

# Using a Total Landed Cost Model to Foster Global Logistics Strategy in the Electronics Industry

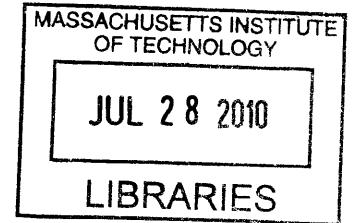
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Submitted to the Engineering Systems Division  
in Partial Fulfillment of the Requirements for the Degree of  
Master of Engineering in Logistics  
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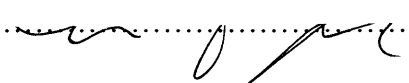



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# **Using a Total Landed Cost Model to Foster Global Logistics Strategy in the Electronics Industry**

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**Apichart Jearasatit**

Submitted to the Engineering Systems Division on May 7, 2010  
in partial fulfillment of the requirements for the degree of  
Master of Engineering in Logistics.

## **Abstract**

Global operation strategies have been widely used in the last several decades as many companies and industries have taken advantage of lower production costs. However, in choosing a location, companies often only consider labor cost and, as a result, overall costs may not be reduced. What other costs besides labor should be considered in locating a global facility? This research examines sourcing, manufacturing and distribution costs and develops a total landed cost model for global operations. We use this total landed cost model to estimate the total cost from raw material to the customer for one sample company operation, Tyco Electronics, across multiple manufacturing and customer countries. This total landed cost model was used to analyze the cost for each manufacturing location, customer, and mode of transportation as well as predict the effect from risks and uncertainties in global supply chain.

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# CHAPTER 1 INTRODUCTION

Most businesses today operate in a global environment with demand and supply points spanning the world. This environment allows companies to sell, manufacture, and source from anywhere globally. Businesses operate globally for several reasons including serving new markets quickly and taking advantage of low labor-costs. For these reasons, global logistics operations have become widely adopted during the past decade.

In order to successfully implement global operations, businesses require a new business infrastructure consisting of warehouses, distribution centers, and production plants. Additionally, businesses need to develop new processes for planning and controlling the flow and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to destination. These processes can lead to increased operational costs.

Moreover, going globally means businesses expose themselves to more risks and uncontrollable factors, i.e. fluctuating exchange rates, volatile labor costs and increasing oil prices. In addition, businesses encounter higher inventory positioning, differences in operating efficiencies and unreliable service from global sourcing suppliers. All of these factors must be managed carefully.

Although global operations have potential risks and uncertainties as discussed above, the benefits from low-labor cost and proximity to customers can be of even greater interest. Accordingly, this research studies the cost factors that a firm should examine in order to implement a global supply chain and develop a total landed cost model. We also review the risks



and uncertainties in global supply chains and apply the total landed cost model to show the impact of these risks on the total cost of the firm.

We believe that this total landed cost model not only helps businesses understand their global operating costs but also make trade-offs in sourcing, manufacturing and distribution.

## **1.1 Problem & Key Questions**

Many businesses often move all production activities to countries of lower labor cost in order to lower operating expenditure. However, many companies only consider a labor cost when selecting production countries. There are several additional costs incurred with manufacturing overseas, such as international transportation cost, inventory holding cost, and import taxes. Additionally, labor costs in many developing countries are likely to rise, thereby eliminating or reducing the initial benefit. As a result, if the business does not consider all cost factors carefully, the total cost of operating in low labor cost countries may be higher than the current business operations.

This thesis addresses these three questions:

- 1) What other costs besides labor should be considered in locating a global facility?
- 2) How are these costs traded-off?
- 3) How can a firm quantify the impact of risks and uncertainties in the supply chain?

