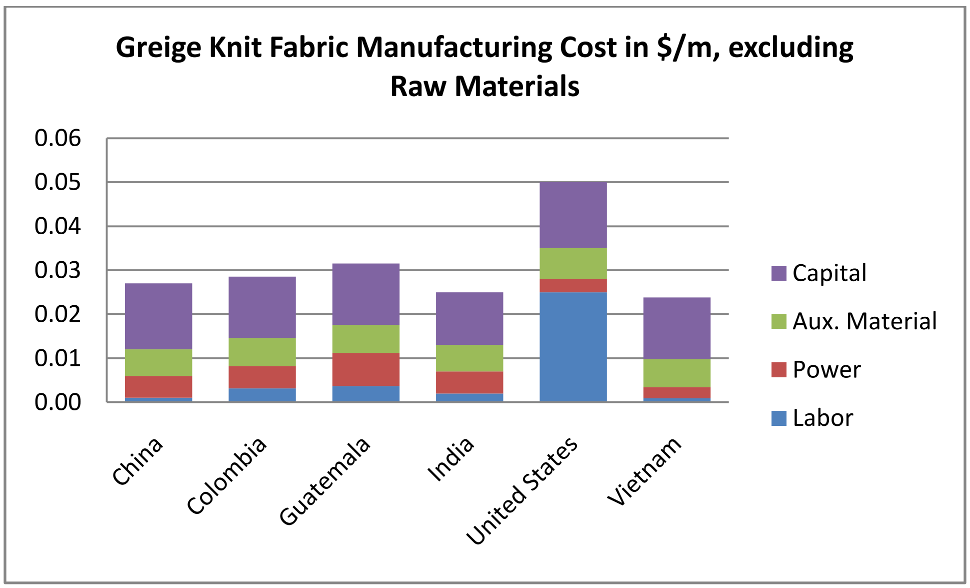

Figure 4.10 - Greige Knit Fabric Costs in $/m, excluding Raw Materials for ITMF and non-ITMF Countries

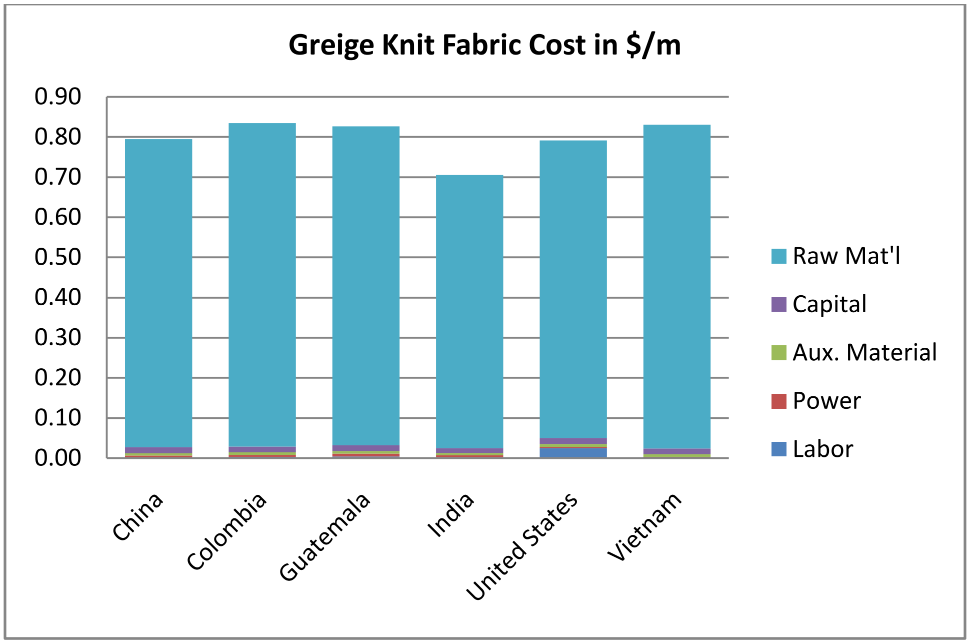

Figure 4.11 – Greige Knit Fabric Costs in $/m for ITMF and non-ITMF Countries

4.3.1.3 Weaving

The report covers three woven fabric structures, with the open-end cotton yarn fabrics being of most relevance to this cost model. The construction of the woven fabric using open-end yarn has a construction of 24.0/24.0 threads per centimeter, with a fabric width of 1.68 meters and 248 gram per meter greige fabric weight for equivalent weights 147.62 grams per square meter (or 4.35 oz/yard^2). The output per machine is 21.9 meters per hour. The calculations for producing the fabric are based on a mill with 72 Sultex B190 N2 EP11 air-jet weaving machines, and also accounts for expenses related to air conditioning, weaving preparation, cloth inspection, and material handling. Table 4.14 and Figure 4.12 document the manufacturing costs associated with producing the rotor yarn fabric, while Table 4.15 and Figure 4.13 also include raw material costs of Ne 20 KPOE yarn as shown in Table 4.9.

Table 4.14 - Weaving Manufacturing Costs in $/m (adapted from ITMF, 2008)

	USA	China	India
Waste	0.007	0.005	0.005
Labor	0.139	0.013	0.014
Power	0.035	0.073	0.082
Auxiliary Material	0.037	0.040	0.075
Depreciation	0.091	0.060	0.063
Interest	0.030	0.018	0.025
TOTAL (USD per m of fabric)	0.339	0.209	0.264

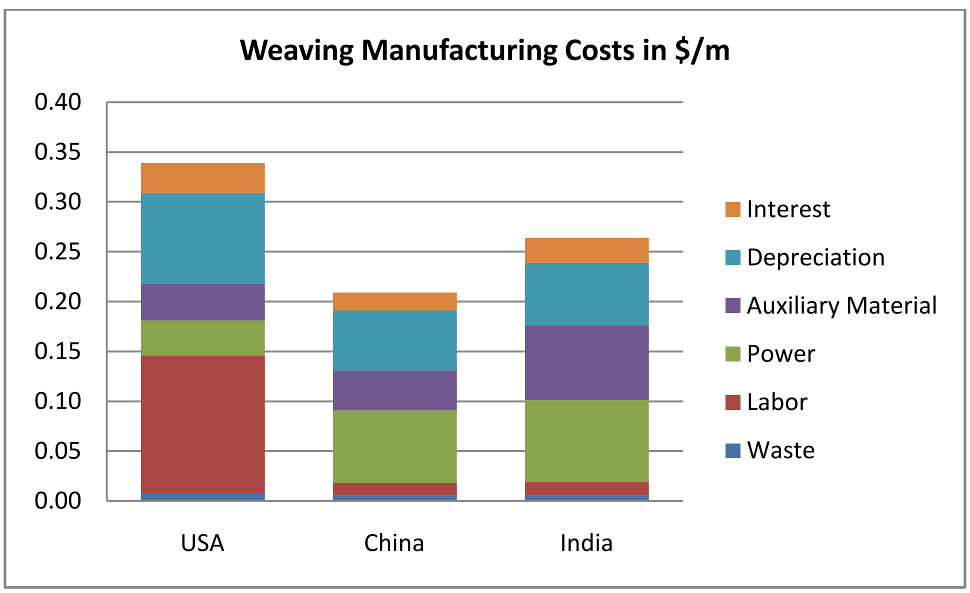

Figure 4.12 - Weaving Manufacturing Costs in $/m (adapted from ITMF, 2008)

Table 4.15 - Woven Fabric Total Costs in $/m (adapted from ITMF, 2008)

	USA	China	India
Waste	0.007	0.005	0.005
Labor	0.139	0.013	0.014
Power	0.035	0.073	0.082
Auxiliary Material	0.037	0.040	0.075
Depreciation	0.091	0.060	0.063
Interest	0.030	0.018	0.025
Raw Material (KPOE Ne 20 Yarn)	0.515	0.637	0.544
TOTAL (USD per m of fabric)	0.854	0.846	0.808

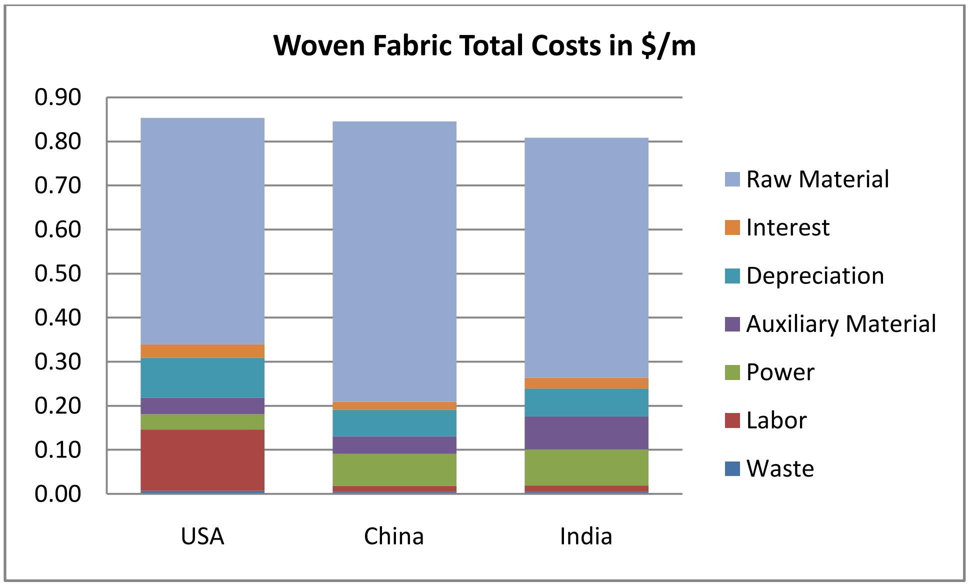

Figure 4.13 - Woven Fabric Total Costs in $/m (adapted from ITMF, 2008)

The yarn and woven fabric structures for basic denim bottoms differ from what is found in ITMF's IPCC 2008 report. Denim jeans require yarn counts that are significantly coarser than Ne 20 and use fabrics with weights heavier than 4.35 oz/yd^2. The basic denim jean included in this study has been assumed to have Ne 6 warp yarns and to have a fabric weight of 12.5 oz/yd^2 or 423.81 g/m^2.

Coarser yarns, such as Ne 6 KPOE yarn compared to Ne 20, will have lower rotor revolutions per minute but require less twist insertion as well, resulting in similar yarn production output rates. For this reason and that yarn costs in ITMF's IPCC 2008 report are presented by weight, which is dictated in its majority by cotton prices, Ne 6 yarn costs was assumed to be equal to the information in ITMF's report for KPOE Ne 20 yarn.

The fabric presented within ITMF's report is of significantly lighter weight compared to the fabric weight assumed, but this difference is accounted for by scaling the yarn raw material costs to reflect the heavier fabric construction. Nonetheless, the fabric width, pick density, pick insertion rate, and linear output of fabric rate are similar. Despite the incongruent product types, the information is the best available for this study and therefore is taken as a basis for denim product cost calculations. Equation 4.4 calculates the cost of raw materials for the heavier fabric weight using yarn costs as detailed in Table 4.9, which is followed by an example calculation for the USA respectively. Table 4.16 summarizes the adapted total fabric costs by substituting the new yarn cost.

Equation 4.4 – Yarn Cost per Meter of Woven Fabric

$$\frac{\$}{m_{fabric}} = \frac{kg}{m^2}\ x\ width_{fabric}\ x\ \frac{\$}{kg_{yarn}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{0.42381\ kg}{m^2}\ x\ 1.68\ m\ x\ \frac{\$2.075}{kg_{yarn}} = \frac{\$1.4774}{m_{fabric}}$$

Table 4.16 – Woven Denim-Weight Fabric Total Cost in $ per Meter of Fabric

	USA	China	India
Waste	0.007	0.005	0.005
Labor	0.139	0.013	0.014
Power	0.035	0.073	0.082
Auxiliary Material	0.037	0.040	0.075
Depreciation	0.091	0.060	0.063
Interest	0.030	0.018	0.025
Raw Material (KPOE Ne 6 Yarn)	1.4774	1.8284	1.5621
TOTAL (USD per m of fabric)	1.8164	2.0374	1.8261

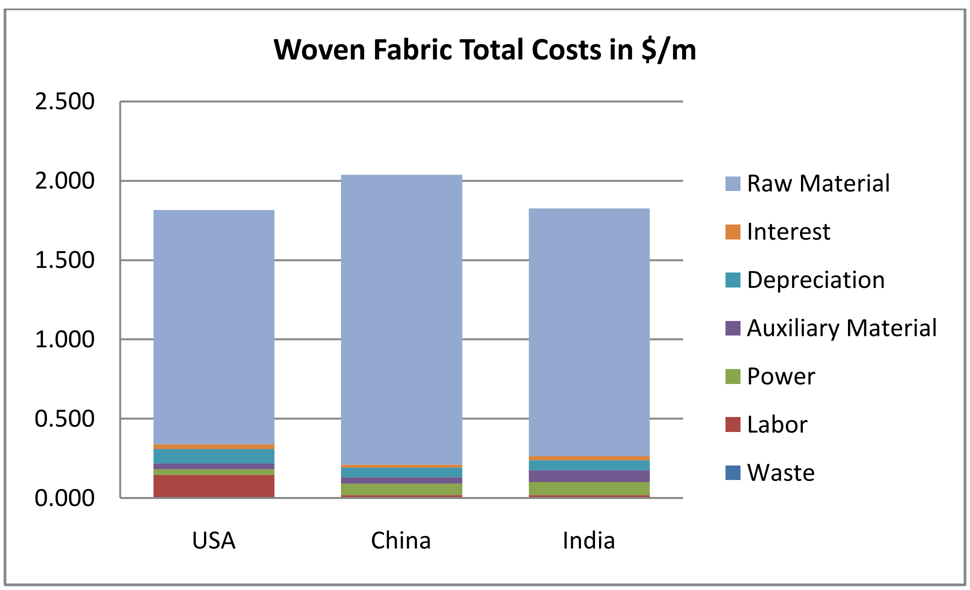

Figure 4.14 – Woven Denim-Weight Fabric Total Cost in $ per Meter of Fabric

The information and cost structure found in Table 4.16 was taken as a base for calculating woven fabric costs for countries not included in the ITMF report, including Guatemala, Vietnam and Colombia. Raw material costs for Guatemala and Colombia were set equal to US yarn cost plus maritime transportation costs, including a 1.87% insurance charge, to the respective country. Vietnam's raw material costs were set to China's yarn costs plus maritime transportation costs, also including a 1.87% insurance charge, from China. The example below uses Equation 4.2 to account for yarn raw material cost calculations for non-ITMF countries including the cost of shipping yarn, for using yarn shipped from the US to Guatemala, using the shipping rates shown in Table 4.12.

