SUPPLY CHAIN DESIGN AND SITE SELECTION FOR THE EXPANSION OF INTERNATIONAL MANUFACTURING CAPACITY

By

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ABSTRACT

The research conducted for this thesis was performed at “Company X”, a U.S.-based engineered goods manufacturer. This project focused on Company X’s overall manufacturing strategy, with an emphasis on how global expansion of manufacturing can allow the company to achieve greater international sales growth.

Company X’s current strategy for supplying non-U.S. markets has largely relied on U.S. manufacturing and assembly, followed by exporting of finished goods. Due to a desire to increase international sales and a need to address tariff and non-tariff barriers in certain key markets, Company X must now evaluate opportunities for in-country manufacturing and assembly in its target markets. This project seeks to evaluate the high-level financial and operational risks of expanding Company X’s current manufacturing operations through the use of three types of analysis:

1) A single-site cost analysis of material and inventory flow to an international site;
2) A global manufacturing capacity plan to serve regional markets; and,
3) An evaluation of qualitative risk factors affecting potential site selection.

The single-site model involves the development of a simplified cost model. This model demonstrates the cost-competitiveness of each supply chain design alternative for serving a single international site, including the sensitivity of the model to changes in key cost drivers. The global model builds on the results of the single-site model and evaluates the opportunities for international sites to serve both in-country and regional demand for the top markets Company X is targeting.

The site selection model addresses the operational and socio-political risks associated with investing in operations in new markets. The results of this analysis provide Company X with additional insights into which markets represent the best and lowest-risk opportunities for operational growth in the near future.

Recommendations provided in this thesis will be used by Company X to expand and develop their new global manufacturing strategy and to achieve its goal of rapid international sales growth.

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I would also like to thank Drs. Don Rosenfield and David Simchi-Levi for serving as my faculty advisors during my internship. Their input helped to shape this project in content and relevance and to keep it on track throughout the course of the internship.

Finally, I would like to thank my family and friends for their support over the past two years, as well as the many that came before LFM. Special thanks must go to Brian, for his help in managing my life and maintaining my sanity during LFM. And, of course, the utmost thanks go to my mom, who listens to my venting, brags about my accomplishments, and has never doubted that I could achieve all of my goals and dreams.
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BIOGRAPHICAL NOTE

Aimee Constantine was born and raised in Grosse Pointe, Michigan. Aimee attended the University of Michigan - Ann Arbor, graduating with a B.S. in Mechanical Engineering and a B.S. in Industrial Engineering in 2003. While at the University of Michigan, Aimee completed three internships in manufacturing and product development at Cummins Inc., leading to her acceptance into Cummins’ Manufacturing Development Program after graduation. The program allowed Aimee to gain experience in operations management, manufacturing, process engineering, distribution, and Six Sigma process improvement through rotational assignments in Indiana, Tennessee, and England. Prior to her acceptance into the MIT Leaders for Manufacturing Program, Aimee was the lead process engineer involved in new process development for the 2007 launch of the 6.7L diesel engine for Chrysler’s Dodge Ram product line. While in this role, Aimee also completed an M.S. in Industrial Engineering from Purdue University, graduating in 2007.

Upon graduation in June 2009, Aimee will take a position as an Operations Manager in the Pathways Operations program at Amazon.com.
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In order to protect proprietary company information, the data presented throughout this thesis does not represent actual values used by Company X. The dollar values and other performance measures have been disguised and the many details have been removed in order to protect competitive information.
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CHAPTER 1: INTRODUCTION

Companies seeking international sales growth face many challenges in selecting a supply chain that will provide them with market access at a minimal level of cost and risk. Increasing cost-of-living in many emerging markets offer opportunities for companies seeking demand growth, but the limited availability of infrastructure, the variability of exchange rates, and the unpredictable economic growth of new markets are just some of the risks that threaten a company’s success in expanding globally through manufacturing and distribution. Any company considering global expansion must evaluate the impacts on both its cost structure and the demand for its products, as well as the operational, financial, and socio-political risks it will encounter within the context of the company’s own corporate strategy. Each company will define its own level of acceptable risk and its ability to invest in growth in new markets. This thesis evaluates the supply chain design and site selection process at “Company X”, a U.S.-based manufacturer of premium, engineered goods, based on an analysis of Company X’s globalization strategy and overall corporate objectives.

1.1 Company Overview

Company X, headquartered in the mid-western U.S., began as a custom fabrication shop for engineered products in the early part of the 1900’s. The company grew significantly during World War I by supplying products to the military, but as a commercial goods manufacturer, the company suffered during the Great Depression. During this time, many competitors left the market, unable to survive the massive declines in demand. For this reason, Company X was able to secure a significant share of the government demand for its products in World War II. Between 1945 and the early 1980’s, the company encountered many successes and challenges in new product introduction, the increased pressure from global competitors, and several changes in internal management structure.

In the early 1980’s, Company X embraced a new corporate strategy that focused on customer loyalty and an emphasis on traditional branding and design. From the mid 1980’s through 2006, Company X achieved an uninterrupted series of annual growth at a CAGR exceeding 16%, as the company’s production volume increased by a factor of almost half of that amount, as shown in Figure 1.
Today, Company X is a well-respected leader in its segment of the industry. While other companies have succeeded at producing lower-cost, higher-volume products to serve a larger share of the overall market, Company X has focused on creating higher value, custom products at a higher profit margin. The company has been able to maintain a respectable profit margin on products due to its marketing and customer relationship management, as well as because of an increased focus on product customization and tailoring. As the company has reached its limits within the mature U.S. market, Company X has focused more of its attention on international sales growth with moderate success. As shown in Figure 2, Company X currently sells 69% of its products in the U.S. market. The challenge now facing Company X is to find a way to continue to serve its premium market in the U.S. while addressing the need to expand internationally to maintain financial and competitive growth.
1.2 Problem Statement

With few exceptions, Company X has historically manufactured and assembled products in the United States and has exported fully assembled products to other countries. Due to declining U.S. demand and the possibility of increased international sales, Company X is expecting international sales to grow at a rate that will exceed domestic sales growth. As international sales volumes become more significant, Company X must now review its manufacturing strategy for providing products to non-U.S. markets due to improved conditions for local economies-of-scale in production and opportunities to reduce high import taxes and tariffs.

Opportunities exist for Company X to gain from international expansion based on a few key changes in the cost structure of their products. First, in many countries, Company X can incur lower tariffs and taxes for locally-assembled and locally-manufactured components and assemblies. Second, because the demand for Company X’s products has increased in some regions, increased economies of scale could now be achieved in foreign plants, decreasing the per-unit production cost and increasing returns on capital investments in capacity expansion.
Although there appear to be many benefits to international expansion, Company X must also address several challenges that have previously discouraged the company from considering expansion investments. These challenges include the following:

- Limited international manufacturing capacity:
- Removing barriers to a realistic customer price (tariffs, taxes)
- Maintaining an American-made brand image

Efforts are being made to determine what additional international capacity is required, and where it should be placed to support further international growth. The recommendations from this research will be reviewed in Company X’s evaluation of opportunities to increase non-U.S. sourcing and manufacturing.

1.3 Project Objectives

This internship research project was developed in coordination with the MIT Leaders for Manufacturing Program to investigate the challenges and benefits of increasing international manufacturing of Company X’s products. The primary goals were to:

1) Develop a framework for evaluating supply chain strategies for serving non-U.S. demand through expansion of international manufacturing; and

2) Incorporate financial, operational, and other risk factors into models for use in identifying optimal placement of future international manufacturing capacity.

The research conducted in the six-month internship focused on:

- Identifying the key drivers in Company X’s supply chain impacting total landed cost,
- Evaluating the impact of variability in these drivers on relative total cost;
- Creating high-level recommendations for minimizing risk and reducing cost in the supply chain for international markets; and
- Assigning value to the emotional/subjective factors affecting Company X’s supply chain design decisions.

From this analysis, recommendations have been developed regarding the future state of international manufacturing, to support the expected growth in sales volumes. These analyses include high-level
recommendations for assembly, sourcing, and logistics for non-U.S. markets based on financial and marketing factors. There are also recommendations for new international manufacturing site selection based on the weighing of costs, business conditions, risk, and workforce/facility concerns.

1.4 Project Methodology

**Strategy**

This project has focused on data collected from Company X’s operations at its one current international manufacturing facility, as well as at six domestic manufacturing facilities, to determine the factors affecting Company X’s supply chain approach for delivering products to international markets.

From this analysis, models were developed to address the following three concerns (as shown in Figure 3):

1) The material flow/inventory process for international operations, considering cost and other implications of selecting semi-knockdown (SKD), complete knockdown (CKD), and direct shipment strategies (single-site),

2) A global model for future manufacturing capacity and flow within a network of international manufacturing sites (multi-site), and

3) A site selection model to evaluate potential locations for future manufacturing facilities.

<table>
<thead>
<tr>
<th>Phase 1: Material Flow and Inventory Model</th>
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<tr>
<td>- Sourcing, kitting, and consolidation process for international sites (such as SKD, CKD, direct shipment)</td>
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<td>- Inventory levels in supply chain</td>
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<td>- Weighted assessment of potential locations</td>
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<td>- Evaluation of risk factors affecting location decisions</td>
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Figure 3 - Project Methodology

**Constraints and Assumptions**

Due to the complexity of modeling global production of multiple products across all markets, it was necessary to narrow the scope of the analysis through a series of limiting assumptions. These
assumptions address the markets, models, and facility configurations considered in the supply chain models evaluated in this research.

Markets

The selection of markets that would be considered in this analysis was done based on three factors:

- The current limitations of sales growth due to cost impacts of high import taxes and tariffs;
- The potential for in-market sales growth and economies of scale in manufacturing and distribution; and
- The potential for low-cost manufacturing operations and distribution.

A key barrier to the entry of Company X into potential growth markets is the existence of high tariffs and taxes on imported goods. The cost analyses conducted in this research evaluate the impact these tax and tariff expenses have on the selection of a manufacturing strategy. For this reason, the markets considered were limited to those markets where taxes and tariffs have been a limiting factor in Company X’s growth into the market. These countries include: Brazil, China, India, Thailand, and Indonesia.

Although the European market makes up 16% of total annual sales, the tariffs on U.S. imports into the Europe are approximately 8% of product value and do not have a significant impact on the demand for Company X’s products. The European market has already grown to a level of demand that could have economies of scale in manufacturing without significant new growth, so these opportunities were not evaluated within the context of this research.

The availability of low cost labor and lower operating costs extended the scope of the research to a few countries that neighbor growth areas or share free trade agreements or lower inter-country tariffs. For example, Thailand does not currently represent a country that is being targeted by Company X as a growth area, but the country has industry-related manufacturing capabilities and lower labor costs than China or India.

Product Offerings

While there is the potential for Company X to develop unique product offerings for international markets, the product-specific customer demand and the design and manufacturing requirements for this new product are still unknown. The analysis described in this thesis assumes that Company X
does not make a significant change to its current product offerings in order to achieve sales growth. Specifically, there are 6 key products (Products B, D, F, S, T, and V) which each offer a wide variety of customer-specified options. For the sake of analytical simplicity, we did not consider product options, and cost and manufacturing requirements will be presented as an average across all configurations of each model.

Facility Configurations

There are many methods Company X could use to serve international markets. These methods vary in levels of upfront investment, ongoing coordination, and onsite manufacturing complexity, as shown in Figure 4. These methods include: 1) Complete Knock Down (CKD), 2) Semi-Knock Down (SKD), and 3) Part-by-Part Assembly (PPA).

![Figure 4 - Increasing Complexity of Manufacturing Capabilities](image)

**Complete knock down (CKD)** represents a supply chain model where unassembled components are kitted into production sets in one country and shipped to another country, where they are assembled and delivered to the local market. Kits may be comprised of a single product's components or a lot-size appropriate for the assembly operation.

**Semi-knock down (SKD)** is similar to CKD in that kits are created, but in SKD, components are assembled into larger subassemblies in the source country, before they are kitted for shipment to the destination country. This model further decreases the complexity of the assembly operations in the destination country.

**Part-by-Part Assembly (PPA)** is a term that refers to a higher level of manufacturing complexity. Sourcing may be handled by employees at the international location, and parts are usually delivered separately, as opposed to in production kits. There may be an increase in the volume of
components sourced from suppliers in the international country, and some in-house manufacturing may also develop on-site.

1.5 Thesis Organization

The first section of this thesis, covered in Chapters 1-4, is devoted to providing background on Company X, its industry, and the current research conducted on international site selection and global manufacturing strategy. Chapter 1 has described the intent and approach of this research. Chapter 2 provides background information on Company X’s current marketing and supply chain strategies. Chapter 3 describes the industry factors impacting Company X’s supply chain design decision-making. Chapter 4 provides insight into previous research conducted on international supply chain design and site selection which helped to shape the models used to evaluate Company X’s expansion opportunities.

The second section of this thesis, covered in Chapter 5-7, focuses on the analytical modeling conducted to evaluate the costs and risks associated with several international manufacturing strategies. Chapter 5 describes the development and output of the Single-Site Material Flow Cost Model. Chapter 6 describes the development and output of the Global manufacturing Capacity Model. Chapter 7 describes the development and output of the Site Selection Analysis.

The final section of this thesis views the results of the previous analysis in the context of Company X’s corporate strategy and conditions within the industry. Chapter 8 outlines organizational challenges to implementing change within Company X which could affect Company X’s ability to act on its new globalization strategy. Chapter 9 provides the specific capacity expansion recommendations derived from the above analysis, as well suggested steps to implement the recommended strategy. Chapter 10 provides the high-level overview of the findings from this research, including the relevance of this research to others outside of Company X and recommendations for further research in the field of globalization of operations.
CHAPTER 2: COMPANY BACKGROUND

Decision-making regarding the global expansion Company X is considering must be shaped by the business objectives and positioning of the company within its industry and the markets it is planning to serve. The optimal supply chain design will provide the best combination of responsiveness, coordination, and efficiency to meet the expectations of both internal stakeholders and customers. For Company X, these objectives can be summarized into two categories – Marketing, and Manufacturing and Supply Chain. Company X has developed a strong brand image and position within its mature markets and this reputation must be considered in determining which new components to the current supply chain network can provide the optimal solution for increasing sales and profitability in the new target markets.

2.1 Marketing Strategy

The two components of the marketing strategy which will have the largest impact on the globalization strategy are its premium market segmentation and strong brand image.

*Premium Market Segment*

Over time, Company X has evolved into a manufacturer of premium products within its industry. This has involved a significant investment in both technology development and product styling. Company X has been able to maintain attractive profit margins on its products because the company has traditionally focused on developed markets, where consumers focus on features and product performance. As a premium goods manufacturer, the availability of suppliers of key components has sometimes been limited due to the close relationship that the company must develop with the supplier and the quality and conformance which must be maintained to meet customer expectations.