$$Ex.)\ \frac{\$}{m_{fabric}} = \left(\frac{container}{16{,}646.84\ kg}\ x\ \frac{\$2851}{container}\ x\ \frac{0.7120\ kg}{m_{fabric}}\right) + \left(\frac{\$2.075}{kg}\ x\ \frac{0.7120\ kg}{m_{fabric}}\ x\ 1.0187\right) = \frac{\$1.6270}{m_{fabric}}$$

Auxiliary materials and capital costs (interest and depreciation) for countries not included in the ITMF report were assumed to be equal to the average of those for the US, China and India. The labor and power cost components were scaled against every ITMF country, using each country's labor and power rates, in dollars per hour and dollars per kWh, respectively. Guatemala, Vietnam, and Colombia were assigned values equal to the average of the scaled values against the United States, China, and India. The calculations for labor and power costs for non-ITMF countries can be calculated using Equation 4.3; labor costs for Colombia are shown below as an example. Table 4.17, Figure 4.15, and Figure 4.16 show greige fabric costs for all countries.

$$Ex.)\ \frac{\$_{labor\ Colombia}}{m}$$

$$= \left[\left(\frac{\$1.42_{Colombia}}{\$1.08_{China}}\ x\,\frac{\$0.0130_{China}}{m}\right) + \left(\frac{\$1.42_{Colombia}}{\$0.51_{India}}\ x\,\frac{\$0.0140_{India}}{m}\right)\right.$$

$$\left. + \left(\frac{\$1.42_{Colombia}}{\$14.10_{US}}\ x\,\frac{\$0.1390_{US}}{m}\right)\right] \div 3 = \frac{\$0.0234_{Colombia}}{m}$$

Table 4.17 – Greige Woven Fabric Costs in $/m for all Countries

	Waste	Labor	Power	Aux. Material	Capital	Raw Mat'l	Greige Total
Country	$/m	$/m	$/m	$/m	$/m	$/m	$/m
China	0.0050	0.0130	0.0730	0.0400	0.0780	1.8284	2.0374
Colombia	0.0057	0.0234	0.0720	0.0507	0.0957	1.6616	1.9089
Guatemala	0.0057	0.0271	0.1076	0.0507	0.0957	1.6270	1.9137
India	0.0050	0.0140	0.0820	0.0750	0.0880	1.5621	1.8261
United States	0.0070	0.1390	0.0350	0.0370	0.1210	1.4774	1.8164
Vietnam	0.0057	0.0063	0.0370	0.0507	0.0957	1.9391	2.1343

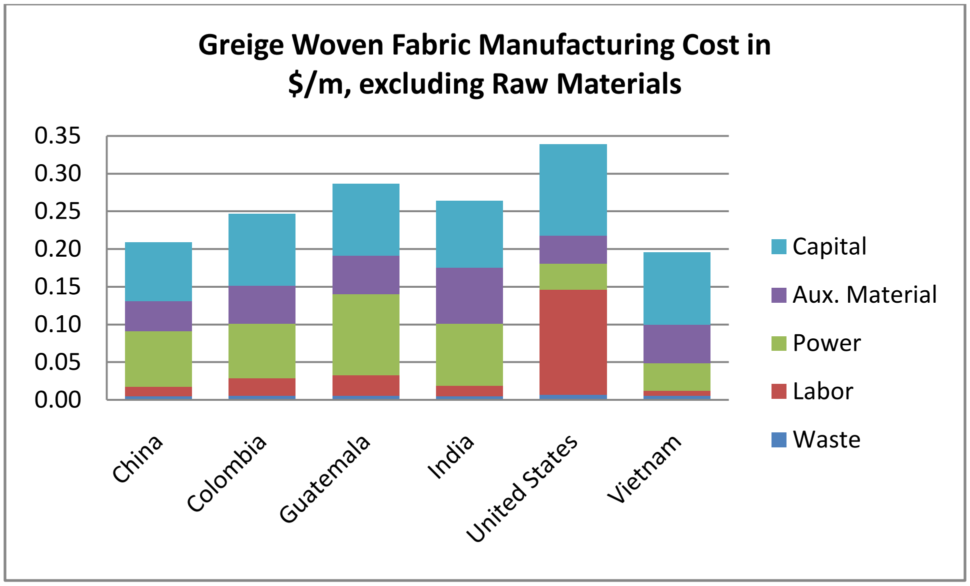

Figure 4.15 – Greige Woven Fabric Costs in $/m, excluding Raw Materials for ITMF and non-ITMF Countries

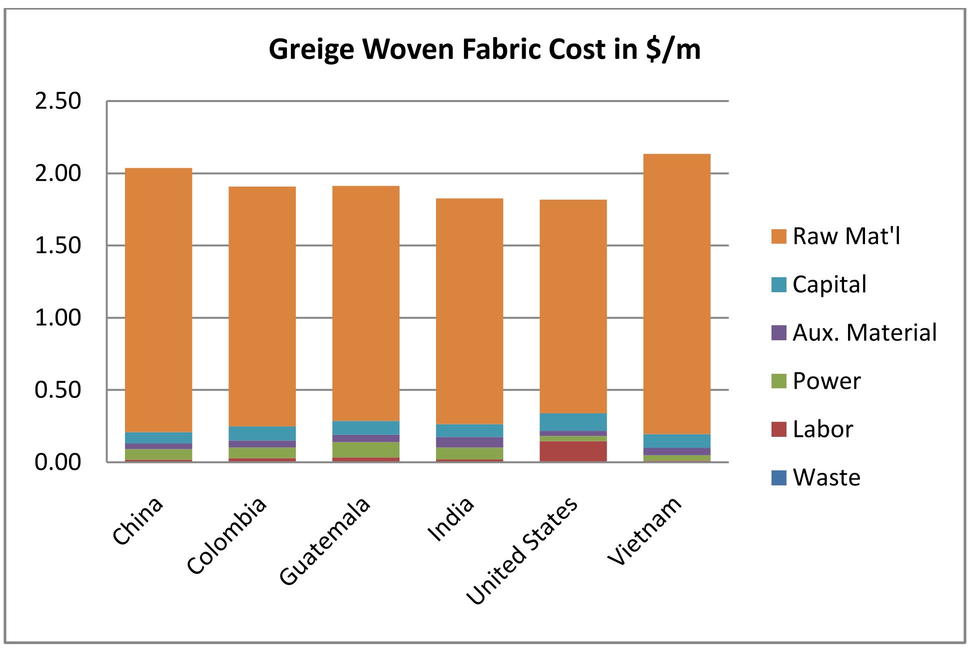

Figure 4.16 – Greige Woven Fabric Costs in $/m for ITMF and non-ITMF Countries

4.3.2 Wet Processing

The wet processing stage of textile operations is characterized by a costly consumption of resources. Dyeing and finishing machinery manufacturer executive Bill Fong, of Fong's Industries Co. Ltd., supplied water consumption data at a recent industry exposition. According to the data presented, the average kilogram of finished fabric can require between 100 and 150 liters of water to be processed (Rupp, 2008). Information supplied by original equipment manufacturers for this study indicate that technology currently available deviates significantly from the previous statistic, as much less water is consumed per kilogram of fabric according to their specifications.

Energy consumption in this stage is considerably high as well. Finishing can account for as much as fifty nine percent of energy consumption from yarn spinning to the finished garment stage. Benchmark data illustrates finishing operations consume 17.9 kWh per kilogram, compared to 1.2 and 6.2 kWh for knitting and weaving, respectively (Stegmaier, 2007). Figure 4.17 details energy consumption along the textile supply chain of a 300-gram cotton shirt made of Ne 45 combed ring spun yarn, with air jet woven fabric (75 g/m^2).

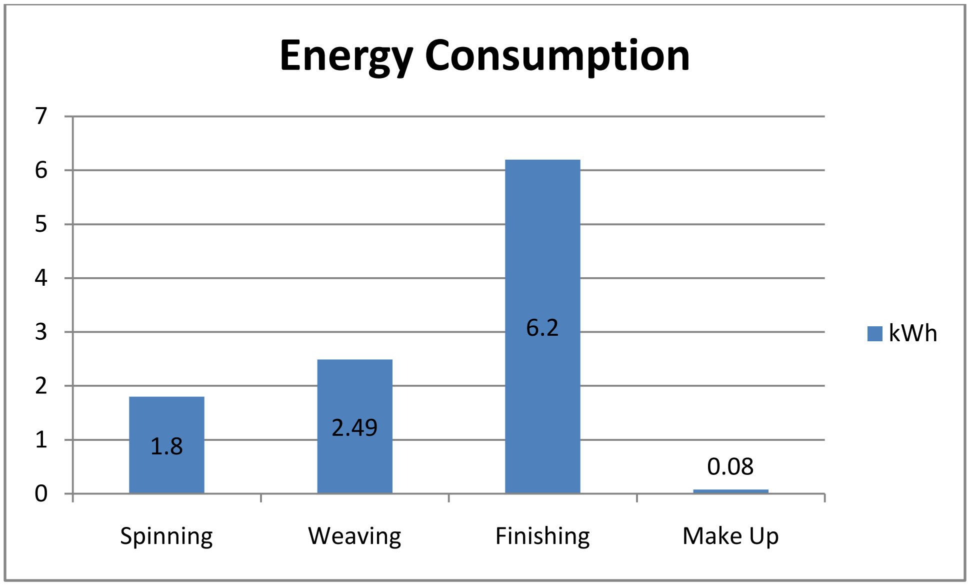

Figure 4.17 - Energy Consumption for a Cotton Shirt (adapted from Stegmaier, 2007)

4.3.2.1 Wet Processing for Knits – Piece Dyeing

Sources of information for wet processing costs were made possible by original equipment manufacturers. Gaston County Dyeing Machine Company provided piece dyeing operating data including labor, chemical, dyes, water, steam, and electric consumption rates for a typical plant setup (Davis, 2009). Information was provided for scouring and dyeing 100% cotton piece goods with a dark shade. The costs are related to processing the fabric on a 2-strand Millennium Dyeing Machine with Charge Tank using reactive dyes. The analysis was setup assuming a 1000 pound load, 4.78-hour cycle time, at 90 percent efficiency for an output of 188 pounds of fabric per hour. Table 4.18 illustrates the resource consumption rates per pound for the given production setup, while Equation 4.5 through Equation 4.9 show cost calculation formulas, followed by an example calculation based on operating in China. Table 4.19, Figure 4.18, and Figure 4.19 summarize dyeing costs for all countries included in the study.

Table 4.18 - Resource Consumption Rates per Pound of Knit Fabric for Piece Dyeing

Component	Unit	Qty
Labor	hour	1/3 x 1/188
Auxiliary Chemical	$	0.0874
Dyes	$	0.6818
Water	gallon	4.8
Steam	lb	2.13
Energy	kWh	0.0853

Equation 4.5 – Labor Cost for Piece Dyeing in $ per Pound of Knit Fabric

$$\frac{\$}{lb_{fabric}} = \frac{\$}{hr}\ x\ \frac{operator}{machine}\ x\ \frac{hr}{lbs_{output}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{\$1.08}{hr}\ x\ \frac{1}{3}\ x\ \frac{hr}{188\ lbs} = \frac{\$0.0019}{lb_{fabric}}$$

Equation 4.6 – Energy Cost for Piece Dyeing in $ per Pound of Knit Fabric

$$\frac{\$}{lb_{fabric}} = \frac{kWh}{lb_{fabric}}\, x\, \frac{\$}{kWh}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{0.0853\ kWh}{lb_{fabric}}\, x\, \frac{\$0.1000}{kWh} = \frac{\$0.0085}{lb_{fabric}}$$

Equation 4.7 – Steam Cost for Piece Dyeing in $ per Pound of Knit Fabric

$$\frac{\$}{lb_{fabric}} = \frac{lb_{steam}}{lb_{fabric}}\ x\ \frac{\$}{lb_{steam}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{2.13\ lb_{steam}}{lb_{fabric}} x \frac{\$0.0086}{lb_{steam}} = \frac{\$0.0184}{lb_{fabric}}$$

Equation 4.8 – Water Cost for Piece Dyeing in $ per Pound of Knit Fabric

$$\frac{\$}{lb_{fabric}} = \frac{gln_{water}}{lb_{fabric}} x \frac{\$}{gln_{water}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{4.8\ gln_{water}}{lb_{fabric}}\ x \frac{\$0.0014}{gln_{water}} = \frac{\$0.0065}{lb_{fabric}}$$

Equation 4.9 – Chemical and Dye Cost for Piece Dyeing in $ per Pound of Knit Fabric

$$\frac{\$}{lb_{fabric}} = \frac{\$_{chemicals}}{lb_{fabric}} + \frac{\$_{dyes}}{lb_{fabric}}$$

$$Ex.)\frac{\$}{lb_{fabric}} = \frac{\$0.0874}{lb_{fabric}} + \frac{\$0.6818}{lb_{fabric}} = \frac{\$0.7692}{lb_{fabric}}$$

Table 4.19 - Piece Dyeing Costs in $/lb and $/m of Knit Fabric

	Labor	Energy	Steam	Water	Dyes & Chem	TOTAL	
						$/lb	$/m
China	0.0019	0.0085	0.0184	0.0065	0.7692	0.8046	0.4080
Colombia	0.0025	0.0091	0.0212	0.0074	0.7692	0.8094	0.4104
Guatemala	0.0029	0.0136	0.0223	0.0045	0.7692	0.8125	0.4120
India	0.0009	0.0096	0.0186	0.0058	0.7692	0.8041	0.4077
United States	0.0250	0.0054	0.0167	0.0062	0.7692	0.8224	0.4170
Vietnam	0.0007	0.0047	0.0175	0.0083	0.7692	0.8003	0.4058

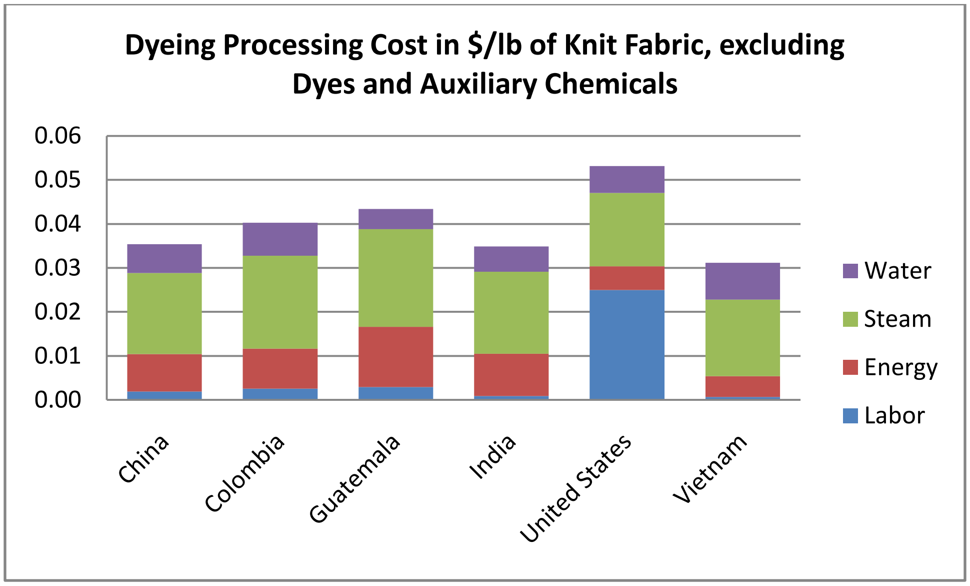

Figure 4.18 – Piece Dyeing Processing Cost in $/lb of Knit Fabric, Excluding Dyes and Auxiliary Chemicals