*Brand Image*

One important driver of Company X’s past success has been derived from a strong brand image and reputation among its loyal customer base. The image Company X has developed is one of a strong commitment to the American lifestyle. Even outside the U.S., customers relate to and demand the American brand image. Impacts of this branding include less globalization of sourcing that seen at competitors and also a concentration of internal manufacturing to the U.S. Only limited information has been available in the past to document what characteristics customers feel align with
the American brand image. Due to the importance of brand preference in customer selection, many operational decisions have been guided by the need to maintain the American-based appearance of the company.

As a result of the need to maintain the brand image, especially among the large U.S. customer base, Company X has made a commitment to retain all U.S. manufacturing and assembly for products intended for sale in the U.S. The analysis documented in this thesis will only evaluate the investments Company X could make to increase manufacturing capacity for serving non-U.S. markets.

2.2 Manufacturing and Supply Chain Strategy

Company X currently has a small domestic manufacturing network and limited international assembly and sourcing experience. These resources, documented below, will demonstrate the achievable scale of a future operation, based on current internal capabilities.

**Main Production Site Locations and Capabilities**

Company X currently operates one technical center and one corporate headquarters in the Midwest United States. Final product assembly takes place at three U.S. assembly facilities (Assembly Plants A, B, and C), while component and sub-system production takes place in four U.S. manufacturing plants (Component Plants D, E, F, and G), as shown in Figure 5. Production of the six current product models (Products 1, 2, 3, 4, 5, and 6) is assigned to each of the final assembly sites, with no overlap. The component manufacturing sites serve all three assembly sites.
International Manufacturing

In addition to its network of U.S. facilities, Company X also operates a low-volume assembly plant in Brazil (Assembly Plant M) to produce products solely for the Brazilian markets. This site, established in 1997, allows Company X to assemble products within an existing Free Trade Zone, decreasing the overall level of tax and tariff charged for the importation of the product into the country from 155% to 30% of total product value.

Production at this site consists of the assembly of products from kits of components from the U.S., consistent with the Complete Knockdown (CKD) model described in Section 1.4. The U.S. manufacturing and assembly facilities currently serve the Brazilian site by coordinating the sourcing of all components from their primary suppliers and manufacturing the majority of in-house components, according to the current domestic manufacturing process. One exception to this process is the need to source a small number of components within the Brazilian market, to meet local content requirements. Currently, within the guidelines for the Free Trade Zone, this local content requirement is low enough to allow Company X to limit in-country sourcing to a small number of non-critical components that have limited impact on performance and appearance.
The current material flow of the CKD model is shown in Figure 6.

Benefits of the CKD model include:

- Significant tariff/tax reductions over delivery of completely built-up (CBU units)
- Increased market potential due to lower retail price
- Lower investment risk than for complete manufacturing functionality

Drawbacks of the CKD model include:

- Higher per-unit cost due to increases in handling and transportation
- High lead times for components and greater inventory carrying costs
- Higher capital investment in additional assembly capacity
- Higher coordination costs in managing global operations

**Sourcing**

Traditionally, Company X has relied on in-house manufacturing of several critical components and high percentages of U.S. sourcing of purchased components. Currently, approximately 3.4% of purchased material enters the company as raw material for use in in-house manufacturing. With the additional conversion costs assigned to manufacturing, this amounts to approximately 6% of component value in the typical Company X product. Approximately 61% of all purchased components are sourced from U.S. suppliers, as an average across the six product models that range
from 46 to 74% of total purchased component value. Non-U.S. sourcing of components is limited to small percentages per supplying country. Based on the number of high-cost country sources in the supplier list and the small percent contributions from low-cost countries, it is clear that Company X has not made any significant efforts to trend toward low cost sourcing.

2.3 Chapter Summary

Company X’s powerful brand image and premium segmentation have been sources of competitive advantage within the company’s current target markets. As the company expands its attention to new markets, it will need to evaluate whether the current branding can be supported by its efforts in these new markets, or is the branding must be modified to meet customer expectations in developing markets. The current supply chain network provides a long history of performance, but limited experience in international operations. These marketing and operational challenges will provide the lens through which Company X will view any potential global supply chain expansion options.
CHAPTER 3: DRIVERS OF INTERNATIONAL EXPANSION

For each company considering international expansion, there is a different set of factors driving this motivation. Companies which are mainly cost driven may seek lower labor and sourcing costs in low-cost countries, while companies focused on innovation may seek proximity to new customers in order to tailor products to the new customer requirements. Company X is currently faced with several reasons to consider international expansion, including: 1) international market growth; 2) potential reductions in trade compliance costs; 3) the high costs of exchange rate variability; 4) the advantages of low-cost labor; 5) opportunities for greater localized product development; and 6) the need to keep pace with competitors that are also expanding globally.

3.1 Market Growth

When looking at Company X's industry at the macro level, there are two key reasons that Company X must investigate opportunities to expand internationally. First, the market for its products in the U.S. has reached maturity, and there will be few opportunities for growth in the near future. Second, while the U.S. market has reached a plateau in sales volume, international markets are continuing to grow as the collective wealth of other populations increase and as the demand for Company X's products in those countries grows.

Maturity of US market

Across many industries, U.S. companies have lagged behind international competitors in globalization of their sales and manufacturing. This is due in part to the large size of the domestic U.S. market, which has allowed companies to become profitable without seeking customers outside the U.S. In the industry in which Company X competes, the U.S. market has matured, and apart from limited new user growth, there are very few opportunities for companies to maintain the rapid growth of previous years. The tapering off of demand in the U.S. market can be seen in the forecasted shrinkage of the U.S market in the next 4 years, as shown in Figure 7.
International Growth

To increase sales and driver greater economies of scale in production, Company X must seek opportunities to sell larger volumes of products to non-U.S. markets. Company X forecasts that, while U.S. demand for their product has stagnated, the company can achieve a more than 12% annual growth rate in international sales over the ten-year period spanning from 2004 to 2014, as shown in Figure 8. These increases will be achieved by tapping into growing international demand for its products due to increasing levels of disposable income in key markets. Further increases are anticipated if the company can decrease the customer price by reducing the manufacturing costs, as well as the impact of taxes and tariffs on the retail price.
Competitors

Within the overall market, Company X faces competition in the many forms, including: 1) large, high-volume manufacturers of lower-end products; 2) other major manufacturers of low-volume, premium products; and 3) a diverse set of small-scale manufacturers and assemblers of custom products. While large manufacturers of the lower end products in the market do not represent direct competition, they do have better economies of scale in manufacturing and also have larger potential markets due to larger numbers of customers in their price ranges. This is especially true in the developing markets being targeted by Company X, where a much smaller percentage of the population has enough disposable income to be in a position to consider purchasing one of Company X's products, as shown in Figure 9. For example, India may represent a large market growth opportunity for Company X due to its large total population, but less than .01% of the current customer base is buying products in the market segment in which Company X plays.
Competitors which have product lines in both the lower and high-end segments may have the opportunity to generate brand loyalty among new customers and retain these customers as they graduate to higher-end products during their lives. Brand loyalty has already been noted as a significant factor in this industry, so it is possible that Company X will have challenges in developing a customer base in developing markets without a lower end product line.

3.2 Tariff and Non-Tariff Barriers

**Tariffs/Taxes**

Taxes and tariffs represent a major barrier to entry for international companies looking to sell their products in local markets. In the industry in which Company X competes, tariffs can represent an additional cost of as much as 150% of the value of the product. In markets that are price sensitive, like those in the developing countries Company X is targeting, this price premium severely hinders the company’s ability to achieve sales volumes that justify efforts to sell in the markets. As shown in Figure 10, taxes and tariffs in Company X’s key markets are significant.
In-Country Manufacturing and Free Trade Zones

By manufacturing or assembling products in the country-of-sale, Company X can achieve reductions in taxes and tariffs that would represent a significant savings for the company, its retail partners, and the end customer, depending on how the savings are distributed across the three parties. One way Company X can position itself to be eligible for these tariff reductions is by establishing their operations within a designated free trade zone. The facility in Brazil is one example of this type of operation.

Free Trade Agreements

Free trade agreements are another way that Company X can exploit opportunities to reduce taxes and tariffs on its products. The formation of regional trade blocs, such as the North American Free Trade Agreement (NAFTA), present some benefits to manufacturers who develop regional manufacturing capacity. In the South American market, the formation of the Mercosur free trade agreement removed many trade barriers between Argentina, Brazil, Paraguay, and Uruguay. The Association of Southeast Asian Nations (ASEAN) offers similar advantages to its member countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

While free trade agreements currently play a major role in the overall cost of importation, there is a high level of uncertainty as to the long-term impact of these agreements as trade barriers are reduced over time. Due to a trend towards reductions in global inter-country tariffs in general and through free trade agreements, the impact of tariffs on the decision to manufacturing internationally is
decreasing. As noted by the World Trade Organization, there has been an overall decline in trade costs, such as tariffs and taxes, over the last half century, and this is expected to continue in the near future. (World Trade Organization 2008) Some economists believe that the benefits of free trade agreements may disappear altogether as economies become more globalized, eliminating this barrier-to-entry for foreign manufacturers seeking to enter new markets.

**Non-Tariff Barriers**

In addition to taxes and tariffs, companies also face challenges importing goods in the form of non-tariff barriers like local content requirements. In order to meet the government requirements for reduced tariffs, companies must often meet requirements for the quantity or value of manufacturing and assembly that is completed in the local market. For example, to meet Brazil's requirements for discounted tariffs, Company X must complete a minimum number of manufacturing operations, as well as a majority of all assembly operations, at their Brazil facility.

Local content requirements would also come into play if Company X were to look at utilizing a new global manufacturing facility to serve more than its home market. If a facility in India were to supply finished goods to the Chinese market, there would be tariff reductions, but only if the local content from India reached a minimum value established in the trade agreement between India and China. In its current state, Company X does not purchase enough materials from any one country to already fulfill local sourcing requirements, but opportunities to serve local markets from a regional manufacturing site could justify greater international sourcing.

Other non-tariff barriers include product standards, labor standards, and legal protection of intellectual property. Product standards, like those related to emissions standards, vary from country to country, and often drive different product design requirements for each country. Labor standards also vary across countries, with lesser-developed countries often maintaining less stringent and less regulated labor standards. For companies where intellectual property is a concern, legal protection of IP will be a non-tariff barrier that will restrict their entry into some countries where there is limited legal recourse against IP theft. While these non-tariff barriers are a concern for Company X, they represent less of a risk to Company X's international expansion strategy than local content requirements.
3.3 Exchange Rate Variability

As exchange rates fluctuate over time, American-made and exported products vary in their relative values when sold in international markets. For example, when the euro surges in relation to the U.S. dollar, a product sold by Company X will become cheaper in comparison to European products. Maintaining in-country manufacturing and assembly capacity represents an opportunity for Company X to create a natural currency hedge against these fluctuations.

![Historical Exchange Rates, 1990-Present](U.S. Federal Reserve 2009)

One limitation of this exchange rate hedging is that, when local currency declines sharply against the U.S. dollar, products with high imported U.S. material content still become very expensive relative to local products because the material cost is a significant component of the total cost. Between 1998 and 2002, the value of the Brazilian Real to the U.S. Dollar decreased by a factor of four, leading to a rapid decline in demand for Company X’s products.

To fully hedge against currency fluctuations, Company X would need to establish high levels of local sourcing, and it is not clear that Company X is in a position to establish the levels necessary to create
independence from currency effects. Order volumes of parts are low due to low overall production volumes, as well as high product mix, and past experience has shown that Company X has had difficulty getting supply contracts at low costs from capable suppliers. This will make any future international manufacturing site vulnerable to fluctuations in demand caused by exchange rate variability, and this risk must be taken into account in evaluating the future profitability of the site.

3.4 Low-Cost Local Production

As the demand for Company X’s products in developing countries increases, the business case for creating local operations becomes more realistic through the growth of local economies of scale. At low volumes, the high overhead of maintaining an international manufacturing site outweighs the benefits of low-cost labor. At higher volumes, the per-unit impact of overhead is decreased and, combined with low-cost local labor and tax and tariff benefits, Company X can justify creating redundant capacity in new markets. Labor costs in developing countries can vary widely both in direct labor costs and in fringe benefits offered to employees. As shown in Figure 12, the labor costs of the selected set of countries demonstrate the variability in costs, even within a single region.

<table>
<thead>
<tr>
<th>Country</th>
<th>Labor costs per hour (US$)</th>
<th>Fringe benefits (% labor cost)</th>
<th>Total labor cost per hour (US$)</th>
<th>Average real wage inflation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>$27.10</td>
<td>29%</td>
<td>$35.04</td>
<td>0.8%</td>
</tr>
<tr>
<td>China</td>
<td>$2.44</td>
<td>50%</td>
<td>$3.66</td>
<td>15.0%</td>
</tr>
<tr>
<td>India</td>
<td>$1.02</td>
<td>45%</td>
<td>$1.48</td>
<td>8.5%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>$0.50</td>
<td>25%</td>
<td>$0.63</td>
<td>-4.2%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>$3.30</td>
<td>15%</td>
<td>$3.80</td>
<td>3.5%</td>
</tr>
<tr>
<td>Singapore</td>
<td>$11.50</td>
<td>65%</td>
<td>$18.98</td>
<td>4.4%</td>
</tr>
<tr>
<td>Thailand</td>
<td>$1.70</td>
<td>40%</td>
<td>$2.38</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

Figure 12 - Selected Labor Rates and Inflation Rates(The Economist Intelligence Unit 2008)

One key consideration which must be made related to labors costs is labor rate inflation. In economies where cost of living is rapidly increasing, like that of China, the benefits of sourcing and manufacturing in-country are diminished year-over-year as the wage gaps between those countries and the U.S. decrease.
3.5 Opportunities for Localized Product Development

As mentioned above in Section 3.1, Company X may face challenges in entering new developing markets due to its lack of an entry product at the lower-end of the price scale. By expanding operations into international markets, Company X can take advantage of local resources and proximity to the customer through localized product development. Localized product development can allow Company X to avoid one main drawback of globalization – the over-standardization of product development. One approach to reducing complexity in a global network of plants could be to limit the product portfolio to a small number of products designed to meet a generalized set of international characteristics. This standardization can sometimes lead to a generic set of products which, in their attempt to appeal to all customers, fail to excite any customers in the individual markets. By diversifying the product mix based on local demand, Company X can design in value-added features that attract greater demand in each market.