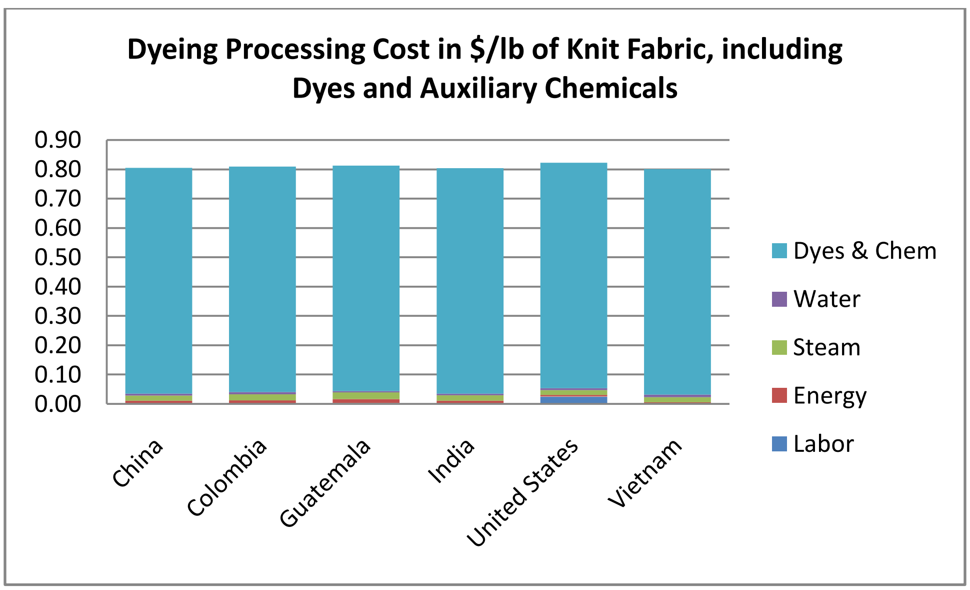

Figure 4.19 – Piece Dyeing Processing Cost in $/lb of Knit Fabric, Including Dyes and Auxiliary Chemicals

Publically available information on resource consumption for drying and compacting of the knit fabric was obtained from Biancalani (2009). Biancalani's Spyra 10 machine was taken as the base for drying and compacting of knits. The Spyra is a tumbler with rotating drums, which operates in continuous form and can dry, soften and compact knits in rope form. According to their brochure, three to thirty five meters of fabric can be processed per minute. For this analysis, 1140 meters per hour were assumed to be output. On average, the machine consumes 80 kWh and 1400 kilograms of steam per hour, plus one operator to perform the drying and compacting of the fabric at the assumed output rates (Biancalani, 2009). Equation 4.10 through Equation 4.12 account for costs of drying and compacting cotton knit fabric, and are followed by an example calculation for sourcing from China. Table 4.20 and Figure 4.20 show the costs for the countries included in this study.

Equation 4.10 – Labor Cost for Drying and Compacting in \$ per Meter of Knit Fabric

$$\frac{\$}{m_{fabric}} = \frac{man}{machine} x \frac{\$}{hr} x \frac{hr}{m_{output}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{1}{1}\ x \frac{\$1.08}{hr}\ x \frac{hr}{1140\ m} = \frac{\$0.0009}{m_{fabric}}$$

Equation 4.11 – Energy Cost for Drying and Compacting in $ per Meter of Knit Fabric

$$\frac{\$}{m_{fabric}} = \frac{hr}{m_{output}} x\ kW\ x \frac{\$}{kWh}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{hr}{1140\ m}\ x\ 80kW\ x \frac{\$0.1000}{kWh} = \frac{\$0.0070}{m_{fabric}}$$

Equation 4.12 – Steam Cost for Drying and Compacting in $ per Meter of Knit Fabric

$$\frac{\$}{m_{fabric}} = \frac{hr}{m_{output}} x \frac{kg_{steam}}{hr}\ x \frac{\$}{kg_{steam}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{hr}{1140\ m} x\ \frac{1400\ kg}{hr}\ x \frac{\$0.0190}{kg} = \frac{\$0.0234}{m_{fabric}}$$

Table 4.20 - Drying and Compacting Costs in $ per Meter of Knit Fabric

	Labor	Energy	Steam	TOTAL
China	0.0009	0.0070	0.0234	0.0313
Colombia	0.0012	0.0075	0.0269	0.0356
Guatemala	0.0014	0.0112	0.0283	0.0410
India	0.0004	0.0079	0.0237	0.0320
United States	0.0124	0.0044	0.0212	0.0380
Vietnam	0.0003	0.0039	0.0222	0.0264

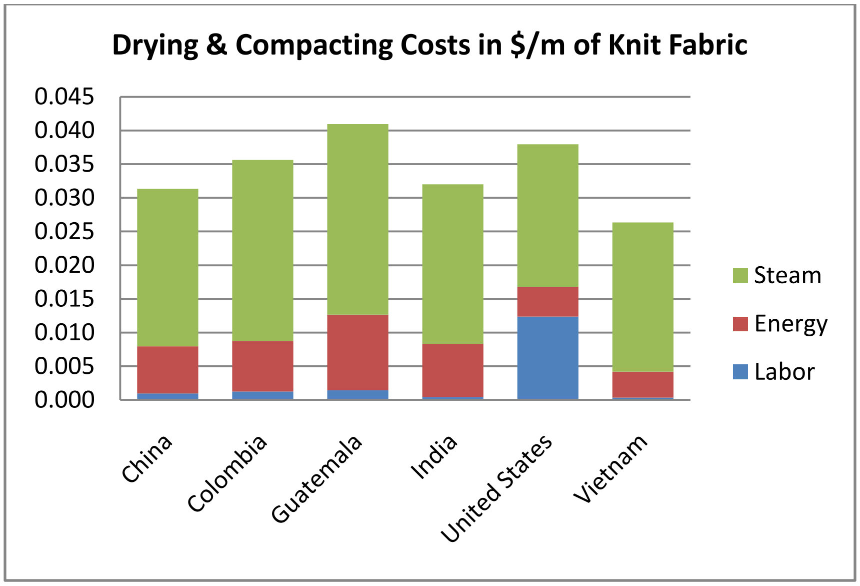

Figure 4.20 - Drying and Compacting Costs in $ per Meter of Knit Fabric

Equation 4.13 shows the summation of greige fabric costs, and subsequent costs of wet processing and finishing, by adding the costs of Equation 4.5 through Equation 4.12. Immediately below the equation is a sample calculation based on sourcing from China. Table 4.21 and Figure 4.21 show total fabric costs for the countries included in this research.

Equation 4.13 – Knit Fabric Cost in $ per Meter including Dyeing, Drying and Compacting

$$\frac{\$}{m_{fabric}} = \frac{\$}{m_{greige}} + \frac{\$}{m_{dyeing}} + \frac{\$}{m_{drying}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{\$0.7950}{m_{greige}} + \frac{\$0.4080}{m_{dyeing}} + \frac{\$0.0313}{m_{drying}} = \frac{\$1.2343}{m_{fabric}}$$

Table 4.21 – Finished Knit Fabric Cost in $ per meter

	Greige	Dyeing	Drying	TOTAL
China	0.7950	0.4080	0.0313	1.2343
Colombia	0.8345	0.4104	0.0356	1.2806
Guatemala	0.8263	0.4120	0.0410	1.2793
India	0.7051	0.4077	0.0320	1.1448
United States	0.7915	0.4170	0.0380	1.2465
Vietnam	0.8308	0.4058	0.0264	1.2630

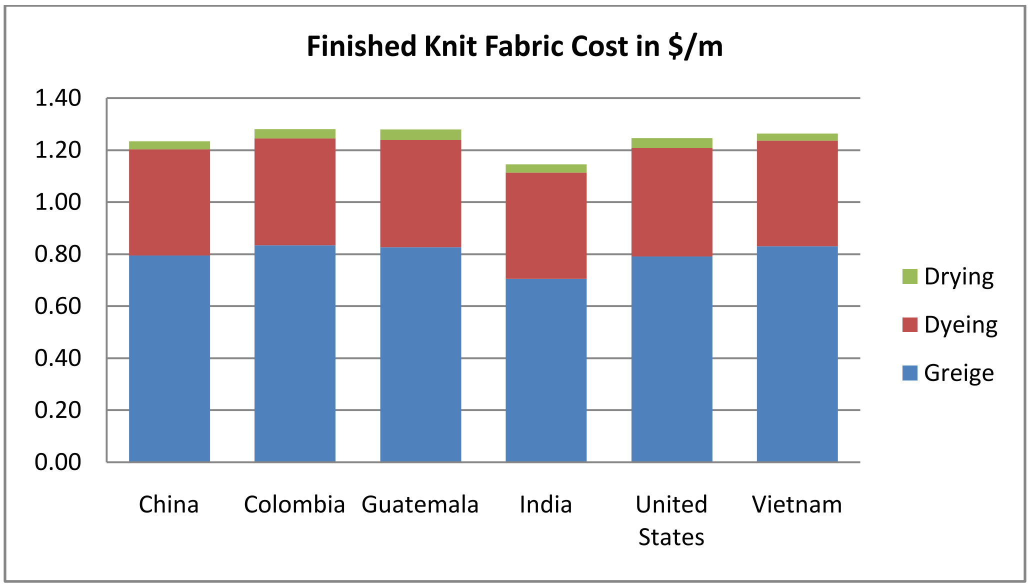

Figure 4.21 – Finished Knit Fabric Cost in $/m

4.3.2.2 Wet Processing for Denim – Indigo Rope Dye Range

The dyeing process for denim products differs from knit goods. For basic denim jeans, the indigo dye is applied only to the warp yarns, and therefore the dyeing process is performed before the fabric is woven. The finishing process is performed after the fabric has been woven to achieve fabric stability and other properties.

Information on indigo dyeing and finishing costs was supplied by Morrison Textile Machinery Co., American Monforts LLC, and DyStar Textilfarben GmbH. The following paragraphs show the operational requirements of these processes.

Morrison Textile Machinery Co. provided data for operating an indigo rope dyeing range including labor, electric, steam, and water consumption rates for a typical plant setup. The requirements are for a basic indigo rope range with a single set of drying cans, 24 ropes of 360 ends per rope, and 17 nips. The analysis for Ne 6 yarn with a 2% shade shows the range operating at an output rate of 3702.9 pounds per hour. DyStar provided cost information for preparation, dyeing, and yarn lubrication for a 2% shade. Table 4.22 shows the hourly resource consumption rates for rope dyeing with the given setup, while Equation 4.14 through Equation 4.18 show cost calculation formulas, followed by an example calculation based on operating in China. Table 4.23, Figure 4.22, and Figure 4.23 summarize dyeing costs for all countries included in the study.

Table 4.22 – Hourly Resource Consumption Rates for Rope Dyeing

Component	Unit	Qty
Labor	hour	3
Water	m^3	19.8
Steam	kg	2930
Energy	kWh	57.5

Equation 4.14 – Labor Cost for Rope Dyeing in \$ per Pound of Dyed Warp Yarn

$$\frac{\$}{lb_{fabric}} = \frac{\$}{hr}\ x\ \frac{operator}{machine}\ x\ \frac{hr}{lbs_{output}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{\$1.08}{hr}\ x\ \frac{3}{1}\ x\ \frac{hr}{3702.9\ lbs} = \frac{\$0.0009}{lb_{fabric}}$$

Equation 4.15 – Energy Cost for Rope Dyeing in \$ per Pound of Dyed Warp Yarn

$$\frac{\$}{lb_{fabric}} = \frac{\$}{kWh}\ x\ kWh\ x\ \frac{hr}{lbs_{output}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{\$0.1000}{kWh}\ x\ 57.5\ kWh\ x\ \frac{hr}{3702.9\ lbs} = \frac{\$0.0016}{lb_{fabric}}$$

Equation 4.16 – Steam Cost for Rope Dyeing in \$ per Pound of Dyed Warp Yarn

$$\frac{\$}{lb_{fabric}} = \frac{\$}{kg_{steam}}\ x\ \frac{kg_{steam}}{hr}\ x\ \frac{hr}{lbs_{output}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{\$0.0190}{kg_{steam}}\ x\ \frac{2930\ kg_{steam}}{hr}\ x\ \frac{hr}{3702.9\ lbs} = \frac{\$0.0151}{lb_{fabric}}$$

Equation 4.17 – Water Cost for Rope Dyeing in \$ per Pound of Dyed Warp Yarn

$$\frac{\$}{lb_{fabric}} = \frac{\$}{m^3_{water}}\ x\ \frac{m^3_{water}}{hr}\ x\ \frac{hr}{lbs_{output}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{\$0.3600}{m^3_{water}}\ x\ \frac{19.8\ m^3_{water}}{hr}\ x\ \frac{hr}{3702.9\ lbs} = \frac{\$0.0019}{lb_{fabric}}$$

Equation 4.18 – Chemical and Dye Cost for Rope Dyeing in \$ per Pound of Dyed Warp Yarn

$$\frac{\$}{lb_{fabric}} = \frac{\$_{chemicals}}{lb_{fabric}} + \frac{\$_{dyes}}{lb_{fabric}}$$

$$Ex.)\ \frac{\$}{lb_{fabric}} = \frac{\$0.0824}{lb_{fabric}} + \frac{\$0.0556}{lb_{fabric}} = \frac{\$0.1380}{lb_{fabric}}$$

Table 4.23 – Rope Dyeing Costs in $/lb of Warp Yarn and $/m of Woven Fabric

Country	Labor	Energy	Steam	Water	Dyes & Chem	TOTAL $/lb (warp yarn)	TOTAL $/m (fabric)
China	0.0009	0.0016	0.0151	0.0019	0.1380	0.1574	0.2295
Colombia	0.0012	0.0017	0.0173	0.0022	0.1380	0.1603	0.2338
Guatemala	0.0013	0.0025	0.0182	0.0013	0.1380	0.1614	0.2353
India	0.0004	0.0017	0.0153	0.0017	0.1380	0.1571	0.2291
United States	0.0114	0.0010	0.0136	0.0018	0.1380	0.1659	0.2418
Vietnam	0.0003	0.0009	0.0143	0.0025	0.1380	0.1559	0.2273