3.6 Competitor Globalization

It may seem trivial to assume that because other competitors are globalizing, it is important for Company X to globalize. In contrast, this issue is far from trivial. Without local knowledge of customer requirements, the company would be at a disadvantage in product development and marketing against competitors with local positioning. Currently, Company X’s understanding of international markets is based on sales of current U.S. products at import price points, and on general industry data. It is difficult for Company X to make product portfolio decisions without having local input on potential new products that appeal to non-U.S. customers.

In addition to the product development disadvantages, Company X could also be at a disadvantage operationally by entering a market after major competitors have already set up operations. In the industry in which Company X competes, the other market leaders have already developed larger regional manufacturing and assembly operations. In the Brazilian market, these competitors have developed local supply bases composed of the most capable suppliers. When Company X has tried to approach these suppliers, the company has had difficulty developing these supplier relationships because of non-compete agreements and capacity limitations due to competitor volumes.
3.7 Chapter Summary

Company X has many reasons for choosing to explore international expansion at this time. Growth opportunities in new markets, improvements in the price and positioning of products in emerging markets, and reduction in operating costs and variability could be key drivers of profitability for the company in the near future, counteracting declines and stagnation in the U.S. market. Over time, Company X could also strengthen its competitive positioning and product offering by increased localization of operations and product development, further increasing the benefits that can be derived from globalization. These opportunities will come at a cost for Company X, in increased short-term operating and capital costs and also in increased complexity of coordination. In Sections 5 through 7, analysis will be provided regarding these costs for the several expansion methods which could be employed by Company X.
CHAPTER 4: LITERATURE REVIEW

Prior to developing any analytical models to evaluate expansion scenarios, a significant amount of research was conducted to better understand how companies have successfully developed international manufacturing strategies in the past, and what methods and tools should be used to weigh the options currently available to Company X. This research was focused in four main areas: overall global manufacturing strategy development, total cost model development, global network modeling, and development of qualitative site selection tools. While the research found is not totally consistent regarding which factors must be considered and the amount of risk which must be taken, they offer several different approaches for evaluating the many factors affecting this decision. Summaries of each category of research are provided below, and this research has been used to develop the models documented in the following three chapters.

4.1 Global Manufacturing Strategy Research

With regard to general manufacturing strategy research focused on globalization, there are two key themes with occur in the body of research that apply to Company X’s situation. First, there are a large number of references regarding the development of a global strategy, including the approach a company can take in determining the optimal course of action for increasing its global reach. The second topic which will become more relevant to Company X over time is the issue of operational coordination, or what role a new international site will play in the company’s operations strategy and how this role will change over time, as volumes and site maturity increase.

Strategy Development

Within the global economy, multi-national firms face competition in international markets, but they also have the opportunity to benefit from their positional advantages in comparison to local competitors. There are many network advantages which can result from a company’s international expansion, among them being economies of scale, economies of scope, transfers of learning, and operational hedging through multi-national dispersion (Pontrandolfo and Okogbaa 1999). These capabilities can impact not only manufacturing processes within the multi-national firm, but also product development, marketing, and engineering.
George S. Yip argues that there are five key global strategy levers, or choices that companies make to determine their approach for globalizing their operations:

- **Market participation** – selection of countries based on their potential to contribute to globalization benefits, not just their individual contribution to revenues (i.e. strategic significance, positioning in target region);
- **Product offering** – tailoring to local needs, using a standardized core requiring minimal adaptation to support cost reduction, or developing a broad product portfolio;
- **Location of value-added activities** – duplication of operations vs. concentration and exportation;
- **Marketing approach** – tailored to each country vs. a standard approach; and
- **Competitive moves** – the level of inter-country coordination in moves against competitors. (Yip 1989)

These drivers represent the breadth of influence an international site can have on the overall global strategy. The company must clearly understand its motivations for expanding globally, as well as the investments it is willing to make in this expansion based on the perceived value of expected revenue growth and market presence. This definition of the expected outcomes of an expansion initiative becomes the foundation of the site location strategy. Each author provides a proposed method for evaluating globalization opportunities, but many can be generalized into the method proposed by MacCormack, Newman, and Rosenfield in their article “The New Dynamics of Global Manufacturing Site Location”:

1) Establish the critical success factors of the business, the degree of global orientation necessary, and the required manufacturing support role.

2) Assess options for regional manufacturing configuration, considering market access, risk management, customer demand characteristics, and the impact of production technologies on plant scale;

3) Define a set of potential sites, primarily based on infrastructure, which adequately supports the business and manufacturing strategies;
4) Rank the most cost-effective solutions, using a quantitative analysis of remaining location options, and define the manner of operation. (MacCormack, Newman III and Rosenfield 1994)

Three key tools for evaluating and identifying an optimal global strategy are through total cost modeling, supply chain network modeling, and site selection analysis. Methods for applying these tools are discussed in Sections 4.1, 4.2, and 4.3, respectively.

In his article reviewing Honda Motor Company’s globalization of its operations, former CEO Hideo Sugiura noted that an overseas strategy must address the possibility of four forms of localization: 1) localization of products, 2) localization of profits, 3) localization of production, and 4) localization of management (Sugiura 1990). Initially, a company may be driven to only consider the implications of a localization of production because of the short-term expected returns of this type of investment. Over time, the value of investing in localization of products, profits, and management become more evident as the site matures. By localizing management, the company can improve the sustainability of performance by limiting the impacts of expatriate turnover. By localizing product offerings, the company can improve local demand by addressing the design needs of the local customer base. And finally, by localizing profits, the company can demonstrate the commitment to operating in the local market, which will garner support from the local government and the local supply base, as well as allow for greater investment in the technology and process capability of the site.

**Coordination**

A major challenge in expanding globally is the coordination required between the new site and others in the manufacturing network, as well as with the product development and marketing organizations. The flows which must be developed to support the new operations include: information, physical flow of components and semi-finished and finished goods, financial flows, and flows of people around the organization. For companies with limited experience in globalization, it is likely that the challenges of coordination will be overlooked initially, given that the challenges of physically installing capacity and developing a functional supply chain will appear to be much greater than developing communications and management systems early in the site development process. As Ferdows noted, “Many companies are not tapping the full potential of their foreign factories. They establish and manage their foreign plants to benefit only from tariffs and trade concessions,
cheap labor, capital subsidies, and reduced logistics costs. Therefore, they assign a limited range of work, responsibilities, and resources to those factories." (Ferdows 1997) However, a lack of coordinating processes will limit the flexibility and responsiveness of the global network to changes to internal operating conditions and to external factors, such as exchange rates and global economic conditions.

Vereecke, Van Dierdonck, and DeMeyer propose that there are four types of international plants that serve very different network roles:

- Isolated plants, where few innovations reach the plant from home country sites, few innovations are transferred to other units, and limited interaction takes place between the manufacturing staff of the plant and other plants;
- Receiver plants, which are similar in form to isolated plants, but receive more product and process innovations from other units in the network;
- Hosting network players, which frequently exchange innovations and have high levels of communication between manufacturing leadership; and
- Active network players, which are similar to hosting network players, but have higher level of communication and flows of innovations, including an emphasis on the outflow of innovations from the site to others, signaling internal innovation. (Vereecke, Van Dierdonck and De Meyer 2006).

One drawback of globalization is that it can lead to higher management costs due to increased coordination and increased staffing levels due to inter-site information management. Another drawback is that it can limit an individual site’s effectiveness if the company demands consistency across all sites, regardless of differences in the drivers of performance across the sites. These risk factors can be resolved by aligning the operations strategy with the main objectives of the global organization. A company must determine the appropriate roles for each plant, based on the levels of integration and innovation they expect to derive from the investment in the site. For example, if a company must build a site in a low-skilled area to reduce costs and increase market access, it may not expect to receive valuable input from the site regarding process improvements or product innovations, so communication may not be valued at a level that would justify the additional investment required to increase the level of coordination with other sites. Understanding this
expected level of coordination will allow the company to determine what level of investment is required in setting up a new international site.

4.2 Total Cost Model Development Research

There have been a large number of theories and approaches for how a company should select an optimal site location. The most common method for evaluating alternatives is through the total cost modeling for each proposed supply chain design. Traditionally, employees focus on direct costs because there is an expectation that indirect costs will fall over time. Alternatively, it is proposed that companies should consider both direct and indirect cost factors, to incentivize the reduction in both costs through planned actions (Ferrin and Plank 2002). Direct costs are considered to be those costs which can be traced directly to the product, such as the following: labor costs, transportation costs, material costs, inventory holding costs, and trade compliance costs. Indirect costs are those costs which cannot be directly related to a specific product, but which impact the overall total operating costs. These costs can include taxes, administration, sales, and other costs usually considered overhead.

The time horizon of the analysis can also affect the selection of an optimal solution based on total cost. Static and dynamic models, which represent a single point in time and changes over time, respectively, are both options which a company can have for modeling total cost over different timeframes. Scenario planning can also be used to test the effects of different situations on the overall performance of the site. Discrete facility location models, like those described by Klose and Drexl in their research, can resolve issues within the following contexts: 1) single stage vs. multi-stage; 2) un-capacitated or capacitated; 3) multiple- vs. single-sourcing; 4) single- vs. multi-product models; 5) static vs. dynamic; and 6) models with and without routing options (Klose and Drexl 2005).

For Company X, a few of these conditions are already determined. For Company X to enter a market, it is important for the company to offer more than one of its products to create a brand presence. At this time, sourcing options are limited, although in more dynamic models, increased local sourcing could be considered. Routing options have been limited to “U.S.-to-Country-of-Sale” and “Use of a third-party assembler” because the number of site locations would be limited to one...
or two sites within Asia to serve all markets. This narrows model configuration decisions to whether static or dynamic modeling is necessary, and whether models should be single- or multi-stage.

Static models represent the operating characteristics of a supply chain at a single point in time. This method is simple and straightforward, making it easier for the company to implement. The resulting model represents the present cost structure of the operation, or that of a specific time period, so it is most appropriate for use in allocating production volumes to sites given a fixed set of cost inputs. This method does not take into account the start-up costs of a new facility, but instead is focused on the on-going costs of operations.

An ideal static model for Company X would be one that maximizes profitability, rather than minimizing cost, due to the market growth opportunities available in new markets and due to price elasticity of demand in new markets that are more price sensitive than markets in which Company X currently excels. Unfortunately, a major limitation to this model, as described by Hodder, is that is required an accurate understanding of the relationship between price and demand for each market (Hodder 1984). Company X currently has limited experience in selling in the markets it is targeting, and has only general knowledge of the impacts their pricing will have on future demand. For this reason, a cost minimization model will be used to allocate production volumes to new site locations.

Dynamic cost models allow the company to model changes in internal and external factors over time. While this long-term view of operating costs can be very valuable in identifying an optimal strategy, this type of model can be significantly more difficult to develop and, due to non-linear relationships between cost factors, is often more difficult to solve. Current, Ratick, and ReVelle offer an example of dynamic facility location when the number of facilities is uncertain, but the models they propose look at two different decision criteria which are less straightforward than total cost: the minimization of expected opportunity loss and the minimization of maximum regret (Current, Ratick and Revelle 1997). These results are may provide the company with greater detail in the expected performance of the site location over time, but would be difficult for Company X to interpret and to use as a guideline for future expansion decision-making.

Scenario planning can offer a compromise between the simplicity of static modeling and the flexibility of dynamic modeling. Company X can demonstrate the sensitivity of the supply chain to changes in key cost drivers by manipulating the input values based on a finite set of scenarios which predict the most likely sets of future operating conditions. Eppen, Martin, and Schrage recommend
the scenario approach for use in evaluating multi-product, multi-plant, multi-period capacity planning problems, like Company X’s decision to locate a small number of plants in optimal locations to serve the Asian markets in a way that would increase profitability, drive greater regional demand, and decrease the company’s vulnerability to fluctuations in the external market. The method they proposed for scenario planning included the use of a mixed integer programming model, employing a finite set of scenarios to determine the system’s performance under varied conditions and fixed investments over time (Eppen, Martin and Schrage 1989). This method will be described in greater detail in Section 6.2, where the global manufacturing capacity model is demonstrated.

One critical challenge in developing total cost models is the lack of accurate, detailed cost information. As Milligan noted, accurate total cost measurement is elusive, because most organizations either don’t understand the calculations or don’t have, or won’t share, the data necessary for such calculations (Milligan 1999). Companies eager to develop an accurate model must first address these internal barriers to open communication and information exchange. The analysis conducted in this thesis was intended to provide high-level insights so in many cases realistic approximations have been made when specific data was not available, especially in the case of new manufacturing sites in countries where Company X has not previously operated.

4.3 Global Network Model Development Research

As a company expands its operations globally, its ability to reach previously un-served markets improves. This can increase the demand for the company’s products in new markets, due to changes in pricing and product offerings that can stem from a global operations strategy. The company also has many options for serving an international market. It can either manufacture its products in the country-of-sale, or in a neighboring country. In order to model the cost impacts of developing different types of supply chain networks, a company can simulate the most likely scenarios across a selection of risk profiles to incorporate changes in highly variable cost drivers. The static, dynamic, and scenario planning models discussed in Section 4.2 can also be applied to a network of more than one site. This will add complexity to any of these models by increasing the number of supply chain design alternatives and the effects of changes in trade compliance and transportation costs due to the larger selection of potential site locations.
The goal of a global network model is to provide insights which allow managers to determine any or all of the following:

- The number, location, capacity, and type of manufacturing plans and warehouses to use;
- The set of suppliers to select;
- The transportation channels to use;
- The amount of raw materials and products to product and ship among suppliers, plants, and warehouses, and customers; and
- The amount of raw materials, intermediate products, and finished goods to hold at various locations in inventory. (Vidal and Goetschalckx 1997)

Global supply chain models have additional levels of complexity, due to the inclusion of taxes and tariffs, multiple exchange rates, non-tariff barriers (i.e. local content requirements), and different costs of operation (i.e. labor rates, utilities, rent, transportation). This added complexity can make global models more difficult to solve and less accurate in their prediction of total cost, due to increased uncertainty about external cost drivers. In many cases, these factors are too complex to include in mathematical models, but they represent considerations a company must make in evaluating the output of any model.

4.4 Site Selection Research

In addition to the financial analysis of potential site performance, a company must also evaluate the impact of risk factors on the outcome of a site selection decision. Applying a framework for comparing the risk and likelihood of external threats, like political unrest or exchange rate variability, can provide an organization with insights into how to best position their future investments to decrease the overall risk affecting future performance. Past LFM research has been conducted in this area, including the work completed by Elizabeth Kao Yang at General Motors in 1996-7. Her research involved the development of a framework for evaluating potential site locations for new manufacturing plants. Her recommended framework is provided below, in Figure 13.(Kao Yang 1997)
The selection of critical factors and the method used to weigh these factors have differed widely within management research. Brush, Maritan, and Karnani proposed that the most critical categories of risk factors were: 1) proximity to downstream and upstream stakeholders; 2) access to factors of production, like raw materials, energy, and labor; and 3) national and regional characteristics, like government policies and labor characteristics (Brush, Maritan and Karnani 1999). They also asserted that the different factors within these categories would vary in importance based on the structure and responsibilities of the new site location. For example, proximity to other plants in the company’s network becomes increasingly more important as the international site becomes more integrated into the network, and as information and product flows increase between the site and other sites. Schmenner focused on the business climate, educational and training capabilities, workforce attitudes toward productivity and change, aesthetic and cultural attributes, and competitive presence in the region (Schmenner 1979). In addition to the factors already described, Ulgado included location attributes like the availability of financial incentives (financial assistance, tax breaks, etc.), international cargo/transportation concerns (Ulgado 1996). Ulgado also proposed that the weighting of these site selection characteristics were weighted differently based on the nationality of the company, implying that company culture and experience in domestic markets can influence the prioritization of desired site attributes. There is no one optimal method for evaluating non-financial metrics for site selection. Instead, the method must be tailored to the strategic goals of the specific organization.

In most methodologies, the process for evaluating site locations involved the following process:

1) Identifying the site attributes which have significant impact on future performance;

2) Weighting the desired site attributes, based on their relative importance to the company’s overall objectives;
3) Selecting a set of potential site locations, based on these desired attributes;
4) Collection of data regarding each site location’s performance against each metric;
5) Ranking each site location based on its performance in each attribute category;
6) Calculating the sum-product of attribute weights and site location rankings for each site location;
7) Comparing each site based on its aggregate score.

The weighting of attributes can be done in a variety of ways. It is suggested that it be agreed upon by a cross-functional group within the organization, representing the full range of interests in the new site location. The simplest method for assigning values for these weights is to assign a percentage weight to each attribute.

4.5 Chapter Summary

This chapter has provided an overview of the previous research that is most relevant to the research conducted at Company X. There is a significant body of knowledge available regarding each of the three models, but there is great flexibility in how each methodology is applied. Chapters 5, 6, and 7 will demonstrate how each method has been adapted to meet the needs of Company X to evaluate the international expansion decision process.
CHAPTER 5: SINGLE-SITE MATERIAL FLOW COST ANALYSIS

5.1 Problem Statement

In the initial phase of considering site locations, Company X must understand the implications of different levels of sourcing and manufacturing content in the U.S. and in the global market. To simplify this analysis, it is possible to consider each country as an independent market to identify which supply chain design would provide the optimal solution for the company. For the purpose of this research, a total cost model was developed for each of the key target markets – Brazil, China, and India – to compare the costs of delivering CKD kits and loose parts across a range of volumes and levels of local component sourcing. In this chapter, this single-site cost model is discussed. Further analysis conducted through a regional network model is discussed in Chapter 6.

5.2 Approach

The model which has been developed evaluates the total cost for supplying a single international manufacturing facility, given different material flows and inventory levels. The two extremes of the model are: 1) full kitting and consolidation of materials and 2) direct shipment of all materials to the facility. These extremes represent the lowest and highest levels of complexity in the international sites. Hybrids of these models could also be evaluated by taking into account different levels of local or direct sourcing, as well as different kitting and consolidation strategies.

The six different scenarios which were considered in this analysis were:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td>Each domestic plant ships non-kitted materials</td>
</tr>
<tr>
<td>1B</td>
<td>Each domestic plant ships kitted materials</td>
</tr>
<tr>
<td>2A</td>
<td>Each domestic final assembly plant ships consolidated, non-kitted materials</td>
</tr>
<tr>
<td>2B</td>
<td>Each domestic final assembly plant ships consolidated, kitted materials</td>
</tr>
<tr>
<td>3</td>
<td>Materials are kitted and shipped by an external consolidator (i.e. 3PL)</td>
</tr>
<tr>
<td>4</td>
<td>Suppliers ship directly; Plants ship non-kitted materials</td>
</tr>
</tbody>
</table>

Figure 14 - Supply Chain Design Scenarios

Diagrams of these supply chain designs are shown in Appendix A.
A total cost model must take into account all costs associated with acquiring materials, processing in-house components and sub-assemblies, preparing them for shipment, and delivering them to the international assembly facility. For Company X, these costs can be broken into 5 categories: Materials, Conversion, Kitting/Consolidation, Transportation, Tariffs/Taxes, and Inventory Costs, as shown in Equation 1.

\[
\text{Total Cost} = \text{Materials Costs} + \text{Conversion Cost} + \text{Kitting and Consolidation Costs} + \text{Transportation Costs} + \text{Taxes and Tariffs} + \text{Inventory Costs}
\]

The output of this model is an estimation of the total cost of manufacturing products under each material flow model, as well as the results of sensitivity analysis conducted on the most critical factors in the model. Based on the results of the analysis, comparisons can be made between strategies to eliminate those material flows which do not represent feasible options for Company X to use to serve non-U.S. markets.

The costs estimated in this model represent the on-going costs of operations, as opposed to the initial start-up costs of the facility. A significant proportion of start-up costs would be associated with the purchase of new equipment and tooling, which would be sourced from existing suppliers, largely in the U.S., so costs would mostly vary based on import tariffs on machinery. These import costs would vary across the different countries in a similar pattern to ongoing operating costs which also depend largely on import costs. Aside from tooling costs, most other start-up costs would be in the development of the U.S. infrastructure to support the new site, or in on-going expenses in the new site location, in the forms of rent and labor. For these reasons, on-going operating costs were considered to be a more significant factor in the site selection decision. For projects that would have greater impact on start-up costs across site locations, it would be necessary to evaluate the net present value (NPV) of the investment in the market to determine the impact of initial start-up costs on the overall return of the project.

5.3 Model Inputs

Data accuracy is one key challenge in the development of useful total cost models. Due to the high variability inherent in business performance, it is difficult to accurately forecast the costs and profitability of future performance. It is also difficult to predict the operating costs of sites which
have not yet been built. In many cases, new production capacity is being added in order to decrease product prices or increase availability to a local market, so future demand is loosely predicted based on the expected uptake by new customers.

As drivers of the output of the cost model, these highly variable inputs have a significant impact on the results of the computation, and on the recommendations derived from the analysis. It is important to simplify the model inputs to a level that is attainable from available data, but to also approximate the levels of variability in key cost drivers. This can be done by developing an understanding of the overall cost structure, and focusing on the costs which have the largest potential impact on cost calculations. Once an optimal solution has been identified, variability in cost factors can be addressed through sensitivity analysis conducted on the most critical cost drivers. Potential future conditions can be used to evaluate the performance of the recommended solution in a variety of possible scenarios.

**Overall Cost Structure**

Before deriving detailed cost breakdowns for the several supply chain design scenarios, it is important to understand the high-level cost structure of the current supply chain designs used to support Company X’s Brazilian market. Direct shipment of completely built-up (CBU) products is one method that has been used to serve the Brazilian market. It represents the simplest method for entering the market, because it does not involve the installation of manufacturing/assembly capacity in the country, and products are produced through the standard domestic manufacturing processes.

Another supply chain design that has been used to serve the market is a CKD model similar to Scenario 2B, where each domestic final assembly plant ships kitted materials consolidated from suppliers, component assembly plants, and their own internal sub-assembly operations.

The cost breakdowns for both models are shown in Figure 15 and Figure 16. These costs represent the pre-margin total cost of the product, delivered to the Brazilian market. They are represented as a percentage of the total CBU costs to represent the cost savings achieved through the CKD model.
<table>
<thead>
<tr>
<th>Cost Driver</th>
<th>CBU</th>
<th>CKD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>19.1%</td>
<td>19.1%</td>
</tr>
<tr>
<td>Labor</td>
<td>1.2%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Non-Labor Conversion</td>
<td>4.9%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Depreciation</td>
<td>0.2%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Inventory</td>
<td>0.4%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Consolidation</td>
<td>0.0%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Transportation</td>
<td>1.1%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Fees</td>
<td>0.5%</td>
<td>2.0%</td>
</tr>
<tr>
<td>State Taxes</td>
<td>11.5%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Federal Taxes</td>
<td>61.1%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>45.9%</td>
</tr>
</tbody>
</table>

Figure 15 – Pre-Margin Cost Structure, as a Percentage of Total Pre-Margin CBU Cost

![Pre-Margin Total Cost Comparison between CBU and CKD, for Brazilian Market](image)

Figure 16 – Pre-margin Total Cost Comparison between CBU and CKD, for Brazilian Market
As shown in the figures above, taxes represent a significant proportion of total cost for the CBU model – greater than 70% of the pre-margin cost of the product. This has been the key driver for Company X to investigate alternative methods for serving Brazilian demand, to reduce the delivered cost of the product, which would lead to a lower customer price and higher levels of demand. The CKD model currently used by Company X has achieved significant decreases in total cost by reducing the tax rates on the product, but this has led to increases in labor, conversion, depreciation, inventory, consolidation, and transportation costs.

The different methods of kitting and local assembly offer opportunities to minimize each of those costs, so cost estimates were generated for each supply chain model across all potential site locations. These scenarios were used to evaluate the financial benefits of locating in one country over another, based on the expected per-unit cost impact.

The cost structure of the Brazil site was used to approximate the cost structure of a new site because it was assumed that the site would have similar levels of manufacturing technology complexity, as well as similar material costs, domestic conversion and handling costs. Differences in international operating costs and taxes and tariffs could be addressed by applying conversion factors to each of these cost drivers in the cost model.

**Materials Costs**

Materials costs comprise 19.1% of the total pre-margin cost for a CBU product in the Brazilian market, so they are one of the critical cost drivers. In Company X’s current strategy, the majority of component sourcing will not change, with the exception of the small levels of local sourcing that are required to meet local content requirements. Over time, volumes will increase at the international site and economies of scale may be achieved which would justify increased local sourcing or manufacturing of components. For the purposes of the cost model, it was necessary to approximate the impact of increased local sourcing on the overall total cost. The cost difference between U.S and local sourcing for the current in-country sourced components was estimated as the percentage cost difference observed currently at the Brazil site, adjusted by the labor cost difference between Brazil and the country-of-manufacture.

At low levels of volume and high levels of product variation, local sourcing may actually lead to higher cost levels, even in countries with low labor costs. Tooling and set-up costs can drive up the
per-piece cost of materials. Also, in less industrialized areas, the availability of qualified suppliers may be limited, and a premium may be charged by those capable of delivering high-quality products. As volumes increase, Company X can negotiate lower per-unit costs and take advantage of local economies of scale.

Conversion Costs

For Company X, conversion costs are accumulated at the international assembly site, as well as at each of the domestic sites responsible for manufacturing components and sub-assembling portions of the product prior to exporting the components to the international site. Conversion costs can be divided into two parts: direct labor and non-labor costs. Non-labor costs include manufacturing overhead costs, such as indirect labor, maintenance, utilities, rent, and property insurance.

To adjust for differences between the Brazilian cost model and a cost model for another country location, labor costs for the international site should be adjusted by conversion factor for labor rate differences between the two countries, as shown in Figure 12. Labor costs represent approximately 20% of the overall conversion cost for the international site.

The remaining 80% of site conversion costs are associated with non-labor conversion costs. Non-labor conversion costs may not vary at the same rates as labor rates, especially in rapidly developing economies where labor rate inflation is high. Less accurate data is available regarding the inter-country comparisons of non-labor costs, because they vary greatly based on region and industry. By using the labor cost ratios as proxy for the non-labor comparisons, the conversion cost estimates may be over-estimated. However, conversion costs only represent about 6% of total costs, so the impact of the error in the approximation will not have a significant impact on the results of the cost calculation.

Kitting/Consolidation Costs

Company X has several options for kitting and consolidating materials, including kitting at each plant, only at the three final assembly plants, and at a third-party logistics (3PL) provider. For in-house consolidation costs, the costs for additional labor and packaging required for assembling kits were used to approximate kitting costs. For external consolidation, an estimate of $1.20 per part number per kited unit was used to estimate the kitting cost. This was based on previous benchmarking that indicated that best-in-class kitting costs are approximately $0.60 per part number
picked, while average 3PL consolidators will charge more because of inefficiencies in lower volume, non-standard products and processes.

**Transportation Costs**

Unlike for domestic transportation costs, international transportation costs are generally not directly tied to distance. They are dependent on the volume of trade on a particular route and the availability of shipping capacity. For example, the ocean freight cost to Brazil is on par with the cost to ship a container to Asia, despite the fact that the total distance is one-third as great as to Asia. This is due in part to the high fixed costs and in part due to the very high volumes of shipping taking place between Asia and the U.S. at this time. The lower demand for the U.S.-Asia direction for shipping compared to the reverse leads to low shipping costs for American companies shipping to Asia. This non-linearity can make it difficult to estimate the impacts of supply chain design decisions on the total cost without specific quotes for each proposed route. For the purposes of this analysis, it was estimated that 50% of the transportation cost could be related to fixed costs, such as loading and unloading and overhead, while about 50% of the cost would be scaled by the distance. No route-specific adjustments were made to the estimated costs because all potential sites were located in Asia. If Company X were to consider non-Asian sites, a factor should be added to the cost estimate to adjust for the lower demand and higher costs on other shipping routes. These per-container cost impacts are shown in freight costs are very sensitive to changes in the overall supply and demand in the shipping industry, so changes in macro-economic conditions can lead to large changes in these costs.

<table>
<thead>
<tr>
<th>To</th>
<th>Per-Container Freight Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>$6,000</td>
</tr>
<tr>
<td>China</td>
<td>$5,500</td>
</tr>
<tr>
<td>India</td>
<td>$6,763</td>
</tr>
<tr>
<td>Malaysia</td>
<td>$6,620</td>
</tr>
<tr>
<td>Singapore</td>
<td>$6,458</td>
</tr>
<tr>
<td>Thailand</td>
<td>$6,474</td>
</tr>
</tbody>
</table>

*Figure 17 - Per-Container Ocean Freight Cost Estimates, from Nearest U.S. Port*

Given that ocean transport only represents 1.1% of the overall total cost, it is not a critical factor at this stage in the analysis, but should be considered in the future, as global sourcing of components is
discussed. On a per-part basis, there may be advantages to evaluating the sourcing of large or low-value components, where transportation costs would be a significant portion of the overall delivered value. By increasing the cost density of kits per container, the overall transportation cost per unit could be decreased. Company X should target large and low-value components are primary opportunities for in-country manufacturing or sourcing as order quantities reach levels that would justify the investment in manufacturing capabilities or re-sourcing.