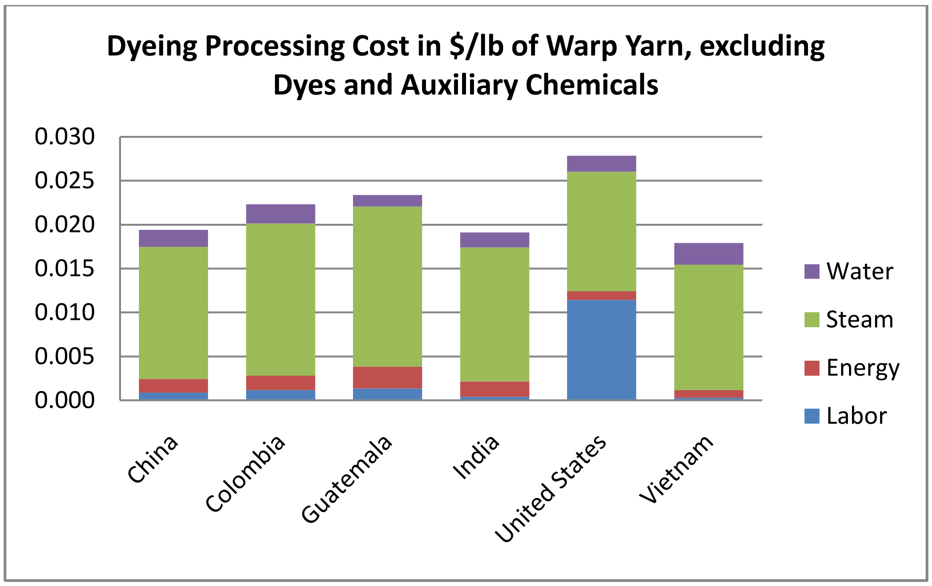

Figure 4.22 – Rope Dyeing Processing Cost in $/lb of Warp Yarn, Excluding Dyes and Auxiliary Chemicals

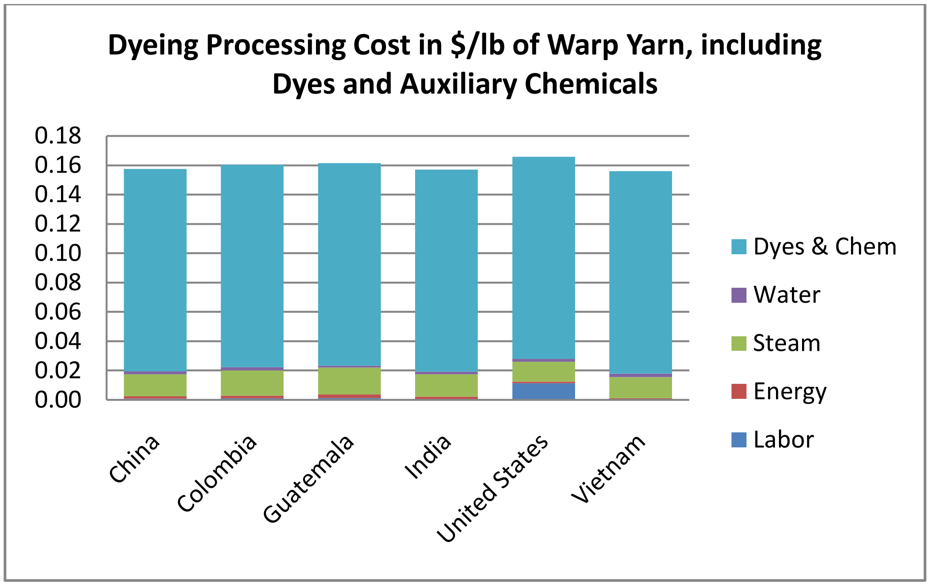

Figure 4.23 – Rope Dyeing Processing Cost in $/lb of Warp Yarn, Including Dyes and Auxiliary Chemicals

Information related to denim fabric finishing was provided by American Monforts LLC. The information was provided for a range with a finishing output of 1800 meters of fabric per hour. The machine consumes 30 kWh, 7 cubic meters of water, and 1400 kilograms of steam per hour, plus one operator to perform the drying and compacting of the fabric at the assumed output rates. Chemical and capital costs for the given output are $0.0365 and $0.0240 per meter of fabric, respectively. Equation 4.19 through Equation 4.22 account for costs associated with finishing denim fabric, and are followed by an example calculation for sourcing from China. Table 4.24 and Figure 4.24 summarize the finishing costs for all countries in this study.

Equation 4.19 – Labor Cost for Finishing Denim Fabric in $ per Meter of Fabric

$$\frac{\$}{\boldsymbol{m_{fabric}}} = \frac{\boldsymbol{man}}{\boldsymbol{machine}}\,\boldsymbol{x}\,\frac{\$}{\boldsymbol{hr}}\,\boldsymbol{x}\,\frac{\boldsymbol{hr}}{\boldsymbol{m_{output}}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{1}{1}\ x\ \frac{\$1.08}{hr}\ x\ \frac{hr}{1800\ m} = \frac{\$0.0006}{m_{fabric}}$$

Equation 4.20 – Energy Cost for Finishing Denim Fabric in $ per Meter of Fabric

$$\frac{\$}{m_{fabric}} = \frac{hr}{m_{output}}\ x\ kW\ x\ \frac{\$}{kWh}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{hr}{1800\ m}\ x\ 30kW\ x\ \frac{\$0.1000}{kWh} = \frac{\$0.0017}{m_{fabric}}$$

Equation 4.21 – Steam Cost for Finishing Denim Fabric in $ per Meter of Fabric

$$\frac{\$}{m_{fabric}} = \frac{hr}{m_{output}}\ x\ \frac{kg_{steam}}{hr}\ x\ \frac{\$}{kg_{steam}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{hr}{1800\ m}\ x\ \frac{1400\ kg}{hr}\ x\ \frac{\$0.0190}{kg} = \frac{\$0.0148}{m_{fabric}}$$

Equation 4.22 – Water Cost for Finishing Denim Fabric in $ per Meter of Fabric

$$\frac{\$}{m_{fabric}} = \frac{hr}{m_{output}}\ x\ \frac{m^3_{water}}{hr}\ x\ \frac{\$}{m^3_{water}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{hr}{1800\ m}\ x\ \frac{7\ m^3_{water}}{hr}\ x\ \frac{\$0.3600}{m^3_{water}} = \frac{\$0.0014}{m_{fabric}}$$

Table 4.24 – Denim Fabric Finishing Costs in $ per Meter of Fabric

Country	Labor	Energy	Steam	Water	Chemicals	Capital	TOTAL
China	0.0006	0.0017	0.0148	0.0014	0.0365	0.0240	0.0790
Colombia	0.0008	0.0018	0.0170	0.0016	0.0365	0.0240	0.0817
Guatemala	0.0009	0.0027	0.0179	0.0010	0.0365	0.0240	0.0830
India	0.0003	0.0019	0.0150	0.0012	0.0365	0.0240	0.0789
United States	0.0078	0.0011	0.0134	0.0013	0.0365	0.0240	0.0841
Vietnam	0.0002	0.0009	0.0140	0.0018	0.0365	0.0240	0.0775

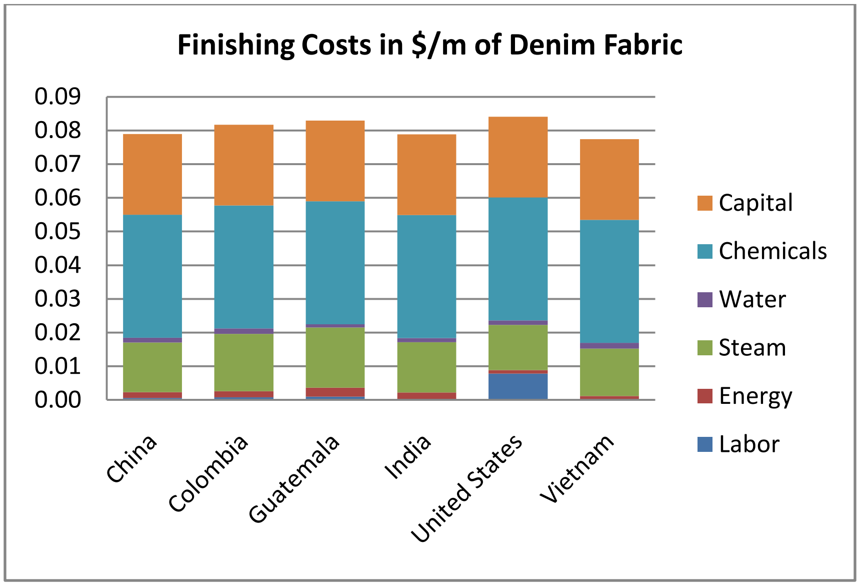

Figure 4.24 – Denim Fabric Finishing Costs in $ per Meter

The sections above show the costs for dyeing and finishing denim fabric. By adding the costs from Equation 4.14 through Equation 4.22, a final finished denim fabric cost is obtained, as shown by Equation 4.23 and the example for sourcing from China immediately following it. Table 4.25 and Figure 4.25 show finished 1.68 meter-wide denim fabric costs, which is ready for the apparel conversion process for all countries.

Equation 4.23 – Denim Fabric Cost in $ per Meter including Dyeing and Finishing

$$\frac{\$}{m_{fabric}} = \frac{\$}{m_{greige}} + \frac{\$}{m_{dyeing}} + \frac{\$}{m_{finishing}}$$

$$Ex.)\ \frac{\$}{m_{fabric}} = \frac{\$2.0374}{m_{greige}} + \frac{\$0.2295}{m_{dyeing}} + \frac{\$0.0790}{m_{finishing}} = \frac{\$2.3459}{m_{fabric}}$$

Table 4.25 – Finished Denim Fabric Costs in $ per Meter

Country	Greige	Dyeing	Finishing	TOTAL
China	2.0374	0.2295	0.0790	2.3459
Colombia	1.9089	0.2338	0.0817	2.2244
Guatemala	1.9137	0.2353	0.0830	2.2320
India	1.8261	0.2291	0.0789	2.1341
United States	1.8164	0.2418	0.0841	2.1423
Vietnam	2.1343	0.2273	0.0775	2.4391

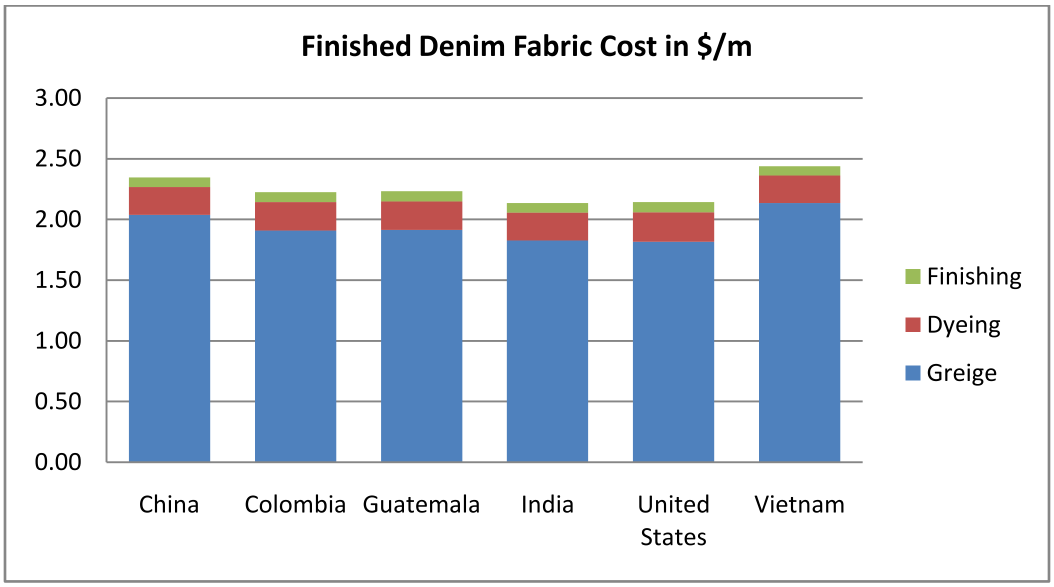

Figure 4.25 – Finished Denim Fabric Costs in $ per Meter

4.4 Apparel Operations

Once a dyed fabric is produced, the t-shirt and denim bottoms conversion process begins, although dyeing can be postponed after garments are sewn in some cases. Unlike textile operations, the apparel industry is not nearly as capital intensive, but considerably more labor intensive. The cost drivers for apparel conversion were determined via professional experiences and industry consultation. The major cost drivers for apparel conversion are fabric, trims, labor, energy, and cost of capital.

The cost of a good is the product of two variables, the amount of resources consumed per unit produced and the cost per unit of those resources. For a given product, the amount of resources consumed has little variation from one country to another. The part of the equation that does change depending on where a product is produced is the cost per unit of a given set of resources.