**Tariffs/Taxes**

Tariffs and taxes are cost factors which are unique to an international manufacturing cost model. As they represent over 70% of the import costs of a CBU product, they are the critical cost drivers for Company X's international cost structure and are the main target of their international strategy. Although these costs are presently known, there is a risk that these fixed rates will change over time through changes in the political and economic relationships between countries. The inter-country differences in taxes and tariffs are displayed in Figure 10. Company X can decrease the impacts of taxes and tariffs by: 1) manufacturing or sourcing in the country-of-sale; 2) manufacturing or sourcing in a country with a trade agreement that involves a lower import tariff rate; 3) importing components from the U.S. to meet in-country assembly content minimums. By manufacturing completely in-country, the company can clearly avoid all import tariffs, but the upfront and on-going investments in maintaining international infrastructure will be high, especially at low volumes. Company X is currently considering mainly options 2 and 3, where the majority of materials will still come from the main sources, routed through the U.S. The main decision is whether it is more cost-effective to assemble the product in the country-of-sale, or to locate an assembly facility in a neighboring country and combine the benefits of an existing free trade agreement between the two countries with the lower operating costs of a lower cost country than the country-of-sale to further drive down total costs. This chapter looks at the impact to the cost structure of serving a single country's demand from a single site. Chapter 6 will provide a model for future analysis of whether a single site can serve regional demand in multiple country markets, given its tariff rates for those countries.
**Inventory Costs**

The selection of a supply chain design has an impact on the inventory which must be held in the system. Inventory must be maintained to cover lead times in supplier delivery, in-house manufacturing, kitting and consolidation, transportation and customs clearance, both the float to cover overage time and a safety stock to cover variation. In the international context, there are many more pain points and causes of variability than in the standard U.S. process, so Company X must understand the advantages and disadvantages of each supply chain design alternative in order to manage the inventory cost and risks.

The inventory costs can be broken down into many lead times involved in the manufacturing, subassembly, kitting, transportation, customs clearance, and final assembly processes. These lead times, for each supply chain model, are estimated in Appendix B.

For domestic operations, the following assumptions were made:

- Raw materials inventories for loose parts at domestic sites are 2 weeks of demand;
- Domestic manufacturing of components, subassemblies, or complete units is 1 week per plant;
- Finished goods inventories at domestic sites is equal to the amount of time required to fill a container, based on an average per-day demand units by the international site;
- Domestic transportation between sites and to consolidation points is 0.5 weeks; and
- Kitting and packaging will take one day for a unit.

Transportation lead times were based on the estimated travel time from the closest U.S. to the main port for each country. These lead times vary across the proposed sites varied from 21 days for Brazil to 44 days for Thailand.

Customs clearance lead times were estimated to be between one and three weeks, with an average of two weeks. This estimate was based on the CKD model for Brazil. For imports of CBU units and loose, un-kitted parts, customs was expected to be more variable, so the customs clearance lead time was estimated to be three weeks for these models.

Pre-production inventory levels at the international site, often referred to as safety stocks, were found to depend on the method used to deliver materials to the site. If loose, un-kitted parts were delivered to the site directly from suppliers in a manner similar to that of a domestic plant, the
inventory level can be evaluated by comparison to the inventory at a domestic site. As noted by Beckman and Rosenfield in their book, “Operations Strategy: Competing in the 21st Century,” Appendix A of Chapter 6, as volumes at a site increase, inventory levels increase with demand but with decreasing returns. A square-root relationship can be assumed between demand and inventory levels, meaning that as demand increases, inventory increases at a rate equal to the square root of the percentage increase in demand (Beckman and Rosenfield 2008). For this case, Company X can estimate the required inventory levels for loose parts by comparing it to levels used to maintain its domestic sites. Assuming Company X manufactures 10000 units in one of its domestic plants, and it is planning for 500 units in its international site, the inventory level required at the international site could be calculated as follows:

\[
\text{International Inventory (in weeks)} = \text{Domestic Inventory (in weeks)} \times \sqrt{\frac{\text{Domestic Volume}}{\text{International Volume}}} \\
= (2 \text{ weeks Inventory}) \times \sqrt{\frac{10,000 \text{ units}}{500 \text{ units}}} \\
= 2\sqrt{20} \text{ weeks } \approx 9 \text{ weeks}
\]

If components were organized into unit kits, the variability in arrival time for parts needed to build one unit would be drastically decreased because all parts would be shipped together. The international site would suffer from far fewer production delays due to missing parts because the site could produce any product for which it had received a kit. Treating a kit like a single part in a domestic plant, Company X’s strategy would require that two weeks of kit inventory be held at the international site.

For components that are consolidated into container loads at domestic plants, but are not formed into unit-based kits, the pre-production inventory level would fall between two and nine weeks. This inventory reduction would be justified by the intermediate level of pooling in arrivals of parts by container. It would reduce the variability in delivery times for components, but more risk would be present than in the full-kit model. For this model, the worst-case example of completely un-kitted materials will be used to represent the full range of inventory holding requirements.
This approach was used to calculate the total time supply of inventory, or the length of time inventory would be held from the initial receipt of components at the U.S. plants through production at the international site. For scenarios where component inventory was held for longer than subassembly inventory, the time supplies of inventory were weighted by the estimated percentage of kit value that would come from components involved in each stage of the kitting and delivery process. This allowed us to compute the time supply of inventory for each stage in the process, which was then totaled into a time supply of inventory for each supply chain design. Detailed calculations of the total time supplies of inventory are provided in Appendix B.

Comparing the weeks of inventory holding for each scenario, shown in Figure 18, the CBU scenario provides the lowest levels of inventory holding, but the shipment of kitted material from each domestic site ("Scenario 1A") only leads to a minimal increase in inventory holding. The inventory for shipment of material from each U.S. site is higher due to the lower levels of component demand per site when demand is distributed across all U.S. plants. The shipment of non-kitted material is higher in inventory holding than the shipment of kits due to the nine weeks of pre-production inventory that must be held for components at the international site, in comparison to the two weeks of kitted inventory which must be maintained.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Description</th>
<th>Total Time Supply of Inventory (weeks)</th>
<th>Total Weighted Average Inventory (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBU</td>
<td>Ship completely built-up units from U.S.</td>
<td>12.3</td>
<td>10.3</td>
</tr>
<tr>
<td>1A</td>
<td>Ship non-kitted inventory from each site</td>
<td>18.8</td>
<td>18.8</td>
</tr>
<tr>
<td>1B</td>
<td>Ship kitted inventory from each site</td>
<td>10.8</td>
<td>10.8</td>
</tr>
<tr>
<td>2A</td>
<td>Ship non-kitted inventory from final assembly plants</td>
<td>22.3</td>
<td>18.5</td>
</tr>
<tr>
<td>2B</td>
<td>Ship kitted inventory from final assembly plants</td>
<td>14.3</td>
<td>11.9</td>
</tr>
<tr>
<td>3</td>
<td>Ship externally kitted inventory</td>
<td>17.1</td>
<td>13.0</td>
</tr>
<tr>
<td>4</td>
<td>Suppliers ship directly</td>
<td>18.8</td>
<td>15.2</td>
</tr>
</tbody>
</table>

Figure 18 - Lead Time and Inventory Holding Estimates, by Scenario
For the purposes of this model, inventory holding costs were assumed to be 10%. This would lead to a per-unit inventory holding cost of:

\[
\text{Inventory Holding Cost} = (10\% \text{ annual}) \times (\text{Product Value}) \times (\text{Inventory Holding(wks)} / 52\text{wks})
\]

5.4 Results

Given the high level of abstraction used in compiling input data, the purpose of the model was not to evaluate the exact total cost of delivering products to the international site, but instead to give a comparative view of the strengths and weaknesses of each supply chain design alternative with respect to the cost structure.

It is clear that, at 61% and 19% of total cost respectively, trade compliance and material costs represent the largest factors in the cost structure of an international site. By focusing on these costs, Company X can make the greatest impact on total cost reduction.

Clearly, there are significant benefits to assembling products locally, where there is the potential to reduce tariffs and taxes. Conversion, handling, and transportation costs can increase by significant amounts without impacting the decision to assemble locally. In the example of Brazil described above, the 73% of the cost structure associated with conversion and transportation could increase almost four-fold before reaching a level that would be equivalent to the cost structure of a CBU product. This implies that Company X can take on greater complexity and less efficient assembly and transportation processes in order to implement local assembly, even at lower volumes.

At the current levels of volume projected, economies of scale cannot be achieved for most local suppliers. In addition to using the total cost method to evaluate capacity expansion, Company X should utilize a total landed cost approach to sourcing. This same approach discussed in this chapter can provide Company X with a framework for evaluating potential local suppliers of material. Understanding that transportation and import tariffs increase the landed cost of imported material by multiples of its value, depending on tariff rates, Company X can calculate the price it is willing to pay within the region. In the Brazil CKD example, suppliers could charge a premium of almost 75% over U.S. suppliers and still deliver a cost savings to Company X. The estimation of this premium assumes that all components contribute to the cost structure equally, but this is not necessarily the case. For components which require additional handling, take up above-average
container space, or require higher inventory levels, landed cost would be greater than the average and would justify an even larger price premium within the local supplier base.

While other factors, like labor and conversion, contribute to the overall product cost, they have a smaller contribution to the overall cost structure and should be optimized within the context of the optimal trade compliance and materials strategy. For example, labor and conversion costs can increase significantly to support a trade-reduction strategy without having a net-negative effect on cost. This unequal tradeoff between tariffs and taxes and operating costs demonstrates why an investment in a local assembly facility would represent a good investment. Although detailed net present value (NPV) calculations have not been conducted, it is clear that the efficiency of operations can be greatly decreased and still provide a positive return for the company, even at low volumes.

With regard to the consolidation method proposed for a local assembly strategy, it can be shown that inventory holding costs are lowest for kitting conducted in-house at each site, followed closely by the in-house kitting of materials at each of the final assembly plants. The impacts of inventory holding cost to the total cost structure range from 2.1 to 3.6% of the total product cost, including the loose shipment of un-kitted materials. The estimated cost of external consolidation is approximately 50% higher than the estimated cost of kitting internally. This cost difference represents the value of hidden costs, like coordination, which are usually overlooked and have probably been left out of the internal cost calculation. The costs of increased communication, IT infrastructure, management, and attention may be greater than Company X is willing to invest in order to make the kitting process efficient. Because this process will still remain a low-volume, low-priority operation in comparison to domestic operations, Company X should invest in external kitting. At a maximum of 1% of total cost, the impact to total cost will be small in comparison to the benefits of efficient handling and communication, which will impact delivery accuracy and precision.

5.5 Chapter Summary

This chapter demonstrates the use of a total cost model in evaluating strategies for serving single international markets. While the method demonstrates the ability to make adjustments to each aspect of the total cost structure, it is most important to focus on the largest cost contributors first,
as sources of the greatest potential cost reductions. This method can also be used to evaluate the total landed cost of individual components to evaluate the potential cost savings from locally sourcing components. Inefficiencies in less-significant cost components can sometimes be required to implement an improved strategy for high-cost factors.

In addition to direct cost impacts, Company X must also consider the impacts of hidden costs, like coordination, in each possible scenario. Company X must select a strategy which fits with its growth strategy in the market, and this may not necessarily lead to the lowest cost option. At this time, Company X should be prepared to take on additional costs to decrease complexity and decrease the costs of scaling rapidly to meet market needs.
CHAPTER 6: GLOBAL MANUFACTURING CAPACITY MODEL

6.1 Problem Statement

While single-site models can provide valuable insights about the optimal supply chain design for serving one international site, it is also important that a company evaluate the possibility of serving larger international regions from a single international site. This can include serving multiple country-markets from one site, or possibly serving a single country-market from a neighboring country where production costs may be lower. In the case of Company X, it was necessary to consider the possibility of serving large markets in India and China from one or more sites in other Asian countries, like Indonesia, Malaysia, Singapore, and Thailand, where tax reductions and lower production costs could be achieved. The trade-offs between labor costs, transportation costs, proximity to suppliers, and proximity to the end market can be evaluated using a simulation model that solves for the optimal global manufacturing capacity allocation.

6.2 Approach

Building on the analysis of the single-site model described in Chapter 5, the global manufacturing capacity model adapts the output of the total cost calculation for use in evaluating the cost of serving these markets using a variable number and arrangement of international manufacturing facilities. The output of this model is a recommendation for the quantity and placement of future international manufacturing facilities, based on the lowest cost to supply major international markets.

To simplify the model, the total cost calculation from Section 5.2 can be split into two parts:

\[
\text{Total Cost} = \text{Site Costs} + \text{Intersite Costs}
\]

\[
= \text{Materials Costs} + \text{Conversion Costs} + \text{Kitting and Consolidation Costs} + \text{Transportation Costs} + \text{Taxes and Tariffs} + \text{Inventory Costs}
\]

\[
\text{Site Costs} = \text{Material Costs} + \text{Conversion Costs} + \text{Kitting and Consolidation Costs}
\]

\[
\text{Intersite Costs} = \text{Transportation Costs} + \text{Taxes and Tariff} + \text{Inventory Costs}
\]
To structure this model as an optimization model, the objective of achieving lowest cost could be modeled as follows:

Inputs:

\[ i = \text{Index for country-of-sale}; \quad i = \{1 \text{ for Brazil, } 2 \text{ for China, } 3 \text{ for India, } 4 \text{ for Indonesia, } 5 \text{ for Malaysia, } 6 \text{ for Singapore, } 7 \text{ for Thailand} \} \]

\[ j = \text{Index for country-of-manufacture}; \quad j = \{1 \text{ for Brazil, } 2 \text{ for China, } 3 \text{ for India, } 4 \text{ for Indonesia, } 5 \text{ for Malaysia, } 6 \text{ for Singapore, } 7 \text{ for Thailand} \} \]

\[ k = \text{Index for product}; \quad k = \{1, 2, 3, 4, 5, 6\} \]

\[ l = \text{Index for consolidation method used}; \quad l = \{1 \text{ for CBU, } 2 \text{ for CKD, } 3 \text{ for consolidated shipment of loose parts, } 4 \text{ for direct shipment from suppliers} \} \]

**Demand Parameter**

\[ D_{ik} = \text{Demand for Product } k \text{ in Country } i \]