4.4.1 Fabric and Trims for a T-Shirt

The most significant cost component in apparel manufacturing is the consumption of fabric. The cutting room is the first and most important area to control the efficient use of fabric. Fabric loss costs in cutting room operations such as spread loss and marker yields were accounted for in cost calculations. Spread loss was set to 0.8 percent. The costs shown in Figure 4.21 are for fabric of 37.80 inches in width, but costing was calculated for an average fabric width for knit t-shirts was set to 22 inches assuming tubular fabric was used, instead of open-width fabric which requires side seam sewing operations. Assuming the production cost structure does not change for different widths, the cost was scaled to a 22 inch-wide fabric. The linear fabric length required for one t-shirt was set to 0.9906 meters. The fabric costs, fabric width scaling, and cutting room factors are accounted for in Equation

4.24. Table 4.26 and Figure 4.26 show the fabric costs per garment for each country in this analysis.

Equation 4.24 – Fabric Cost per T-Shirt

$$\frac{\$_{fabric}}{garment} = \frac{\$}{m_{fabric}}\ x\ \frac{m_{fabric}}{garment}\ x\ (1 + loss_{spread})\ x\ \frac{width_{new}}{width_{original}}$$

$$Ex.)\ \frac{\$_{fabric}}{garment} = \frac{\$1.2343}{m}\ x\ \frac{0.9906\ m}{garment}\ x\ 1.008\ x\ \frac{22\ inch}{37.80\ inch} = \frac{\$0.7174}{garment}$$

Table 4.26 - Fabric Cost per T-Shirt

	$/gmt
China	0.7174
Colombia	0.7443
Guatemala	0.7436
India	0.6654
United States	0.7245
Vietnam	0.7341

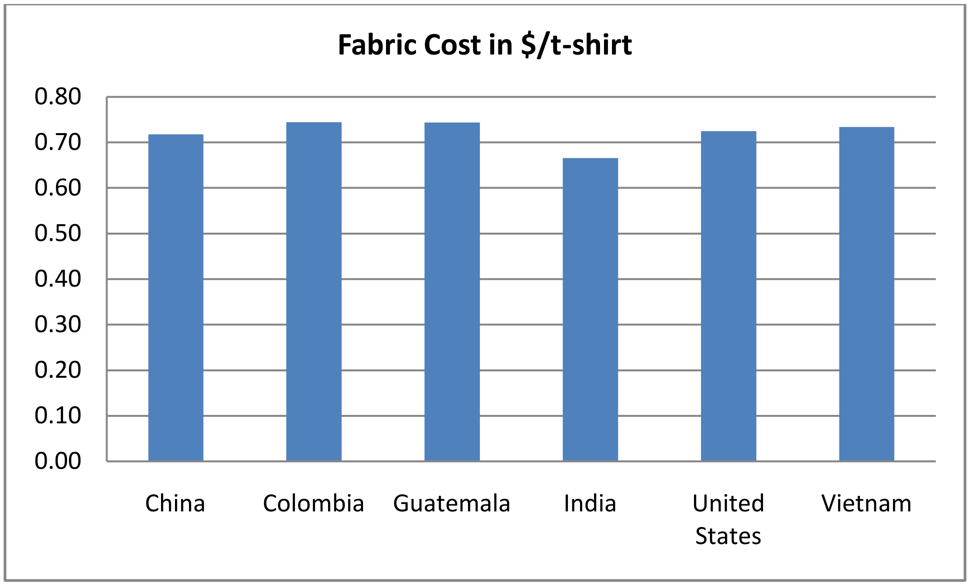

Figure 4.26 – Fabric Cost per T-Shirt

Secondary materials are required for garment manufacture, such as thread, neck labels, packing materials, zippers, buttons, and others. Secondary materials and floor-ready packaging trim cost data were gathered from a trim and findings procurement manager in the knit goods industry (Procurement Manager 1, 2009). Prices for trims are very similar throughout all apparel producing companies with large production volume, so trim costs were set equal for all countries. Though trims are a collection of many small items with relatively low costs, they can represent a significant percent of the total fabric and trims cost, with thread accounting for the largest cost of trims. Table 4.27 and Equation 4.25 show the trim materials required and their respective costs for a retail floor-ready t-shirt.

Table 4.27 - Trim Requirement and Costs for a Floor-ready T-Shirt

Materials	Requirement		$/UOM	$/garment
	UOM	Qty		
Thread	lb	0.08	1.9200	0.1536
Tagless neck label	unit	1	0.0180	0.0180
Poly bag	unit	1	0.0160	0.0160
Swiftachs	unit	1	0.0010	0.0010
Hang tags	unit	1	0.0320	0.0320
Size strips	unit	1	0.0210	0.0210
Boxes	unit	1/60	0.8900	0.0148
Tape	ft	0.08	0.0029	0.0002
TOTAL				**0.2567**

Equation 4.25 – Trim Cost per T-Shirt

$$\frac{\$_{trims}}{garment} = \sum_{i=1}^{n}\left(\frac{\$}{trim_i}\,x\,\frac{trim_i}{garment}\right)$$

$Ex.)$

$$\frac{\$}{garment} = (\$1.92\ x\ 0.08) + (\$0.018\ x\ 1) + (\$0.016\ x\ 1) + (\$0.001\ x\ 1) + (\$0.032\ x\ 1)$$

$$+ (\$0.021\ x\ 1) + \left[\$0.89\ x\ \left(\frac{1}{60}\right)\right] + (\$0.0029\ x\ 0.08) = \frac{\$0.2567}{garment}$$

4.4.2 Labor for a T-Shirt

Apparel production is labor intensive, with less complex products easily requiring five standard allowed minutes (SAM) for cutting room operations and garment assembly. Labor data sources are available through international organizations and also via private consultancies; the two are quite different in their data acquisitions methods and timeliness of data dissemination. Most reports include fully-loaded wage rates, which include social benefits, fringes, and other similar labor related expenses.

The labor requirements are based on benchmark rates of labor requirements for product types. Each garment style has its own set of operations and complexity, and therefore requires a specific amount of labor resources. The sewing operations for the t-shirt in this study were set to require 7 standard allowed minutes (SAMs). Operator efficiency rates and time on-standard (non-idle time) were factored into the labor cost calculation, and were set to 85 and 90 percent, respectively. Indirect labor support personnel were also taken into consideration for apparel conversion costs, by using industry benchmarks for indirect to direct personnel ratios (Production Manager 1, 2007), and were set to a 1 to 5 ratio. Indirect labor rates were assumed to be eighty percent of direct labor rates. Equation 4.26 and Equation 4.27 illustrate the labor cost calculations for apparel assembly, while Table 4.28 and Figure 4.27 show labor costs for all countries.

Equation 4.26 – Apparel Conversion Direct Labor Cost per T-Shirt

$$\frac{\$_{direct\ labor}}{garment} = \frac{\$}{hr}\ x\ Efficiency\ x\ Time_{on-standard}\ x\ \frac{1\ hr}{60\ min}\ x\ \frac{SAM}{garment}$$

$$Ex.)\ \frac{\$_{direct\ labor}}{garment} = \frac{\$1.08}{hr} x \frac{1}{0.85} x \frac{1}{0.90} x \frac{1\ hr}{60\ min} x \frac{7\ SAM}{garment} = \frac{\$0.1647}{garment}$$

Equation 4.27 – Apparel Conversion Indirect Labor Cost per T-Shirt

$$\frac{\$_{indirect\ labor}}{garment} = \frac{\$}{hr}\, x\ Efficiency\ x\ Time_{on-standard}\ x\, \frac{1\ hr}{60\ min}\, x\, \frac{SAM}{garment}\, x\ Ratio_{direct\ to\ indirect}$$

$$Ex.)\ \frac{\$_{indirect\ labor}}{garment} = \frac{\$0.86}{hr}\, x\, \frac{1}{0.85}\, x\, \frac{1}{0.90}\, x\, \frac{1\ hr}{60\ min}\, x\, \frac{7\ SAM}{garment}\ \ x\, \frac{1}{5} = \frac{\$0.0264}{garment}$$

Table 4.28 – Apparel Conversion Labor Cost per T-Shirt

	\$/gmt
China	0.1911
Colombia	0.2512
Guatemala	0.2919
India	0.0902
United States	2.4944
Vietnam	0.0672

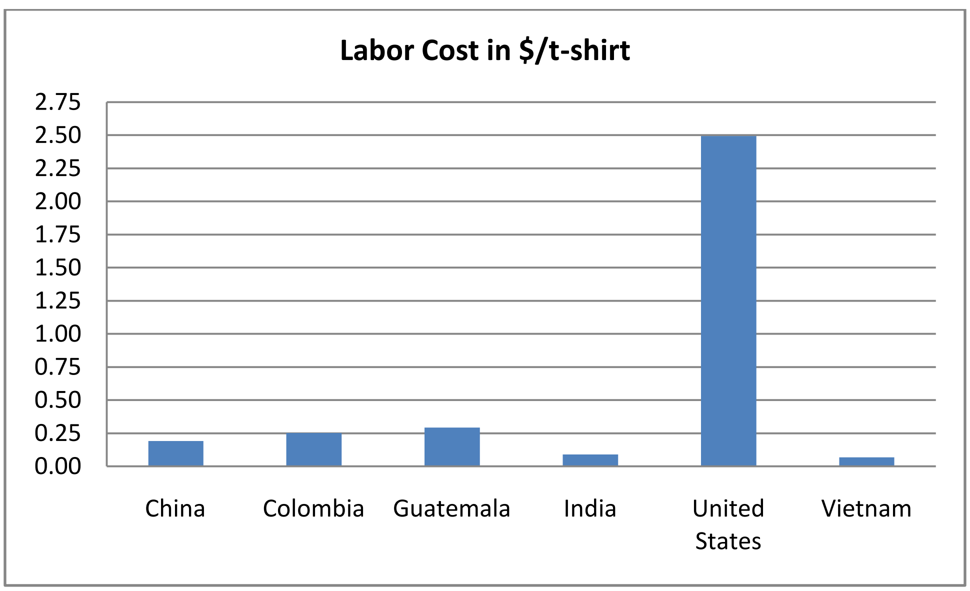

Figure 4.27 – Apparel Conversion Labor Cost per T-Shirt

4.4.3 Energy for a T-Shirt

Compared to textile operations, apparel manufacturing does not consume a significant amount of energy. While, energy consumption does not impact overall costs as much as raw materials and labor, it is nonetheless important to know how it affects the bottom line. The energy consumption for the cut and sew of a knit t-shirt was calculated to be 0.1248 kWh. The energy consumption rates were calculated by taking typical sewing equipment, lighting, and estimated supporting equipment power requirements and relating them to the average space requirement for sewing and total SAMs required to cut, sew and finish a garment as shown by Equation 4.28.

Equation 4.29 and the example for sourcing from China following it, show energy costs related to apparel assembly, while Table 4.29 and Figure 4.28 summarize energy costs for all countries in the study.

Equation 4.28 – Apparel Conversion Energy Consumption per T-Shirt

$$\frac{kWh}{garment} = \left(kWh_{sewing\ machine} + kWh_{support} + \left(\frac{kWh_{lighting}}{m^2_{floorspace}} \, x \, \frac{m^2_{floorspace}}{work\ station} \right) \right) x \, \frac{SAM}{garment} \, x \, \frac{1}{60}$$

$$Ex.)\ \frac{kWh}{garment} = \left(0.4\ kWh + 0.3\ kWh + \left(\frac{0.1850\ kWh}{m^2} x\ 2\ m^2\right)\right)\ x \frac{7\ SAM}{garment} x \frac{1}{60}$$

$$= \frac{0.1248\ kWh}{garment}$$

Equation 4.29 – Apparel Conversion Energy Cost per T-Shirt

$$\frac{\$_{energy}}{garment} = \frac{\$}{kWh} x \frac{kWh}{garment}$$

$$Ex.)\ \frac{\$_{energy}}{garment} = \frac{\$0.10}{kWh} x \frac{0.1248\ kWh}{garment} = \frac{\$0.0125}{garment}$$

Table 4.29 – Apparel Conversion Energy Cost per T-Shirt

	$/gmt
China	0.0125
Colombia	0.0134
Guatemala	0.0200
India	0.0140
United States	0.0079
Vietnam	0.0069

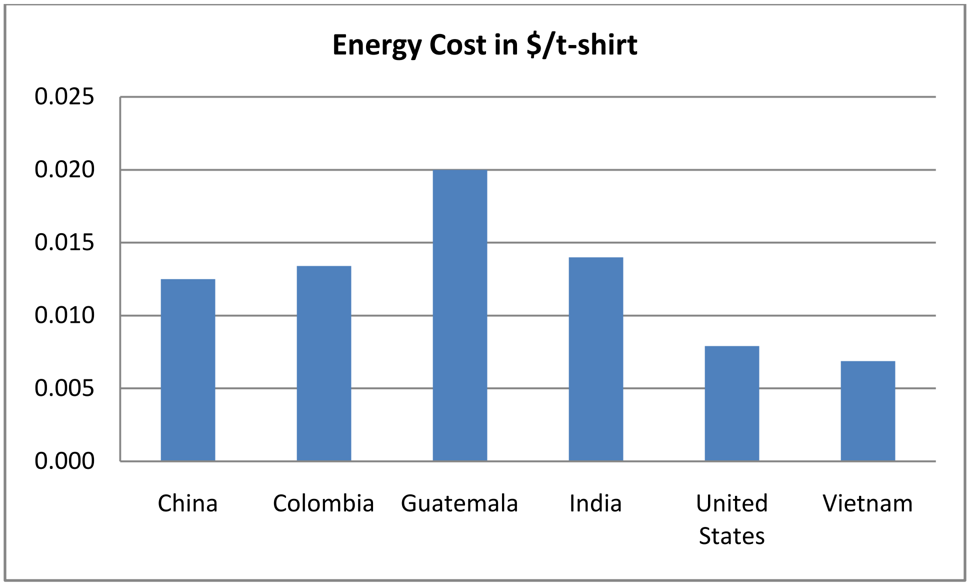

Figure 4.28 – Apparel Conversion Energy Cost per T-Shirt

4.4.4 Off-quality and Process Yield for a T-Shirt

The previous sections covered direct inputs of the apparel industry, but there are other issues to consider as well. As with all manufacturing processes, the apparel conversion industry has quality issues which affect process yields. For this study, a two percent off-quality factor has been applied to the entire apparel conversion process. Equation 4.30 shows the costs associated with non-acceptable goods output, followed by an example calculation for Chinese production. Table 4.30 summarizes the costs for each country in this study.

Equation 4.30 – Apparel Conversion Process Yield Cost per T-Shirt

$$\frac{\$_{off-quality}}{garment} = \left(\frac{\$_{fabric}}{garment} + \frac{\$_{trim}}{garment} + \frac{\$_{labor}}{garment} + \frac{\$_{energy}}{garment}\right) x\ factor_{off-quality}$$

$$Ex.)\ \frac{\$}{garment} = (\$0.7174 + \$0.2567 + \$0.1911 + \$0.0125)\ x\ 0.02 = \$0.0236$$

Table 4.30 – Apparel Conversion Process Yield Cost per T-Shirt

	\$/gmt
China	0.0236
Colombia	0.0253
Guatemala	0.0262
India	0.0205
United States	0.0697
Vietnam	0.0213

4.4.5 Capital Cost for a T-Shirt

As previously mentioned, the apparel industry is much less capital intensive when compared to textile operations. In this cost model greater focus is placed on short term financing expenses, especially related to working capital. Guidance on practices and costs related to wholesale product financing was obtained through contact with the CIT Group (Tabb, 2009). As an active participant in the financial area of the apparel industry, CIT Group offers services including factoring, credit protection, accounts receivable management, and lending services to apparel companies.

Throughout the research process, it became evident that limited information is available publically on costs of capital for countries. Macroeconomic factors and indexes, such as country risk ratings are available and published by many organizations, but the limited information does not translate into specific quantifiable costs of capital for a given country. Country specific cost of capital would have to be collected in a manner similar to ITMF's approach, which includes obtaining data from specific companies operating in different countries.

The Senior Vice-President and New Business Manager for CIT in the southeast region, Mr. Lewis Tabb, provided insight on trade trends and financing. He had specific observations related to trade financing with China and Central America. Mr. Tabb has seen that China has benefitted from a significant increase in available capital for the industry in recent years. He believes that the consolidation of participants in the industry will help that country. On another note, Latin America is positioned to make improvements as well. He cited that the Central American banking industry was highly fragmented, with many small and conservatively run banks. He believes that the numerous regional acquisitions in the area by large multinationals will bring many improvements to the system. Long term averages for the cost of capital for apparel have accounted for approximately three percent of wholesale costs. The costs of capital are applied to fabric, trims, direct labor, indirect labor, energy and process yield costs in apparel operations as illustrated by

Equation 4.31 and the example following it for sourcing from China. Exit-factory values can be calculated using Equation 4.32, which is followed by an example calculation for sourcing from China.

Equation 4.31 – Capital Cost per T-Shirt

$$\frac{\$_{capital}}{garment} = \left(\frac{\$_{fabric}}{garment} + \frac{\$_{trim}}{garment} + \frac{\$_{labor}}{garment} + \frac{\$_{energy}}{garment} + \frac{\$_{off-quality}}{garment}\right) x \; Capital_{rate}$$

$$Ex.) \; \frac{\$_{capital}}{garment} = (\$0.7174 + \$0.2567 + \$0.1911 + \$0.0125 + \$0.0236) \; x \; 0.03$$

$$= \frac{\$0.0360}{garment}$$

Equation 4.32 – Exit-Factory Cost per T-Shirt

$$\frac{\$_{exit-factory}}{garment} = \frac{\$_{fabric}}{garment} + \frac{\$_{trim}}{garment} + \frac{\$_{labor}}{garment} + \frac{\$_{energy}}{garment} + \frac{\$_{off-quality}}{garment} + \frac{\$_{capital}}{garment}$$

$$Ex.) \; \frac{\$_{exit-factory}}{garment} = \$0.7174 + \$0.2567 + \$0.1911 + \$0.0125 + \$0.0236 + \$0.0360$$

$$= \frac{\$1.2373}{garment}$$

4.4.6 Export Rebate Taxes for a T-Shirt

One of the countries included in this study, China, has provided exporters of apparel goods with incentives to promote trade. Export tax rebate (ETR) rates for Chinese products have risen to fifteen percent recently (Xinhua News Agency, 2009) and must be accounted for as well. This rebate is applied to "exit-factory" prices, as documented by Equation 4.33 and the example immediately below it. Table 4.31 shows exit-factory, rebate, and FOB values for all countries in this study.

Equation 4.33 – Export Tax Rebate per T-Shirt

$$\frac{\$_{rebate}}{garment} = \frac{\$_{exit-factory}}{garment} \ x \ Rate_{rebate}$$

$$\frac{\$_{rebate}}{garment} = \frac{\$1.2372}{garment} \ x \ 0.15 = \frac{\$0.1856}{garment}$$

Table 4.31 – Exit-Factory, Export Tax Rebate, and FOB Values per T-Shirt

	Exit-Factory	Rebate	FOB Value
	$/gmt	$/gmt	$/gmt
China	1.2372	0.0000	1.2372
China (w/ rebate)	1.2372	0.1856	1.0516
Colombia	1.3296	0.0000	1.3296
Guatemala	1.3785	0.0000	1.3785
India	1.0782	0.0000	1.0782
United States	3.6596	0.0000	3.6596
Vietnam	1.1187	0.0000	1.1187

4.5 Logistics, Trade, and Landed Costs for a T-Shirt

There are two critical elements of information that affect retail performance within logistics operations. The first element collected is the cost of shipping full twenty-foot (TEU) and forty-foot equivalent unit (FEU) containers. For the purposes of this research, no less-than-container shipping costs were considered in the analysis. The Landmark Ocean Shipping Reform Act requires maritime liner companies shipping to the United States to make their shipping costs available to the general public, which makes data collection possible. The online database tools available provide a great amount of detail on the cost elements of shipping, including usage of the Panama Canal, Suez Canal, documentation fees, security charges, customs clearance, paperwork correction charges, bunker fuel surcharges, and more. For the Americas, the company with the most complete information available online is Seaboard Marine. For shipping rates from Asia, Orient Overseas Container Line, Ltd. (OOCL) and Yang Ming Marine Transport Corp. made their information available with the greatest amount of detail. For every route available the companies made available their maritime and total transit times. This second data point collected can have a large effect on sourcing and retail performance. Equation 4.34 shows the shipping costs per garment shipped, followed by an example of shipping garments from China to the United States using FOB prices and applying a 1.87% rate of insurance charge to this value. Table 4.32 summarizes transportation costs and maritime transit times to the United States for all the countries in the study.

Equation 4.34 – Transportation Cost per T-Shirt

$$\frac{\$_{transportation}}{garment} = \left[\left(\frac{\$}{container}\,x\,\frac{container}{garments}\right) + \left(Insurance\ Rate_{shipping}\,x\,\frac{\$_{FOB}}{garment}\right)\right]x\,(1 + Capital_{Rate})$$

$$Ex.)\ \frac{\$_{transportation}}{garment}$$

$$= \left[\left(\frac{\$2780}{container}\,x\,\frac{container}{38000\ garments}\right) + \left(0.0187\,x\,\frac{\$1.0516}{garment}\right)\right]x\,(1.03)$$

$$= \frac{\$0.0956}{garment}$$

Table 4.32 – Maritime Transit Times in days and Transportation Costs per T-Shirt

Country	Transit (days)	$/40ft container	$/gmt
China	13	2780	0.0992
China (w/ rebate)	13	2780	0.0956
Colombia	4	2644	0.0973
Guatemala	3	2771	0.1017
India	18	2979	0.1015
United States	0	0	0.0000
Vietnam	19	3100	0.1056

The price per barrel of oil fluctuated significantly over the research period of this project. Given that maritime transportation cost structures are in part dependent on the prices of bunker fuel, it is important to note how much impact soaring oil prices can have on specific routes and sourcing strategies. During the first quarter of 2009 with oil prices at approximately $40 per barrel, total maritime transportation costs for Far East routes to the US East Coast were lower than western hemisphere routes. Bunker surcharges accounted for six to seven percent of costs of western hemisphere routes, compared to twelve to thirteen percent of costs of Far East routes. If bunker surcharges are directly proportional to oil prices, this makes Far East routes more sensitive to higher oil prices. If this assumption holds true and oil prices surge while other costs remain equal, transportation costs should be higher for Far East routes compared to western hemisphere routes as illustrated by Figure 4.29.

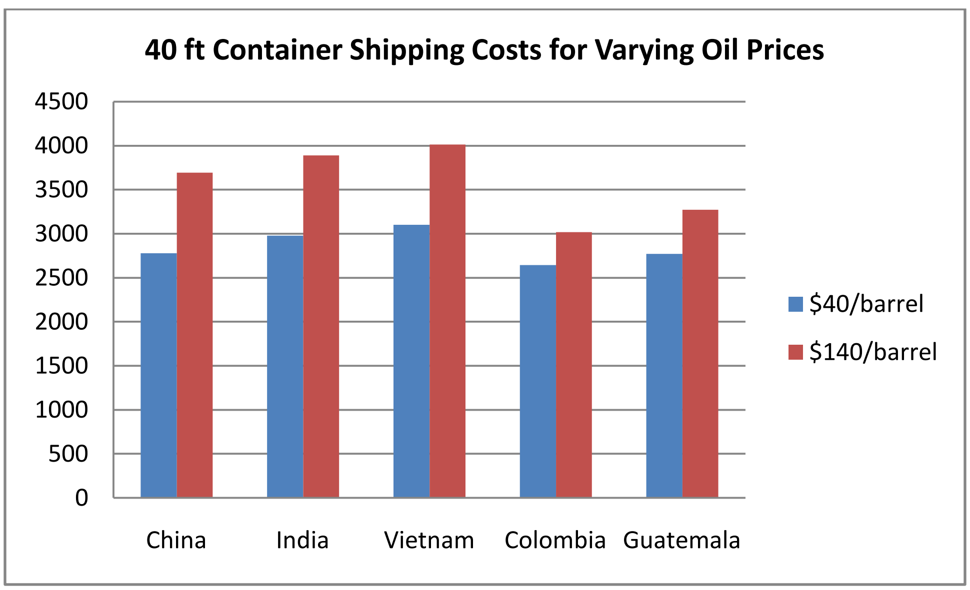

Figure 4.29 - Comparison of Transportation Costs for 40 ft Containers Assuming Bunker Surcharges are Directly Proportional to Oil Prices

Tariff rates for entry to the US market heavily impact final landed costs of goods, and therefore impacts a country's competitiveness as a supplier of apparel goods. The United States International Trade Commission makes all Harmonized Tariff Schedule information available on their website. Rates of duty for countries outside of free trade agreements are in the order of 16.5% for cotton t-shirts and 16.6% for denim trousers. Countries with FTAs with the United States benefit from duty-free access when rules of origin are met (United States International Trade Commission, 2008). The duty rates for each garment and country can be calculated using Equation 4.35 and the duty rates shown in Table 4.33. The final landed cost of goods is obtained by adding FOB values, transportation, and duty costs. The landed cost is heavily impacted when the duty component is factored in, as summarized by Table 4.34.

Table 4.33 - Duty Rates for Entry into the United States and Foreign Export Tax Rebates

	Duty	Rebate
Country	%	%
China	16.5	15
Colombia	16.5	0
Guatemala	0	0
India	16.5	0
United States	0	0
Vietnam	16.5	0

Equation 4.35 – Duty Cost per T-Shirt

$$\frac{\$}{garment} = FOB_{value}\ x\ Duty\ Rate$$

$$Ex.)\ \frac{\$}{garment} = \$1.0516\ x\ 0.165 = \frac{\$0.1735}{garment}$$

Table 4.34 - Landed Cost per T-Shirt

	$/gmt
China	1.5405
China (w/ rebate)	1.3207
Colombia	1.6462
Guatemala	1.4802
India	1.3576
United States	3.6596
Vietnam	1.4089

4.6 Landed Cost for T-Shirts Using Open-End Yarn

The cost structure for t-shirts changes when open-end yarns are used instead of ring spun yarns. It is important to note how cost advantages are gained or lost through the use of different raw materials. The landed costs for each country can be obtained by using the yarn costs listed in Table 4.9, and these are listed below.

Table 4.35 - Landed Cost per T-shirt Using Open-end Yarn

	$/gmt
China	1.4123
China (w/ rebate)	1.2117
Colombia	1.4515
Guatemala	1.3126
India	1.2307
United States	3.4983
Vietnam	1.2783

4.7 Apparel Conversion Costs for a Denim Bottom

The previous sections show how to calculate the apparel conversion, trade, and logistics costs of a t-shirt. This section calculates the costs for a denim bottom, in a manner similar to the t-shirt costing process and additional garment washing processing costs.

The cost of fabric per pair of jeans can be calculated in a similar manner to t-shirt fabric consumption costs, except that there is no need to scale fabric width for jeans. The costs per meter of finished denim fabric are those seen in Table 4.25. The linear fabric length required for one denim bottom was assumed to be 1.5453 meters, with a cutting table spread loss of 3.0 percent. The fabric costs and cutting room factors for a pair of jeans are accounted for in Equation 4.36. Table 4.36 and Figure 4.30 show the fabric costs per denim jean for each country in this analysis. Table 4.37 list all trim requirements and costs for a retail floor-ready denim jean for all countries.

Equation 4.36 – Fabric Cost per Denim Bottom

$$\frac{\$_{fabric}}{garment} = \frac{\$}{m_{fabric}}\ x\ \frac{m_{fabric}}{garment}\ x\ (1 + loss_{spread})$$

$$Ex.)\ \frac{\$_{fabric}}{garment} = \frac{\$2.3459}{m_{fabric}}\ x\ \frac{1.5453\ m}{garment}\ x\ (1.03) = \frac{\$3.7340}{garment}$$

Table 4.36 – Fabric Cost per Denim Jean

	$/gmt
China	3.7340
Colombia	3.5405
Guatemala	3.5527
India	3.3969
United States	3.4100
Vietnam	3.8824

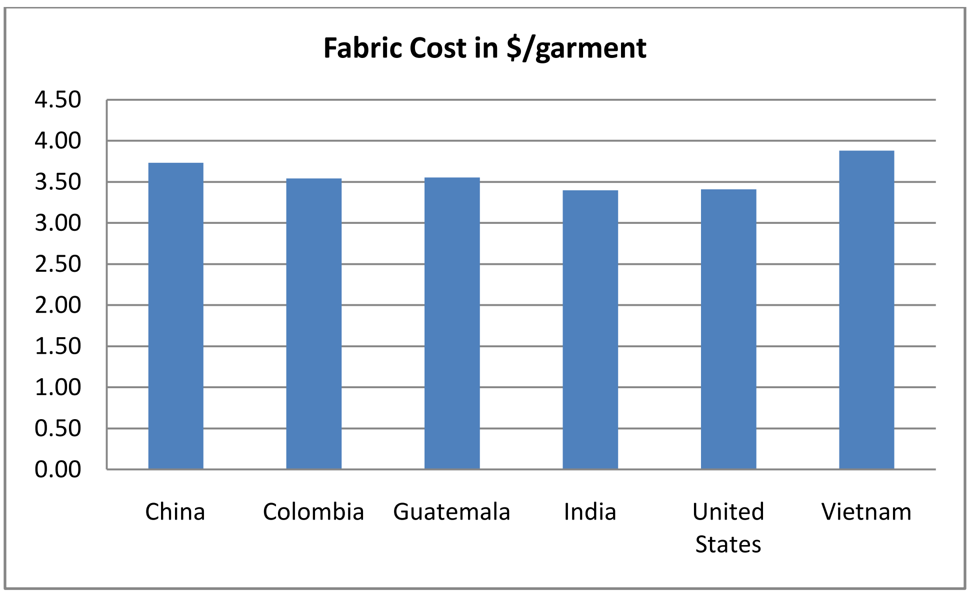

Figure 4.30 – Fabric Cost per Denim Jean

Table 4.37 – Trim Requirement and Cost for a Floor-Ready Denim Jean

Materials	Requirement		$/UOM	$/garment
	UOM	Qty		
Pocketing	unit	2	0.1663	0.3326
Zipper	unit	1	0.1550	0.1550
Thread	lb	0.19	2.0550	0.3905
Fusionables	unit	1	0.0077	0.0077
Patch Label	unit	1	0.0490	0.0490
Woven Care Label	unit	1	0.0666	0.0666
Country of Origin Label	unit	1	0.0146	0.0146
Size Strip	unit	1	0.0409	0.0409
VM Foldover	unit	1	0.0200	0.0200
Hang tag	unit	2	0.0320	0.0640
Swiftachs	unit	1	0.0016	0.0016
Poly bag	unit	1	0.0375	0.0375
Boxes	unit	1/24	0.8900	0.0371
Tape	ft	0.19	0.0029	0.0006
Tack	unit	5	0.0102	0.0510
Button	unit	1	0.0285	0.0285
Rivets	unit	6	0.0138	0.0825
TOTAL				**1.3795**