**Cost Parameters**

\[ DC_{k} = \text{U.S. conversion cost and depreciation for Product } k, \text{ not including international transportation or trade compliance, independent of location of final conversion} \]

\[ CS_{kl} = \text{Consolidation costs for Product } k \text{ using Consolidation Method } l \]

\[ MAR_{k} = \text{Desired margin for Product } k \]

\[ LC_{jk} = \text{Additional per-unit labor and conversion costs to produce Product } k \text{ in Country } j \]

\[ I_{ij} = \text{Inbound transportation cost (from U.S. to country-of-manufacture)} \]

\[ O_{ij} = \text{Outbound transportation cost (from country-of-manufacture to country-of-sale)} \]

\[ TG_{ij} = \text{Trade compliance costs for import of materials from the US into Country-of-manufacture } j \]

\[ TG_{ij} = \text{Trade compliance costs for import of products from Country-of-manufacture } j \text{ to Country-of-manufacture } i \]

\[ INV_{l} = \text{Weeks of total inventory for Consolidation Model } l \]

\[ f = \text{cost of capital} \]
Decision Variables

\[ X_{ijk} = \text{Volume of Product } k \text{ produced in Country } j \text{ for sale in Country } i \]

\[ Y_j = 1 \text{ if a site in Country } j \text{ is used, } 0 \text{ if no site in Country } j \text{ is used (based on a volume threshold)} \]

\[ Z_l = 1 \text{ if Consolidation Method } l \text{ is used, } 0 \text{ if it is not used} \]

Objective Function

Minimize Cost \[= C_{ijk}X_{ijk} \]

Where \[ C_{ijk} \]

\[ = \text{the cost of producing one unit of Product } k \text{ in Country } j \text{ for sale in Country } i \]

\[ = \left( DC_k + \left( \sum_{t=1}^{4} (CS_k * Z_l) \right) \right) * \left( 1 + MAR_k \right) * \left( 1 + TC_j \right) + \left( LC_{jk} * Z_l \right) \]

\[ + \left( \sum_{t=1}^{4} f * \frac{INV_t}{52} * Z_l \right) \]

Constraints

Capacity Strategy: \[ \sum_{l=1}^{7} \sum_{k=1}^{6} X_{ijk} > 1000 * Y_j \text{ for all } j \in (1, 7) \text{ (a plant in Country } j \text{ is only opened when demand is greater than 1000 units)} \]

\[ X_{ijk} \geq 0 \text{ for all } i, j, k \text{ (all production volumes are non-negative)} \]

Demand: \[ \sum_{j=1}^{7} X_{ijk} \cdot Y_i \geq D_{ik} \text{ for all } i \in (1, 7), k \in (1, 6) \text{ (volume of Product } k \text{ produced for sale in Country } i \text{ is at least as great as demand in Country } i) \]

Consolidation: \[ \sum_{l=1}^{4} Z_l = 1 \text{ (only one consolidation method used)} \]

This model assumes that the value-add from the international site is negligible with respect to the trade compliance costs of transferring materials from the country-of-manufacture to the country-of-sale.

The difficulty in implementing this model is that it is non-linear and complex. The use of this model should be reserved for cases where less-complex analysis cannot be used to accurately distinguish between different scenarios. As previously noted, this model takes demand as deterministic, but given price elasticity, there would be dynamic shifts in demand as the customer price varies with cost. It would be possible to model this shift in demand by setting demand variables for each
country based on price threshold, allowing the model to optimize for the capacity required to serve the most profitable demand volume. This would add further complexity to the model and would make it more difficult to solve.

6.3 Model Inputs

The cost inputs for each site in the network model are equivalent to the single site costs calculated in Chapter 5. Additional data was required for the transportation costs, inventory costs, and trade compliance costs of shipping materials between non-U.S. countries.

Transportation Costs

Transportation costs for this section were approximated using the same assumptions as in Chapter 5.3, including the assumption of a 50% fixed/50% variable cost breakdown for ocean freight and of similar cost scales for transportation within all parts of Asia. These assumptions led to calculation of the approximate inter-country transportation costs shown in

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>China</th>
<th>India</th>
<th>Malaysia</th>
<th>Singapore</th>
<th>Thailand</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>$0</td>
<td>$3,553</td>
<td>$2,553</td>
<td>$2,390</td>
<td>$2,394</td>
<td></td>
</tr>
<tr>
<td>India</td>
<td>$3,553</td>
<td>$0</td>
<td>$2,406</td>
<td>$2,541</td>
<td>$2,917</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>$2,553</td>
<td>$2,406</td>
<td>$0</td>
<td>$1,542</td>
<td>$1,918</td>
<td></td>
</tr>
<tr>
<td>Singapore</td>
<td>$2,390</td>
<td>$2,541</td>
<td>$1,542</td>
<td>$0</td>
<td>$1,755</td>
<td>$0</td>
</tr>
<tr>
<td>Thailand</td>
<td>$2,394</td>
<td>$2,917</td>
<td>$1,918</td>
<td>$1,755</td>
<td>$0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 19 - Per-Container Ocean Freight Cost Estimates, Within Asia

These cost estimates lead to an approximate per unit transportation cost range of $86 to 197 for CKD kits and $64 to $148 for CBU units.

Inventory Costs

Lead times for products kitted in the U.S., shipped to an intermediate country for assembly, and then shipped to the country-of-sale would be greater than those for products routed directly from the U.S. to the country of sale. The additional delivery buffer would be approximately two weeks of inventory. The additional transportation lead time would range from 9 to 21 days, depending on the
intermediate and final country destinations. The total impact to lead time and inventory holding period would be between 23 and 35 days, or .65% to .84% of total material value in additional costs.

**Trade Compliance**

The additional acts of importing and exporting components within the intermediate country location would lead to increases in trade compliance costs in the form of greater import fees, taxes, and tariffs. For the purpose of this analysis, the following assumptions were made:

- Trade compliance costs would be increase linearly as a factor of the number of countries in the supply chain channel;
- Materials imported into an intermediate country, solely for export after assembly, would not incur import tariffs, if local content requirements set by the intermediate and final country were met;
- If local content requirements were not met, import tariffs would be applied at the U.S. import rate for the value of the product imported into the intermediate country, and at the intermediate country import rate for any additional materials and conversion costs incurred within the intermediate country.

The trade compliance rates relevant to Company X's product are shown in Figure 20.

<table>
<thead>
<tr>
<th>Country-of-Sale</th>
<th>Imported From USA</th>
<th>Lowest Tariff Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>45%</td>
<td>45%</td>
</tr>
<tr>
<td>India</td>
<td>138%</td>
<td>79%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>178%</td>
<td>94%</td>
</tr>
<tr>
<td>Malaysia</td>
<td>86%</td>
<td>43%</td>
</tr>
<tr>
<td>Singapore</td>
<td>53%</td>
<td>37%</td>
</tr>
<tr>
<td>Thailand</td>
<td>81%</td>
<td>19%</td>
</tr>
</tbody>
</table>

*Figure 20 - Inter-country Trade Compliance Rates*

**6.4 Results**

As mentioned in Section 6.2, the complex optimization model should only be used when simpler analysis cannot distinguish between alternatives. In the current case facing Company X, the factors
affecting the site location are simplified by the fact that demand is concentrated in a small number of locations.

Location of manufacturing capacity outside the country-of-sale can be explained by two motivations: 1) to take advantage of lower labor costs in a neighboring country to decrease costs for a high-volume country market; 2) to take advantage of economies-of-scale in a large market to decrease costs for lower-volume, neighboring countries. These two cases have different implications and must be evaluated separately.

For a large country-market, there may be advantages to locating assembly within a neighboring country, to take advantage of lower labor and operating costs. This opportunity is further encouraged by the availability of free-trade agreements between many Asian countries, either through ASEAN or independent agreements between two countries. The one barrier to this alternative is the high local content requirement that is present in most agreements. It is unlikely that Company X will achieve the 40-55% local sourcing required to meet free-trade requirements. For this reason, the cost savings will be limited to the labor and conversion cost savings, and tax savings on materials and conversion accumulated in the country-of-manufacture. The maximum reduction possible within the Asian region is an 80% reduction in costs, between the highest and lowest cost market. Assuming local assembly costs represent 5% of the conversion cost, this would lead to an overall decrease of 4% in total costs, but this is an extreme maximum, based on assumptions. Transportation and handling costs would increase by as much as 50%, or .75% of total cost. Import fees would double, due to multiple country entries, to 4% of total cost. Finally, inventory holding costs would increase by .1-.2% of total cost due to the increased lead time of transporting the finished goods from the country-of-manufacture to the country of sale. Based on this high-level analysis, there is definitely the possibility of locating in capacity in a lower-cost country to serve large markets.

It is important to note that this potential cost savings assumes the best-case reduction in costs. Using China and India as target markets, the potential labor savings for China is almost 80%, but for India is only 50%. Labor is less than 30% of total conversion, and assuming that non-labor conversion varies less than labor means that the impact to total cost could be significantly less than the 4% approximated above.
For smaller markets, where economies of scale do not exist for local assembly or manufacturing, there are advantages in assembling in the neighboring country only if labor, conversion, and transportation costs outweigh the additional transportation and import fees. Since it has been assumed that local content requirements would not be met, tariff and tax benefits would not be in effect, and tax benefits on the lower conversion and material costs from regional assembly would be minimal.

6.5 Chapter Summary

This chapter demonstrates the use of a global network model to evaluate the capacity requirements and site location recommendations for serving multiple demands within a region. Due to the large number of inter-related cost impacts, the optimization model required to accurately evaluate total cost is very complex and difficult to solve. Instead, by understanding the relationships inherent in the model, Company X can approximate the impacts of locating sites in a finite set of locations.

As with the total cost model described in Chapter 5, Company X must evaluate the output of any network analysis within the context of its global strategy. Although a certain scenario may represent the lowest-cost alternative for Company X, it may not allow Company X to scale up for greater volumes or may increase the risk associated with operating the site. The cost outputs of this model represent just one factor for Company X to consider in its evaluation of international site location alternatives.
CHAPTER 7: COUNTRY/SITE SELECTION MODEL

7.1 Problem Statement

In addition to the financial considerations evaluated in the two previous models, Company X must also consider other risk factors which will affect the future performance of any international site. These operational, economic, and political risk factors represent many of the sources of variability that will affect the future site, and must be considered in aggregate to determine which potential sites are lower in overall risk than others. Unlike with financial analyses, risk analyses do not easily translate into quantitative results that can be compared across alternatives. For example, it is very difficult to assess the financial value of having a local workforce with industry-relevant experience, while this factor will have a significant impact on the productivity of the workforce. For this reason, it is necessary to employ tools such as a site selection matrix to weight the relative importance of risk factors, and assess each site alternative’s expected performance against each metric.

7.2 Approach

Method

This weighted averaging can not only demonstrate which site is best capable of responding to variability in a specific risk factor, but also how each site performs against the larger set of factors that are scaled by their importance to the site’s performance. While the overall ranking of each site is valuable, it is also possible to weight the key factors by their impact on Company X’s main business objectives for international expansion: 1) increasing profitability; 2) managing risk; 3) generating revenue growth; and 4) expanding brand relevance. Understanding the performance of each site against each business objective will provide Company X with insights into the trade-offs being made in selecting any site.

The steps used to develop the site selection matrix were:

1) Selection of a set of potential site locations;
2) Development of a set of site characteristics representing key risk factors;
3) Weighting of each characteristic based on its potential impact on each corporate objective;
4) Calculation of the overall relative weight of each site characteristic based on the weighted average of across the four business objectives;
5) Collection of data for each site’s performance against each site characteristic;
6) Normalization of data into numerical rankings; and
7) Calculation of the weighted average scores for each site as a sum of its weighted performance in each site characteristic.

Site Selection

For Company X, site selection is still being considered at the highest level of evaluating the relative desirability of certain countries as potential sites for a new international assembly facility. For this reason, a set of possible country locations were identified, with the objective of selecting a future sight for operations serving the Asian markets. The countries being considered – China, India, Indonesia, Malaysia, Singapore, and Thailand – each have advantages and disadvantages related to their selection as the future site.

Risk Factor Selection and Weighting

The next step in developing a site selection evaluation tool was to identify a set of characteristics which best represented the critical risk factors affecting the future performance of the international site. There has been a significant amount of research conducted on the selection of the correct factors, as described in Section 4.4. A list was created of the many different factors which could be considered, which is documented in Appendix C. This list was narrowed to a set of 28 factors, as shown in Figure 21.
The three main categories of site characteristics investigated were related to: 1) costs; 2) business conditions; and 3) workforce. Although costs have been evaluated in the financial models, these characteristics represent the risks and variability inherent in issues such as labor cost and skill level, taxation, exchange rate fluctuations, infrastructure, and market demand. Each factor represents a different level of risk for the company, so it was necessary to develop a scoring method that would weight each characteristic based on its importance to the overall risk profile for the site.

The four business objectives were considered to be scenarios in which Company X would view site selection based on its impact to each objective independently. For example, the objective of
“Increasing Profitability” was translated into a scenario, where a lowest total cost strategy would be preferred. The objective of “Managing Risk” was translated into a scenario where Company X was risk averse, and preferred to select alternatives which minimized variation in site performance. The objective of “Generating Revenue Growth” developed into a scenario where Company X would weight market opportunities higher than the risks related to cost or workforce performance, because growth was a priority. And finally, the objective of “Strengthening the Brand” led to a scenario where Company X would be strongly averse to options which could affect the company brand, such as through the risk of IP violations. Because these objectives do not exist independently of each other, weightings were assigned based on the perceived importance of each objective to employees at Company X. Growth and brand were considered to be larger drivers of international expansion at Company X, so a weight of 35% was assigned to each scenario. Cost was somewhat less important, and was assigned a weight of 20%. Because the relative size of a new international site would be small compared to domestic operations, the risk of expansion would be small, so the risk scenario was assigned a weight of 10%.

Each characteristic was given a score of 1, 3, or 9, representing its level of impact on each of the four business initiatives. These scores are defined in Figure 22.

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Increase Profitability</th>
<th>Manage Risk</th>
<th>Generate Revenue Growth</th>
<th>Strengthen the Brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Significant impact on costs</td>
<td>Significant impact on perceived risk profile</td>
<td>Significant impact on incremental sales</td>
<td>Impacts ability to attract and retain customers</td>
</tr>
<tr>
<td>3</td>
<td>Moderate impact on costs</td>
<td>Moderate impact on perceived risk profile</td>
<td>Moderate impact on incremental sales</td>
<td>Minor impact on brand perception</td>
</tr>
<tr>
<td>1</td>
<td>Little to no impact on costs</td>
<td>Little to no impact on perceived risk profile</td>
<td>Little to no impact on incremental sales</td>
<td>No impact on customer perception of brand</td>
</tr>
</tbody>
</table>

Figure 22 - Scoring Weights for Site Selection Matrix

The “total weight” for each site was calculated as a weighted average of the scores in each of the four categories, as follows:
Total Weight_{characteristic \, i}
\begin{align*}
&= (20\%)(\text{Cost Score}_i) + (10\%) \times (\text{Risk Score}) + (35\%) \times (\text{Growth Score}) + (35\%) \times (\text{Brand Score})
\end{align*}

The “relative weight” was calculated as a normalized weight, or the total weighted score for each characteristic divided by the sum of all total weighted scores. These relative weights are the percentage of the risk profile that is dependent on the specific site characteristic:

\[
\text{Relative Weight}_{characteristic \, i} = \frac{\text{Total Weight}_i}{\sum_{i=1}^{28} \text{Total Weight}_i}
\]

Based on the relative weights, it could be seen that cost factors made up 32% of the risk profile, business condition factors made up 52%, and workforce factors made up 16%.

Once the relative weights were calculated, data was collected for each site alternative for each site characteristic. The data collection process is documented in Section 7.3. Another set of 1-3-9 rankings were applied to this data to translate qualitative results into numerical values that represented low, moderate, and high levels of performance.

An overall weighted result was calculated for each site as a sum of the weighted ranking for each site characteristic, as follows:

\[
\text{Overall Weight}_{site \, j} = \sum_{characteristic \, i = 1}^{28} \left( \text{Relative Weight}_i \right) \times (\text{Ranking}_j)
\]

The results of this analysis are presented in Section 7.4.

7.3 Model Inputs

The performance of each country against each site characteristic was investigated through a number of external sources, including the U.S. Federal Reserve and the Economist Intelligence Unit (EIU). These rankings can be seen in Appendix D. For factors where quantitative data was available, levels were set based on the values for each site. For factors where only qualitative data was found, sites were ranked as Low, Moderate, and High, comparatively. A ranking of 1 was assigned to any site that performed at a Low or undesirable level; a ranking of 3 was assigned to any site that performed
at a Moderate or average level; a ranking of 9 was assigned to any site that performed at a High or preferred level.

### 7.4 Results

The main output of the site selection model was an overall weight for each site, representing the weighted total of the site’s performance against all risk factors. As shown in Figure 23, the results indicate that Brazil is the strongest site for an international facility, based on Company X’s needs. This confirms Company X’s decision to install the assembly capacity they have already installed. In contrast to Brazil, the site alternatives for a facility in Asia are not as strong, but China represents the highest overall ranking. Comparatively, India represents the weakest overall alternative for site selection in the region.

<table>
<thead>
<tr>
<th>Country</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>539.4</td>
</tr>
<tr>
<td>China</td>
<td>513</td>
</tr>
<tr>
<td>India</td>
<td>410.2</td>
</tr>
<tr>
<td>Indonesia</td>
<td>418.8</td>
</tr>
<tr>
<td>Malaysia</td>
<td>494</td>
</tr>
<tr>
<td>Singapore</td>
<td>476.2</td>
</tr>
<tr>
<td>Thailand</td>
<td>443.8</td>
</tr>
</tbody>
</table>

**Figure 23 - Site Selection Model Results**

In order to understand the factors affecting the overall ranking of the country sites, it is possible to further analyze the data to see which factors and which scenarios were the main drivers in the overall results. In Figure 24, the overall results are broken down by business objective. In this breakdown, it is shown that the data collected indicates that, although Malaysia is not the optimal site selection, it does rank higher than China in the areas of cost-competitiveness and market growth. Overall, China ranks higher than Malaysia because of its better performance in the minimization of risk and maintenance of brand strength. Although India has high market growth potential in direct sales volume growth, other factors, such as price inflation and exchange rate
variability, make investments in India considerably more risky.

**Site Selection Model Results, By Business Objective Scenario**

![Site Selection Model Results](image)

**Figure 24 - Site Selection Model Results, By Business Objective Scenario**

### 7.5 Chapter Summary

In this chapter, a site selection analysis was conducted to evaluate the comparative strength of each potential site location, based on its performance in many cost, business objectives, and workforce metrics. Based on the overall results, China represents the strongest candidate for the next international site, with its core strengths of limited exchange rate variability, current volume of FDI, and industry-relevant experience. In comparison, India – another potential source of demand growth – ranked lower due to low current demand, high tax rate, and low workforce performance scores. While Company X may choose a site other than China for its first Asian assembly operation, this analysis can provide insights into the operational, political, and economic limitations of the location. This information would provide the expansion team with the information needed to hedge against those risks, and allow the site to prepare for high levels of variability in critical external factors.
CHAPTER 8: ORGANIZATIONAL ASSESSMENT

“Executives who understand how operational innovation happens – and who also understand the cultural and organizational barriers that prevent it from happening more often – can add to their strategic arsenal one of the most powerful competitive weapons in existence.” (Hammer 2004)

In addition to developing a global manufacturing strategy, Company X must also align its current organization to support the new operation(s). Over the course of this research, observations were made regarding the barriers which exist in Company X’s organization that would limit the company’s ability to implement the proposed strategy. These cultural, political, and organizational design issues must be resolve for Company X to create the levels of coordination between all plant sites and between the international site and the supporting functions based in the U.S.

8.1 Cultural Factors

As discussed in Section 2.1, Company X has built over 100 years of growth on a strong brand image and relationship with its U.S. customers. As Company X has expanded sales to other countries, foreign customers have also shown appreciation for the brand by demanding for American design and manufacturing. For this reason, Company X has not investigated international sourcing or manufacturing to nearly the extent of other competitors, and has accepted the limitations this decision brings with it, until now. Assembly of products outside the U.S. to avoid high import tariffs represents one opportunity Company X has to take advantage of the potential sales volumes in new regions. Unfortunately, the perception of increased international sourcing and manufacturing could damage the brand if it is misinterpreted by the current customer base.

That this project deals only with foreign demand growth, and not the use of foreign labor to manufacture products for the U.S. market, lessens the impact on customer expectation. This has been made very clear in every discussion of the topic of international expansion, so the message is consistent and clear to everyone involved. The company has committed to only seek international manufacturing capability when excessive tariffs or transportation costs prevent the company from currently selling in that region. Company X views this growth as an expansion of the American brand image, not a departure from it.

While this research has investigated the value of increased manufacturing content and sourcing in non-U.S. locations, recommendations will need to be tempered by the impact of these decisions on
customer perception and value for the brand. Company X is unlikely to be willing to challenge customer expectations in order to implement these recommendations if significant expansion of international manufacturing and sourcing will likely be recommended. Instead, Company X must be provided with evidence of the levels of cost savings and demand growth which could come from incremental changes in sourcing and redistribution of manufacturing. With this information and a clearer understanding of what defines customer expectation, senior leaders can make future decisions about the approach the company will take to meet international demand.

8.2 Organizational Design Factors

One major challenge to the development of an international manufacturing strategy is that strategy development is a very cross-functional process and does not clearly lie within the responsibility of any one group. Until recently, international manufacturing was a secondary priority to Company X’s U.S. operations – a non-standard process put in place to facilitate the sale of a moderate number of units in Brazil. Now that demand has increased in Brazil and there is growing potential in many other countries, Company X has begun to commit resources to investigating the supply chain strategy for serving these markets. There are currently three main groups focused on the future of international manufacturing within Company X: 1) Advanced Manufacturing; 2) a CKD Steering Committee; and 3) Sales & Marketing, as shown in Figure 25.

Advanced Manufacturing is focusing on how Company X can develop common processes across all facilities and add international capacity to optimally serve non-U.S. markets, in whatever form that process should take. Advanced Manufacturing has also brought in the help of an external consulting group which is “pulling back the roof” and evaluating the company’s overall manufacturing strategy. The CKD Steering Committee has been created to address the need to expand the current CKD operation to meet growing demand in Brazil, and to copy this model and apply it to new non-U.S. markets, as needed. This group has a shorter time horizon and is limiting its focus to the use of CKD as the recommended assembly strategy for international demand. This is limiting compared to the breadth of options being considered by the Advanced Manufacturing group, but this team receives greater visibility and resources, including representatives from every plant and many functions affected by the expansion of the CKD process.
The Sales & Marketing team is focused on identifying new business opportunities outside of the U.S. and determining the impact of pricing and availability on demand in these regions. This team is not directly concerned with the process used to deliver product to these regions, but is more concerned with the cost of doing so, and the effects it has on customer price. This team is currently responsible for identifying which regions could be most profitable for Company X and for defining the growth strategy in those markets.

![Diagram of Teams Involved in International Manufacturing Strategy Development](image)

**Figure 25 - Teams Involved in International Manufacturing Strategy Development**

### 8.3 Political Factors

Conflicting interests are evident among three groups that are working on the international manufacturing strategy. The Sales & Marketing team is independently developing forecasts for
volumes based on the pricing they expect, but with limited consideration of the processes used to deliver product to the markets. The CKD Steering Committee has the appropriate level of resources focused on the issue of expansion, but the team feels pressured to deliver results in a short timeframe and is currently sub-optimizing in order to keep the list of potential options manageable. Advanced Manufacturing has brought in the resources needed to conduct a thorough analysis of the overall manufacturing strategy, but has less buy-in from members of the Manufacturing and Materials communities, who have already committed themselves to the CKD Steering Committee. The Advanced Manufacturing strategy team, which has also included external consultants (professional and MIT-LFM), is not directly responsible for day-to-day manufacturing or sales operations so credibility and long-term consistency challenges the team faces in making recommendations. There is very little shared experience in the Sales & Marketing and Manufacturing organizations (i.e. cross-training, inter-organizational transfers), so there are very few people who are considering both the supply and demand sides of the issue. Without a facilitator or a common approach, these three groups are allowed to operate independently, generating plans which do not always agree.

It is possible to better align the interests of these three groups, but it is difficult to see who would be responsible for driving that re-alignment. For example, the CKD Steering Committee could expand their range of options to include non-CKD alternatives, which would match the view Advanced Manufacturing is currently taking. This would require some additional time to explore these alternatives, and would also require additional resources with experience in international sourcing and manufacturing site development. The reporting structure of the Steering Committee is such that there is a heavy weight placed on the impact to domestic plants, due to their much larger volumes, and the domestic plants are interested in selecting an option which protects their current production volumes and requires the least effort – which leads to the CKD process. Sales & Marketing are incentivized to identify new markets and set aggressive demand forecasts based on estimated costs, but there is currently no reason for them to get involved in the strategic planning of manufacturing capacity. If Advanced Manufacturing could develop more detailed information about the costs and methods of providing products to different markets, Sales & Marketing could develop more accurate forecasts. This would benefit Advanced Manufacturing as well because it would allow them to plan capacity more accurately over time, and to develop a long-term strategy that is optimal in the long run, not pieced together to support short-term fire-fighting.
8.4 Impact on Global Expansion

Based on observations made during the LFM internship, Company X is currently structured in a way where sub-optimal fire-fighting has been used to manage support for the international site. This short-term focus leaves the company vulnerable to missed growth opportunities and excessive costs, but the company has recently committed a large number of resources to the development of their international manufacturing strategy, and any results from these efforts are expected to far exceed the current methods. Aside from the normal challenges of leading a multi-national company, Company X’s senior leaders are also faced with the threat of damaging a strong customer value and brand. The weight of public opinion must be factored into any analysis and recommendations, and will largely shape the options Company X will be willing, and able, to consider.

8.5 Chapter Summary

To fully support a growing international manufacturing network, Company X must not only develop communication channels between existing plants and the new site(s). Coordination must also extend from the corporate functions to the new site, and new channels must be developed between corporate functions which have not previously been so closely linked. The additional complexity of the expanding network should be managed as a main component of the expansion strategy to hedge against the inefficiencies that would result if the current processes for managing an international operation were allowed to be copied to new sites.
CHAPTER 9: RECOMMENDATIONS

9.1 Key Recommendations

Based on the analysis conducted in during the LFM internship, it is recommended that Company X act on three major initiatives in the near future: 1) to create a cross-functional expansion team; 2) to improve the general understanding of price sensitivity and market potential; and 3) to select an external partner for kitting and consolidation. These actions will prepare Company X for the potential rapid demand growth that could result from increasing access to new markets.

Create a Cross-Functional Expansion Team

In order to guarantee alignment of all involved parties within the Company X organization, a cross-functional team must be created to oversee the expansion process. Alignment of Sales and Marketing targets with long-range planning in Manufacturing will be crucial in allowing Company X to optimize the performance of the new international site(s). In addition to these two main players, Purchasing, Product Costing, Product Development, and Finance should all be involved in mapping the possible outcomes that could face Company X as it expands internationally. Scenario planning for the potential rapid expansion of demand, and therefore capacity, will allow Company X to prepare contingency plans for the high variability of success in these new markets.

Improve Understanding of Price Sensitivity and Market Potential

Price sensitivity in international markets is a major factor that has not been addressed by the analysis contained in this thesis. Constant demand was assumed in the cost structure in the total cost model, but given the price sensitivity of the markets Company X will be trying to enter, this underestimates the impact of cost reductions. As the per-unit delivered cost declines, Company X can price products progressively lower, increasing the potential market for its products and increasing the economies of scale which can be achieved in each market. By neglecting price sensitivity, it was not possible to evaluate the possibility of achieving levels of demand that could justify greater in-country manufacturing capability, but Company X should evaluate this opportunity further once price sensitivity is better understood.
Select an External Partner for Kitting and Consolidation

Although external kitting and consolidation does incur a higher per-unit cost at the current scale, it is recommended that Company X seek an external partner for the purposes of freeing up internal resources to support internal coordination with the international site, and to allow for flexibility in expansion of capacity for the international site, depending on the success of the initiative. Based on the upper bound of volume estimates, Company X would need to make significant upfront investments in equipment and warehouse space to cover peak volume targets, or would need to frequently monitor volume levels and expand capacity over time. These efforts require resources which, at this time, are better spent on improving the processes at domestic plants in serving the international site, and in developing new relationships with supporting functions, like Purchasing and Product Development, that will function differently from those that exist to support domestic operations. Over time, as international markets mature and demand levels off, Company X can evaluate the cost benefits of bringing kitting and consolidation in house, or in replacing kitting with a combination of direct shipment of parts and local manufacturing. Partnering with a third-party logistics provider will provide Company X with the short-term flexibility to determine what those future needs will be.

9.2 Future Opportunities

In addition to the financial advantages of locating manufacturing closer to the end market, the globalization of operations can also be one way to build strategic capabilities within the organization. Three key opportunities which are relevant to Company X's future growth are: 1) increased manufacturing and assembly capability at the international site; 2) the opportunity to expand product development to include the development of a more diverse product line influenced by global demands; and 3) increased network capabilities through increased levels of inter-plant coordination.

Increased Manufacturing and Assembly Capability at the International Site

As demand increases in international markets and greater economies of scale are achieved, additional in-country manufacturing capability and higher-efficiency assembly operations can be considered. For components currently manufactured in the U.S., there is a currently a premium paid for each component in the form of additional handling and taxes and tariffs. On a per-part basis, Company X can evaluate where the break-even point is between this current price premium and the start-up
and variable costs involved in in-country manufacturing. Each part will have a different volume threshold representing the economic scale required. This scale will also be relevant to the external sourcing decision, in terms of determining at what point local sourcing is justified.