The operations required to assemble a jean are significantly higher than a t-shirt. The labor required to sew a jean was assumed to be 21 SAMs. The operator efficiency and non-idle time was assumed to be 85% and 90%, respectively. Equation 4.26 and Equation 4.27 can be used to calculate direct and indirect labor costs, as detailed by the following two example calculations for sourcing from China. Table 4.38 and Figure 4.31 summarize labor costs required to cut, sew, and pack a jean for all countries.

$$Ex.)\ \frac{\$_{direct\ labor}}{garment} = \frac{\$1.08}{hr} x \frac{1}{0.85} x \frac{1}{0.90} x \frac{1\ hr}{60\ min} x \frac{21\ SAM}{garment} = \frac{\$0.4941}{garment}$$

$$Ex.)\ \frac{\$_{indirect\ labor}}{garment} = \frac{\$0.86}{hr} x \frac{1}{0.85} x \frac{1}{0.90} x \frac{1\ hr}{60\ min} x \frac{21\ SAM}{garment}\ x \frac{1}{5} = \frac{\$0.0791}{garment}$$

Table 4.38 – Apparel Conversion Labor Cost per Denim Jean

	$/gmt
China	0.5732
Colombia	0.7536
Guatemala	0.8757
India	0.2707
United States	7.4831
Vietnam	0.2017

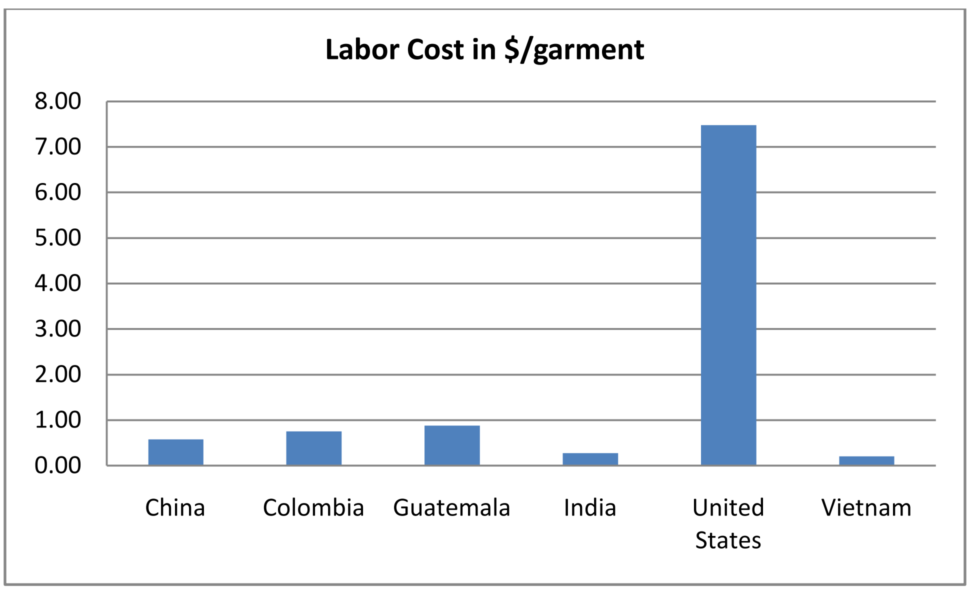

Figure 4.31 – Apparel Conversion Labor Cost per Denim Jean

The energy consumption for the cut and sew of a denim jean was calculated to be 0.3745 kWh. The energy consumption rates were calculated by taking typical sewing equipment, lighting, and estimated supporting equipment power requirements and relating them to the average space requirement for sewing and total SAMs required to cut, sew and finish a garment as shown by the example calculation below using Equation 4.28. Energy costs for the same example can be calculated by employing Equation 4.29 related to apparel assembly as shown below, while Table 4.39 and Figure 4.32 summarize energy costs for all countries in the study.

$$Ex.)\ \frac{kWh}{garment} = \left(0.4\ kWh + 0.3\ kWh + \left(\frac{0.1850\ kWh}{m^2} x\ 2\ m^2\right)\right) x \frac{21\ SAM}{garment} x \frac{1}{60}$$

$$= \frac{0.3745\ kWh}{garment}$$

$$Ex.)\ \frac{\$_{energy}}{garment} = \frac{\$0.0100}{kWh} x \frac{0.3745\ kWh}{garment} = \frac{\$0.0375}{garment}$$

Table 4.39 – Apparel Conversion Energy Cost per Denim Jean

	$/gmt
China	0.0375
Colombia	0.0401
Guatemala	0.0599
India	0.0419
United States	0.0236
Vietnam	0.0206

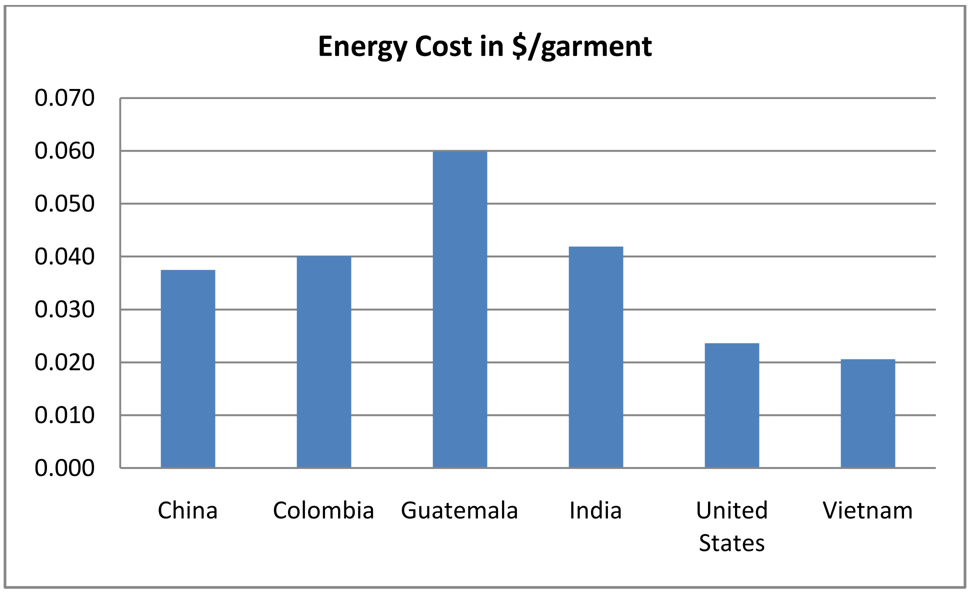

Figure 4.32 – Apparel Conversion Energy Cost per Denim Jean

Garment finishes and washes for basic jeans are of limited complexity, when compared to the seemingly infinite garment dry processes and washes of fashion denim jeans. Basic denim jeans do require a significant amount of labor resources for dry processing, including sanding, grinding, spraying of solutions on sanded areas, and other means of mechanical agitation. The dry garment processing is rarely automated. Instead it is executed in large part by human action. Garment washing consumes steam, electric energy, water, softeners, detergents, enzymes and other auxiliary chemicals. A denim laundry facility manager in Latin America provided labor and water requirement data for these processes. Equation 4.37 and Equation 4.38 can be used to calculate the labor and water costs related to garment dry processing and washing. The examples following each equation are for sourcing from China. Table 4.40 shows the garment processing costs for all countries.

Equation 4.37 – Labor Cost for Denim Jean Dry Processing

$$\frac{\$}{garment} = \frac{\$}{hr}\ x\ \left(\frac{hr}{garment_{sanded}} + \frac{hr}{garment_{sprayed}} + \frac{hr}{garment_{ground}}\right)$$

$$\frac{\$}{garment} = \frac{\$\ 1.08}{hr} x\ \left(\frac{hr}{25\ garments} + \frac{hr}{75\ garments} + \frac{hr}{75\ garments}\right) = \frac{\$0.0720}{garment}$$

Equation 4.38 – Water Cost for Denim Jean Washing

$$\frac{\$}{garment} = \frac{\$}{gln_{water}}\ x\ \frac{gln_{water}}{load}\ x\ \frac{load}{garments}$$

$$\frac{\$}{garment} = \frac{\$0.001363}{gln_{water}}\ x\ \frac{2400\ gln_{water}}{load}\ x\ \frac{load}{120\ garments} = \frac{\$0.0273}{garment}$$

Table 4.40 – Denim Jean Dry Processing and Washing Costs in $ per Garment

	Labor	Water	TOTAL
China	0.0720	0.0273	0.0993
Colombia	0.0947	0.0310	0.1257
Guatemala	0.1100	0.0189	0.1289
India	0.0340	0.0242	0.0582
United States	0.9400	0.0257	0.9657
Vietnam	0.0253	0.0347	0.0601

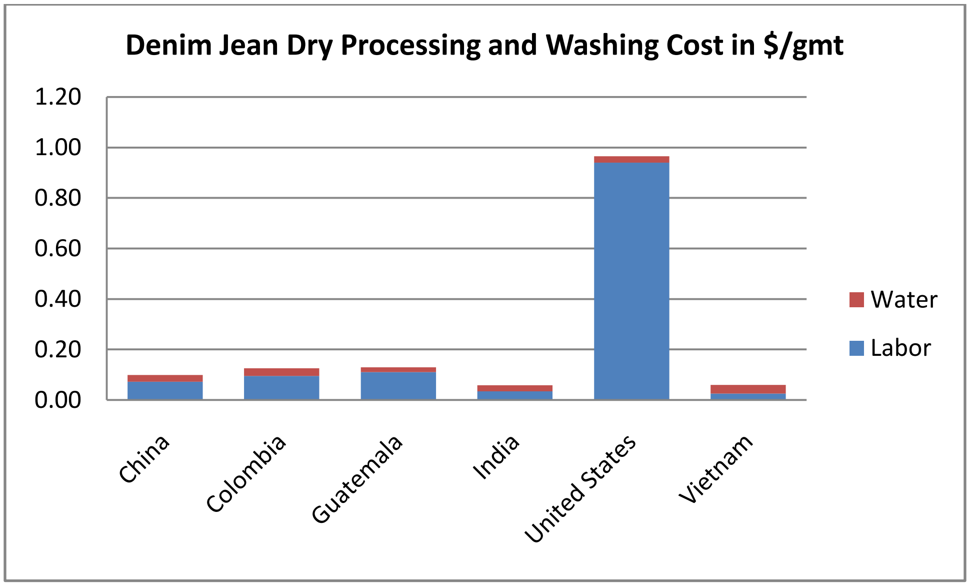

Figure 4.33 – Denim Jean Dry Processing and Washing Cost

The process yield for denim bottoms construction and subsequent processing is lower than for t-shirt production, with a three percent off-quality factor being applied to conversion process, including costs related to fabric, trims, labor, energy, and garment processing. Equation 4.39 accounts for process yield costs, while the example following it calculates process yield costs for sourcing from China. Table 4.41 shows the costs for all countries.

Equation 4.39 – Apparel Conversion Process Yield Cost per Denim Jean

$$\frac{\$_{off-quality}}{garment} = \left(\frac{\$_{fabric}}{garment} + \frac{\$_{trim}}{garment} + \frac{\$_{labor}}{garment} + \frac{\$_{energy}}{garment} + \frac{\$_{garment\ finish}}{garment}\right) x\ factor_{off-quality}$$

$$Ex.)\ \frac{\$}{garment} = (\$3.7340 + \$1.3795 + \$0.5732 + \$0.0375\ + \$0.0993)\ x\ 0.03$$

$$= \$0.1747$$

Table 4.41 – Apparel Conversion Process Yield Cost per Denim Jean

	$/gmt
China	0.1747
Colombia	0.1752
Guatemala	0.1799
India	0.1544
United States	0.3979
Vietnam	0.1663

The costs of capital for denim jeans can be calculated by using Equation 4.40. The 3% capital rate is applied to fabric, trims, direct labor, indirect labor, energy, garment finishing, and process yield costs in apparel operations. The example following Equation 4.40 calculates capital costs for sourcing from China. Exit-factory values can be calculated using Equation 4.32, which is followed by an example calculation for sourcing from China.

Equation 4.40 – Capital Cost per Denim Jean

$$\frac{\$_{capital}}{garment} = \left(\frac{\$_{fabric}}{garment} + \frac{\$_{trim}}{garment} + \frac{\$_{labor}}{garment} + \frac{\$_{energy}}{garment} + \frac{\$_{garment\ finish}}{garment} + \frac{\$_{off-quality}}{garment}\right) x\ Capital_{rate}$$

$$Ex.)\ \frac{\$_{capital}}{garment} = (\$3.7340 + \$1.3795 + \$0.5732 + \$0.0375\ + \$0.0993 + \$0.1747)\ x\ 0.03 = \frac{\$0.1799}{garment}$$

Equation 4.41 – Exit-Factory Cost per Denim Jean

$$\frac{\$_{exit-factory}}{garment} = \frac{\$_{fabric}}{garment} + \frac{\$_{trim}}{garment} + \frac{\$_{labor}}{garment} + \frac{\$_{energy}}{garment} + \frac{\$_{garment\ finish}}{garment} + \frac{\$_{off-quality}}{garment} + \frac{\$_{capital}}{garment}$$

$$Ex.)\ \frac{\$_{exit-factory}}{garment} = (\$3.7340 + \$1.3795 + \$0.5732 + \$0.0375\ + \$0.0993 + \$0.1747 + \$0.1799) = \$6.1780$$

Export tax rebates and FOB values can be calculated in a similar manner to t-shirts. The table below summarizes exit-factory, rebate, and FOB values for all countries.

Table 4.42 – Exit-Factory, Export Tax Rebate, and FOB Values per Denim Jean

	Exit-Factory	Rebate	FOB Value
	$/gmt	$/gmt	$/gmt
China	6.1780	0.0000	6.1780
China (w/ rebate)	6.1780	0.9267	5.2513
Colombia	6.1950	0.0000	6.1950
Guatemala	6.3619	0.0000	6.3619
India	5.4607	0.0000	5.4607
United States	14.0695	0.0000	14.0695
Vietnam	5.8818	0.0000	5.8818

The transportation costs for a denim jean can be calculated in a manner similar to a t-shirt, with the exception that 17,500 garments can be stuffed in a forty-foot container. Duty costs paid for entry to the United States can be calculated in the same manner as t-shirts, with the exception that denim bottoms are subject to a 16.6% duty rate, compared to 16.5% for t-shirts. The transportation and landed costs are summarized by Table 4.43 and Table 4.44, respectively.