As the international site matures and growth levels off, the company should investigate the optimal assembly process technology required to support efficient operations. This may include increased automation and material handling, as well as a shift away from the kitted model toward a fully-capable assembly factory model.

**Improved New Product Development for Non-U.S. Markets**

Entry into new markets will provide Company X with customer access representing a more diverse customer base than it currently reaches. If Company X taps into this customer base through outreach and marketing, it can derive information about the unique customer requirements specific to each region. While this information can be used to shape the marketing efforts Company X applies to that market, it is even more valuable for Company X to use that to tailor product development to market needs. As mentioned in the industry overview, the Asian markets sought by Company X seek a product mix that differs greatly from Company X’s current product offering. Company X can use its newly developed customer access to determine which new product offerings could allow them to successfully gain a greater market position. The importance of brand in Company X’s strategy relies on a visible customer base, so investments in product tailoring will be an important part of Company X’s market capture strategy.

**Increased Levels of Inter-plant Coordination**

Initially, Company X will focus on developing the new site location as an outpost with minimal coordination. As volumes increase and the site becomes a larger contributor to overall production, Company X should focus on increasing the level of coordination between the international site, the U.S. plants, and the supporting functions at the company headquarters. As Kogut discussed, “Through increased coordination with its international sites, companies can gain from building the network advantages such as economies of scale, economies of scope, sources of learning, and multinational dispersion (Kogut 1990). The learnings which can be derived from Company X’s efforts in expanding internationally can help employees to build a set of best practices which can be applied to new markets. By using the current Brazil site as a test bed, Company X can determine the optimal approach for increasing local sourcing and in-country manufacturing, and can transfer this
experience to the new site, which has the potential to grow even more rapidly than the Brazil site. By accelerating the rate at which Company X can enter new markets, increased coordination can empower Company X to increase its rate of market capture.

Once international sites have become fully-capable manufacturing and assembly sites, best practices can be shared regarding day-to-day operations, so even domestic sites can benefit from the experience and investment in international operations. Increased global sourcing experience from seeking in-country suppliers also has the potential to unleash sourcing advantages that Company X has not yet considered.

9.3 Barriers to Implementation

Internal and external barriers exist which have the potential to limit Company X’s ability to successfully expand internationally. The team responsible for coordinating the expansion process must not only be aware of these risks, but must put actions into place which will mitigate these risks going forward.

Risks

In her thesis, Elizabeth Kao Yang (LFM’97) noted some common risks associated with expanding globally, based on General Motors’ approach, including:

- Not understanding the foreign customer and not offering the right product;
- Large scale mistakes related to the expansion of the span of the market;
- Loss of focus on profitability due to the increase in complexity of operations;
- Challenges in maintaining IP and technology protection;
- Rapid changes in the political landscape, like an increase in protectionism;
- Social and financial upheaval, such as a major shift in currency exchange; and
- Missing the boat, if competitors are globalizing and you are not. (Kao Yang 1997)

These risks are present in Company X’s situation, and must be considered before action is taken to implement the recommended international expansion. Greater research into local market dynamics will be needed to drive marketing and product strategy, and may required external resources in the
form of local consultants or partners. Because there is great uncertainty in the estimation of market potential, Company X must invest in increased flexibility in its operations to allow for scale, as needed, but to also maintain an efficient cost structure at lower-than-expected volumes. Use of third-party logistics providers is one example of this flexibility. With regard to the macro-level political and economic risks, Company X must use the analysis provided in this thesis, as well as the experience of local partners, in determining the effects of these risks and the operational ways to hedge against them. Overall, Company X must continue to question the ways in which the international aspect of this expansion affects the decisions it must make. Treating this process in the same way as a domestic expansion could leave Company X unprepared to deal with unexpected changes in the market.

**Internal Barriers**

In addition to the market risks discussed above, Company X must also be willing to commit to addressing the internal barriers that exist between functions in the overall organization. As described in Chapter 8, the current organizational structure of Company X has been designed to support the product-specific operations of the domestic plants. International expansion at higher volumes will required increased attention from all parts of the organization, and will require higher levels of coordination. Communication will need to increase between functions which have previously been at arm’s length, because international operations increase the complexity of decision-making regarding the operations and marketing strategies. If Company X continues to support international operations with the same processes it currently uses, it will be inefficient in its ability to serve the market, and this inefficiency will manifest itself in the forms of higher costs, lower responsiveness to customer demand, and lower overall capture of market share.

**9.4 Refinement of Methodology**

The analysis conducted in this thesis has been driven by high-level assumptions due to the early stage Company X is at in determining its global expansion opportunities. These assumptions, like the relationship between labor and conversion cost variation by country, can lead to error in the cost modeling. In the future, Company X must continue to revise costing models based on increased understanding of the cost impacts of locating capacity in different locations.
The modeling conducted in this thesis also did not evaluate the cost impacts of increasing manufacturing capability in the new international site location. By adding manufacturing capacity for certain components, Company X could shift the conversion cost breakdown between U.S. and domestic plants, and increase the cost savings from tax and tariff benefits. This analysis was left out of the total cost calculation due to the large number of components manufactured in-house, and the complexity of determining the fixed and variable costs of in-house manufacturing and the upfront investment required.

With regard to the site selection model, weights were placed on the site selection criteria and the selection scenarios based on an approximation of the priority Company X places on these interests. For a more detailed evaluation of the site selection alternatives, a survey could have been conducted of Company X employees to determine these weights more accurately.

9.5 Opportunities for Future Research

Outside of the context of Company X, there are opportunities to expand research in a few key areas. Based on the review conducted of operations management research, two topics which were not adequately discussed were: 1) the evaluation of the impact of operations strategy on the value of a company’s brand, and 2) the evaluation of the value of flexibility in the expansion of growing operations.

For Company X, a major factor in determining its operations strategy has been the maintenance of its strong brand. By expanding internationally, both in assembly and sourcing, Company X is threatened with the possibility of affecting its brand value both in the U.S. and in international markets. Most globalization research focuses on the methods companies can use to expand their current brand to other markets, or to tailor its brand presence to the customer needs in specific markets. Significantly less attention was given to the issue of how to maintain their brand value in their current markets while expanding into new markets. For companies that rely on their strong brand to drive demand in mature markets, this is a major concern that may lead them to select less-than-optimal operations strategies. Research into methods which can be used to assign value to the semi-tangible concept of brand would allow companies to incorporate this value into financial cost-benefit analyses for expansion projects.
For companies looking to expand globally, a major factor affecting their operations strategy is the amount of flexibility they must build into operations to prepare for variability in demand. Additional research could be conducted regarding the value of investments in flexibility and the payoffs which would be derived from being better prepared for peak demand, while also maintaining reasonable operating costs at low volumes.
CHAPTER 10: CONCLUSIONS

The main goal of this thesis was to provide insights into the critical factors affecting international expansion. Based on the analysis described above, as well as the observations made during the on-site internship, the following high-level conclusions can be made regarding Company X’s approach to international expansion:

- Although Company X’s strategy may not target lowest cost, it is important to understand the value the company is placing on choosing higher cost alternatives.
- Even in the absence of detailed cost data, estimates can still provide insights into key drivers of supply chain performance.
- Focusing on the improvement of the most visible cost (i.e. logistics) will not always have the largest impact on total cost or profitability. To achieve the greatest impact, the company should focus on top cost factors, while selecting a strategy that maximizes performance and flexibility in the lower-impact cost factors.
- Cross-departmental communication can be as much of a challenge as the physical installation of international manufacturing capacity.
- Even the most straightforward supply chain analysis can be more about organizational processes than process optimization.
APPENDICES

Appendix A – Supply Chain Designs

**Option 1A – Ship non-kitted material from each site**

Option 1B – Ship kitted material from each site
Option 2A – Ship non-kitted material from final assembly plants

Option 2B – Ship kitted material from final assembly plants
Option 3 – Ship externally kitted material

Option 4 – Suppliers ship directly to international site
Appendix B – Inventory Cost Calculations

INVENTORY COSTS

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBU</td>
<td>Ship Completed Products</td>
</tr>
<tr>
<td>Option 1A</td>
<td>Ship non-kitted inventory from each site</td>
</tr>
<tr>
<td>Option 1B</td>
<td>Ship kitted inventory from each site</td>
</tr>
<tr>
<td>Option 2A</td>
<td>Ship non-kitted inventory from final assembly plants</td>
</tr>
<tr>
<td>Option 2B</td>
<td>Ship kitted inventory from final assembly plants</td>
</tr>
<tr>
<td>Option 3</td>
<td>Ship externally kitted inventory</td>
</tr>
<tr>
<td>Option 4</td>
<td>Suppliers ship directly</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Description</th>
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</thead>
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<tr>
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<td>CBU Ship Completed Products</td>
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<td>Raw materials inventory</td>
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<tr>
<td>Component production</td>
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</tr>
<tr>
<td>Transport</td>
<td>0.5</td>
</tr>
<tr>
<td>Component inventory</td>
<td>2</td>
</tr>
<tr>
<td>Complete Assembly production</td>
<td>1</td>
</tr>
<tr>
<td>Kitting</td>
<td>0</td>
</tr>
<tr>
<td>Finished goods inventory</td>
<td>0.75</td>
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<tr>
<td>Transport</td>
<td>3</td>
</tr>
<tr>
<td>Customs</td>
<td>2</td>
</tr>
<tr>
<td>Total - Time Supply of Inventory</td>
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<tr>
<td>Total - Weighted Average Inventory</td>
<td>10.25</td>
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<table>
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<th>Description</th>
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<tr>
<td>(in WEEKS)</td>
<td>Option 1A Option 1B</td>
</tr>
<tr>
<td>Raw materials inventory</td>
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</tr>
<tr>
<td>Component/sub-assembly production</td>
<td>1</td>
</tr>
<tr>
<td>Kitting</td>
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</tr>
<tr>
<td>Finished goods inventory</td>
<td>0.75</td>
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<tr>
<td>Transport</td>
<td>3</td>
</tr>
<tr>
<td>Customs</td>
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</tr>
<tr>
<td>Pre-production inventory</td>
<td>8.94</td>
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<tr>
<td>Production</td>
<td>0.14</td>
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<tr>
<td>Total - Time Supply of Inventory</td>
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<td>Total - Weighted Average Inventory</td>
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<td>Subassembly production</td>
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<td>Finished goods inventory</td>
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<td>Transport</td>
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<td>Customs</td>
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<tr>
<td>Pre-production inventory</td>
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<td>Production</td>
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### Option 3

<table>
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<tbody>
<tr>
<td>Component/sub-assembly production</td>
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<tr>
<td>Finished goods inventory at plants</td>
<td>0.75</td>
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<td>Transport to 3PL</td>
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<td>Inventory at 3PL</td>
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<tr>
<td>Kitting</td>
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<td>Transport</td>
<td>3</td>
</tr>
<tr>
<td>Customs</td>
<td>3</td>
</tr>
<tr>
<td>Pre-production inventory</td>
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<tr>
<td>Production</td>
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</tr>
<tr>
<td>Total - Time Supply of Inventory</td>
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<td>Total - Weighted Average Inventory</td>
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### Option 4

<table>
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</thead>
<tbody>
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<td>Component/sub-assembly production</td>
<td>1</td>
</tr>
<tr>
<td>Kitting</td>
<td>0</td>
</tr>
<tr>
<td>Finished goods inventory</td>
<td>0.75</td>
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<tr>
<td>Transport</td>
<td>3</td>
</tr>
<tr>
<td>Customs</td>
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</tr>
<tr>
<td>Pre-production inventory</td>
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<tr>
<td>Production</td>
<td>0.14</td>
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<tr>
<td>Total - Time Supply of Inventory</td>
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</tr>
<tr>
<td>Total - Weighted Average Inventory</td>
<td>15.24</td>
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</table>
Appendix C – Factors Affecting Site Selection Decision

Costs:
- Operating:
  - Logistics
  - Labor
  - Energy
  - Inventory carrying cost
- Logistics
  - Quality of road access
  - Congestion /expeditious access
  - Quality/proximity of sea port/airport
  - Proximity to suppliers/dealers
- Human resources
  - Labor climate/militant unions
  - Work ethic/education
  - Expat living conditions
  - Skilled professional pool
  - Quality of life
- Manufacturing site
  - Topography/soil qty
  - Access
  - Utilities/materials
  - Corporate pres/other
- Inventory
  - Avg. inventory
  - Safety stock
  - Pipeline inventory
  - Warehousing
- Purchasing
  - Material
  - Packaging
  - Qualification
  - One-time
- Trade Compliance
  - Duty
  - Tariffs
  - Customs fees
- Labor
  - Cost of labor
  - Labor wage growth
- Corporate tax rate
- Exchange rate volatility
- Government incentives
- Geographic proximity to customers
- Infrastructure investments
  - Investments – building
    - Lease
  - Investments – equipment
  - Inventory build
    - Carrying costs
    - Logistics and duties
    - Outsourcing/resourcing

Business conditions:
- Future GDP growth
- Risk (economic, political)
- Political imperatives:
  - Government instability
  - Local content requirements
  - Tax abatements
  - Political advocates
- Regionalized trade economies (Mercosul, ASEAN)
- Market demand characteristics
- Transport/telecom infrastructure
- Intellectual property (IP) protection
- Environmental restrictions
- FDI confidence
- Receptiveness to FDI by local and state governments
- Real estate availability

Workforce:
- Education level of workforce
- Available labor market
- Outsourcing experience
- Language barriers and literacy rates
- Turnover rates
- Productivity and work ethic
## Wage Inflation
- **Average real wage inflation (%%)**

### Labor Costs
- **Labor costs per hour (US$)**
- **Fringe benefits (%)**

### Tariffs
- **Tariffs, without effects of free trade agreements**

### Currency
- **Exchange rate variability (%)**
  - % Change over past 3 years

### Infrastructure
- **Government incentives**
  - Comparative ranking of government incentives
  - Comparative quality of infrastructure
  - Current market size
  - Market growth
  - Local content requirements
  - Industry experience/availability
  - Environmental risk
  - Economic/political instability
  - IP protection
  - Foreign GDP growth
  - Consumer price inflation
  - Sovereign rating
  - Education
  - Available labor market
  - Labor force growth (%) (%%)
  - Unemployment rate (%)
  - Industry experience
  - Turnover rates

### Rank
- **TOTAL**
- **20% Cost**
- **50% Score**
- **30% Growth**

### Appendix D – Site Selection Results
(The Economist Intelligence Unit 2008), (U.S. Federal Reserve 2009)
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