Table 4.43 – Maritime Transit Times in days and Transportation Costs per Denim Jean

Country	Transit (days)	$/40ft container	$/gmt
China	13	2780	0.2826
China (w/ rebate)	13	2780	0.2648
Colombia	4	2644	0.2749
Guatemala	3	2771	0.2856
India	18	2979	0.2805
United States	0	0	0.0000
Vietnam	19	3100	0.2957

Table 4.44 – Landed Cost for Denim Jeans

	$/gmt
China	7.4862
China (w/ rebate)	6.3878
Colombia	7.4983
Guatemala	6.6475
India	6.6477
United States	14.0695
Vietnam	7.1540

4.8 Yarn-Forward vs. Fabric-Forward

Some countries within this study could benefit from using imported fabric raw material inputs. Equation 4.42 accounts for the transportation costs related to using foreign fabric inputs. Assuming that 17,000 kilograms of denim fabric can be shipped in a forty-foot container (Panjiva, 2009), the landed cost of denim jeans are summarized in Table 4.45.

Equation 4.42 – Fabric Shipping Costs

$$\frac{\$}{m_{fabric}} = \left(\frac{container}{kg_{fabric}} x \frac{\$}{container} x \frac{kg}{m_{fabric}}\right)$$

Table 4.45 – Yarn-forward and Fabric-forward Garment Costs

Fabric Source	Garment Operations	$/gmt
United States	Guatemala	6.6987
Guatemala	Guatemala	6.6475
United States	Colombia	7.6410
Colombia	Colombia	7.4983
China	Vietnam	7.1173
Vietnam	Vietnam	7.1540
China	China	6.3878
India	India	6.6477
United States	United States	14.0695

4.9 Landed Cost for Jeans Using Ring Spun Yarn

The cost structure changes when ring spun yarn is used instead of open-end yarn. It is important to note how cost advantages are gained or lost through the use of different raw materials. The landed costs for each country can be obtained by using the yarn costs listed in Table 4.7, and these are listed below.

Table 4.46 – Jeans Landed Cost Using Ring Spun Yarn

Fabric Source	Garment Operations	$/gmt
United States	Guatemala	8.1068
Guatemala	Guatemala	8.0819
United States	Colombia	9.2784
Colombia	Colombia	9.1663
China	Vietnam	8.2160
Vietnam	Vietnam	8.2732
China	China	7.3217
India	India	7.7350
United States	United States	14.4509

4.10 Discussion of Supply Chain Costs

The sections above document the costs associated with sourcing a t-shirt and denim jeans through an entire textile and apparel supply chain for multiple countries. The landed costs are the summation of many costs accrued through the many processing steps. By looking at the different inputs and processes it is possible to see how they make countries and regions lose or gain competitiveness. The following sections describe the major differences in cost structures.

Some resources are used throughout numerous textile and apparel processes, including labor, energy, water, and steam. To little surprise, it can be seen that labor rates are much higher in the lone developed nation of the study (United States), compared to the developing and under-developed nations of China, Colombia, Guatemala, India, and Vietnam. In this second group of nations, it is evident that India and Vietnam have more competitive wages.

Energy rates are high in Guatemala, and there seems to be little price relief in that country and other Central American countries, given their dependence on thermal energy created by bunker fuels which are dependent on oil prices. Vietnam offers the lowest energy rates, but could be forced to increase rates to attract investment for much needed power projects to meet increasing energy demand. The United States offers competitive energy rates as well.

Steam costs vary slightly from one country to the next. Water rates vary from one facility to the next even within the same country. Water prices are different based on whether water is drawn from private wells or supplied by local municipal agencies. Treatment of water prior to process use also influences water costs.

Given the information on resource costs above it is natural to expect textile operations and their costs to vary from one country to another. Ring spun and open-end yarns have significantly different cost structures. The most significant cost driver is the price of cotton. The United States has a significant advantage over China in the prices of cotton, while India has slightly higher cotton prices than the US. Ring spinning manufacturing costs are higher than those for manufacturing open-end yarn. The cost of labor required for ring spinning makes US yarn prices less competitive, but cotton prices make it more competitive. India has access to relatively competitive cotton prices and low operational costs. Of the three countries, the US has the most competitive open-end yarn prices.

Knitting operations have a relatively small impact on price, given that at least 94% of knit fabric cost is accounted by yarn costs. Yarn costs account for lower percentages of total costs for weaving operations, but they are still the main driver. Dyes and auxiliary chemicals are the most significant cost in both dyeing for knit piece goods and indigo rope dyeing.

Maritime transportation costs are similar for all countries in the study, except for the United States which does not have this cost within their supply chain. Trade costs and policies do impact landed costs in a very important manner. Export tax rebates issued by the Chinese government in the order of 15% of exit-factory prices tilt costs to their favor. Countries that have free trade agreements, such as Guatemala benefit greatly from preferential tariff rates which make their products more cost competitive. The approval of the pending US-Colombia Free Trade Agreement could make Colombia a significant supplier of apparel to the US, given their competitive labor wages and geographic proximity.

Landed cost rankings for all countries follow similar patterns for t-shirts and denim jeans. Landed costs have been calculated for China with and without export tax rebates. With export tax rebates China provides the most competitive landed cost for t-shirts. India, Vietnam, Guatemala, China without export tax rebates, Colombia, and the United States follow.

Similar ranking holds true for denim jeans of open-end yarn, except that Guatemala ranks more favorably than both India and Vietnam. This can be attributed to highly cost competitive open-end yarn input costs from the US being paired with Guatemalan apparel conversion labor and duty free access advantages. Denim jeans of ring spun yarn follows similar patterns with China being the most cost-competitive supplier, followed by India, Guatemala, Vietnam, Colombia, and the

United States. It is important to note Guatemala, Colombia, and Vietnam have very similar final landed costs when using imported fabric-forward inputs compared to yarn-forward inputs as detailed in Table 4.45 and Table 4.46.

4.11 Retail Operations and Simulations

Retailers incur significant profitability erosion when they are forced to move aging inventory at discounted prices. This surplus inventory can occur when their sales forecasts are overly optimistic compared to real sell-through. The other side of the situation is when forecasts are pessimistic; resulting in stockouts and poor customer service levels. The latter cost is more complex to measure in purely financial terms.

The costs associated with having too much or too little stock are obtained by running simulations. The tool used in this study for simulations is the Sourcing Simulator™. By entering the landed cost of goods from the sourcing cost model and each country's respective transit time plus a four week manufacturing lead time, performance metrics can be obtained through the final link in the supply chain.

4.11.1 Retail Performance Simulations for T-Shirts

Simulations were set in order to evaluate the performance of different supplying countries. Information related to the Buyer's Plan, Cost Data, Markdowns and

Promotions, Sourcing Strategy, Vendor Specification, and Consumer Demand make up the retail scenario. The following paragraphs illustrate the retail scenario tested.

The Buyer's Plan was set to have a 20-week selling cycle with an average of 9800 units planned to be sold per week. The anticipated weekly demand was set to mid peak. The product offering was set to a single style in six colors and five sizes for a total of 30 stock keeping units. The initial and replenishment cost were set equal to the landed cost of each country, with a ten percent inventory carrying cost and a $20,000 program overhead cost. The retail selling price was set to ten dollars per unit.

The selling season included two planned promotions and one planned markdown of 25% and 75% price reductions, respectively. Each event had a duration of one week. The first promotion was set to take place on week five, the second promotion on week fifteen, and the final markdown for the last week of the selling season.

The manufacturer was assumed to be a perfect supplier, and therefore there is no variation in delivery times or quantities shipped by the supplier compared to what is ordered. Unlike supplier performance, a forecast error of 25 percent was assumed as well as SKU mix error with a 30 percent error in color mix, 30 percent error in size mix, and no style error since a single style was modeled.

The optimal performance for each supplier was found by maximizing adjusted gross margin and service levels. With an initial inventory of fifty percent of the plan delivered before the start of the selling season, it was found that reordering twice within the selling season from both supplying countries performed better than traditional sourcing and reordering once. The performance metrics for the most responsive and cost-competitive supplier from the Western Hemisphere and Asia are summarized in Table 4.47 and Table 4.48 below.

Table 4.47 – Optimal Retail Performance Metrics for T-Shirts of Open-End Yarn

	Guatemala	China (with ETR)
Manufacturing Lead Time	28 days	28 days
Transit Time	8 days	18 days
Unit Costs	$1.31	$1.21
Service Level	96.30%	93.10%
Adjusted Gross Margin	$1,956,722	$1,920,146

Table 4.48 – Optimal Retail Performance Metrics for T-Shirts of Ring Spun Yarn

	Guatemala	China (with ETR)
Manufacturing Lead Time	28 days	28 days
Transit Time	8 days	18 days
Unit Costs	$1.48	$1.32
Service Level	96.30%	93.10%
Adjusted Gross Margin	$1,910,930	$1,890,676

4.11.2 Retail Performance Simulations for Denim Jeans

Similar simulations were run to determine retail performance for denim jeans. The Buyer's Plan was set to have a 20-week selling cycle with 9800 units planned to sale per week. The anticipated weekly demand was set to mid peak. The product offering was set to a single style in two colors and thirty sizes for a total of 60 stock keeping units. The initial and replenishment cost were set equal to the landed cost of each country, with a ten percent inventory carrying cost and a $100,000 program overhead cost. The retail selling price was set to twenty five dollars per unit.

The selling season included two planned promotions and one planned markdown of 25% and 75% price reductions, respectively. Each event had a duration of one week. The first promotion was set to take place on week five, the second promotion on week fifteen, and the final markdown for the last week of the selling season.

The manufacturer was assumed to be a perfect supplier, and therefore there is no variation in delivery times or quantities shipped by the supplier compared to what is ordered. Unlike supplier performance, a forecast error of 25 percent was assumed as well as SKU mix error with a 30 percent error in color mix and 30 percent error in size mix.

The optimal performance for each supplier was found by maximizing adjusted gross margin and service levels. With an initial inventory of fifty percent of the plan delivered before the start of the selling season, it was found that reordering twice within the selling season performed better than traditional sourcing and reordering once. The performance metrics for the most responsive and cost-competitive supplier from the Western Hemisphere and Asia are summarized in Table 4.49 and Table 4.50.

Table 4.49 – Optimal Retail Performance Metrics for Denim Jeans of Open-End Yarn

	Guatemala	Guatemala using US Fabric	China (with ETR)
Manufacturing Lead Time	28 days	28 days	28 days
Transit Time	8 days	8 days	18 days
Unit Costs	$6.65	$6.70	$6.39
Service Level	95.80%	95.80%	93.10%
Adjusted Gross Margin	$3,949,053	$3,935,658	$3,865,111

Table 4.50 – Optimal Retail Performance Metrics for Denim Jeans of Ring Spun Yarn

	Guatemala	Guatemala using US Fabric	China (with ETR)
Manufacturing Lead Time	28 days	28 days	28 days
Transit Time	8 days	8 days	18 days
Unit Costs	$8.08	$8.11	$7.32
Service Level	95.80%	95.80%	93.10%
Adjusted Gross Margin	$3,565,969	$3,557,932	$3,613,764

5 Conclusions

The analysis of the textile, apparel, and retail supply chains showed there are numerous cost factors that need to be accounted for in order to understand cost structures. Each process has its own set of factors to which its total costs are highly sensitive to. There are certain issues that can change the landscape of textile and apparel activity.

Access to raw materials, especially yarns and therefore cotton, can largely impact a supply chain's ability to supply cost competitive products. As stated previously, cotton drives the largest part of yarn cost. For this reason, knitters and weavers can benefit greatly by having access to yarn that uses US or Indian cotton, as market prices for both are much lower than those in China.

Free trade agreements and their provisions for duty free access to the United States market can have a great impact on landed costs. Without preferential duty rates Colombia is the least cost effective foreign supplier of t-shirts and jeans. If the pending free trade agreement with Colombia granted the duty-free access to the US markets, this would make them much more competitive. Colombia could supply t-shirts at costs more competitive than Guatemala, and come to a close second for some types of denim jeans after China.

A more complicated trade issue is the export tax rebates given to the textile and apparel industry by the Chinese government. In the case that China is found to be at fault for this practice in the World Trade Organization it could be forced to eliminate such rebates or face commercial retaliation. The elimination of the 15% rebate would significantly reduce the competitiveness of Chinese textiles and apparel products. Under those circumstances China would be less competitive than India, Vietnam, and Guatemala in both product categories.

The apparel industry is highly dependent on labor wages and its stability. Labor rates have risen considerably on both sides of the Pacific in recent years, including China and Central American nations. Increases in labor costs can reduce a country's ability to compete as a supplier of apparel products. Along with access to raw materials, the apparel industry is highly dependent on labor wages.

Sourcing decisions require exhaustive landed cost analysis, as well as supplier responsiveness. This study has shown that labor wages are very important to apparel operations, but much more than this factor needs to be considered in sourcing decisions. Access to raw materials, trade agreement provisions, government subsidy policies, and stability of resource costs must be considered.

The cost model developed in this study provides insight into entire supply chain cost structures. This tool can assist companies to look both forward and backwards outside their area of operation and have a broader appreciation of the markets they participate in. By using this model, companies can identify opportunities and threats to their business models. They can identify broad issues related to their strategic partnerships with suppliers and customers and investigate these in more detail. By pairing supply chain costs and their transportation time and manufacturing responsiveness, analyses can be performed to identify scenarios where responsiveness is more critical than cost effectiveness. This analysis for retail performance can be performed using the Sourcing Simulator™ software system and can help identify additional business growth opportunities.

Employing the cost model developed in this study along with the Sourcing Simulator™ has shown that speed and responsiveness can outweigh landed cost price of goods in the scenarios tested. Retailers sourcing from supply chains that use U.S. yarn-forward or fabric-forward inputs and Latin American apparel operations can see higher service levels and adjusted gross margins compared to when sourcing from more cost-effective but less responsive suppliers from Asia.

6 Future Works

There are numerous opportunities for future research based on this research. This study analyzed the supply chain costs of two major apparel products. This approach can be extended to much more products. Many more yarn counts, fabric structures, and garment styles can be modeled. There are numerous amounts of products that can be analyzed additionally. Each one of the processing steps and their cost structures can be dissected and analyzed further to enable the costing of a wider amount of products. More countries can also be included in future analysis.

Additional simulations can be run to measure manufacturing response times and transportation times. Further analysis of the effects of end-consumer and retail store interaction can be studied. Forecast error, drift, SKU mix, and other retail performance characteristics can provide insight to optimize sourcing decisions.

This study finds that it is feasible for the Western Hemisphere textile and apparel complex to successfully compete with speed and responsiveness. Although this concept is powerful, it is necessary to take into account the region's limitation in access to raw materials. It would be beneficial to identify the shortcomings of fabric availability in the region.

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