## 1.2 Objective and Scope

This thesis examines the total costs incurred from global supply chain operations. Specifically, this thesis develops a total landed cost model and tests it on a sample company, Tyco Electronics. Tyco Electronics has manufacturing, warehousing, sourcing and customers around the world. We study the connector products that are produced in Brazil. Currently, Tyco Electronics' Brazil plant produces connectors to serve customers in Brazil, Argentina, and Germany. However, the production costs in Brazil are higher than other countries such as China, Mexico and India. Accordingly, the challenging questions emerged: should Tyco Electronics move production to other countries? If yes, where should it be? and how much will the total cost be reduced? Our research addresses to the question above. We framed the scope of the thesis to study four other manufacturing countries: China, Mexico, Czech Republic, and India. These selected countries are initially believed to have lower production cost than Brazil. Next, we study how Tyco Electronics should distribute the finished products from the production countries to customer countries. We study five product SKUs, which have unique characteristics in term of weight, costs, demand variability and production processes.

The first objective of this thesis is to provide a guideline based on total costs and flexibility for a firm to select manufacturing locations and distribution strategies. To do so, we develop a total landed cost model incorporating all related costs incurred from the global supply chain operation on five focused countries: Brazil, China, Mexico, Czech Republic, and India. The model can also demonstrate the impact to total landed costs of changing such variables as ordering period, mode of transportation, customer service level, demand variability, and raw material sourcing locations. The model analyzes the cost of individual products at a time with

different characteristics production processes. The total landed cost model is designed to be used for fast analysis with minimal information.

The next objective is to use the model to show the impact of various supply chain risks on the total landed cost. The risks that we study in this thesis are the change in oil price and labor costs. These risks may not proportionally impact the total landed cost. The result from this analysis help businesses gain an appreciation of the global logistics operation complexities and also make a better decision in choosing manufacturing location.

### **1.3 Tyco Electronics Business Overview**

Tyco Electronics is a US\$10.3 billion global provider of engineered electronic components for thousands of consumers and broad array of industries such as including automotive, data communication systems and consumer electronics, telecommunications, medical and etc. Tyco Electronics has 45 manufacturing plants located worldwide and has customers in almost 50 countries. Tyco Electronics revenues for year 2008 are \$14 billion which consists of four reporting units; Electronic Components (\$9.277 billion), Network Solutions (\$2.162 billion), Specialty Products (\$1.769 billion), Telecommunications (\$1.165 billion).

In the Electronic Components industry, Tyco Electronics is one of the world's largest suppliers of passive electronic components, including connectors. Tyco's electronics products are used primarily in the automotive, computer, and communications equipment. Tyco business strategy is to produce innovative, early design products to customer. In addition, Tyco supply chain strategy is to deliver new products to market faster, and realize greater efficiencies in their manufacturing processes.

In this thesis, we focus on the electronics industry market which is the main business of Tyco. We study the supply chain of connector products which is the main components of automotive industry.

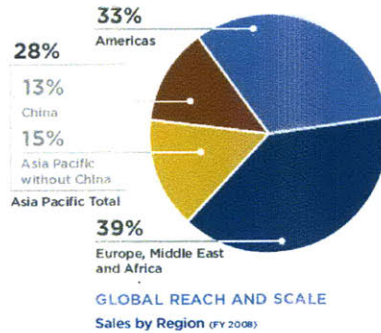


Figure 1.1: Tyco Electronics Sales<sup>1</sup>

## 1.4 Outline of Thesis

This thesis has four remaining chapters. Chapter 2 explores the past use of the total landed cost models and global supply chain risks. Chapter 3 presents the development of a total landed cost model. The complexity of assessing related costs is discussed. The formulas used in this total landed cost model are demonstrated. Chapter 4 uses the total landed cost model to analyze different business decisions. Finally, Chapter 5 provides a synopsis of the thesis and suggests future research.

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<sup>1</sup>Additional information on Tyco Electronics sales can be found at <http://www.tycoelectronics.com/>

## **CHAPTER 2 REVIEW OF LITERATURE**

We conducted a review of total landed cost models in both the research and business literature. This section begins with the development and improvement of the total landed cost model. Then, the purpose of using the landed cost model in practice is reviewed.

Next, we review the study of global logistics operation. The literature related to the global logistics operation primarily consists of descriptive studies about designing global supply chains and the associated risks and the impact from global supply chain operations. The objective of most of this research is to provide a framework for businesses to use in designing global supply chains.

### **2.1 Total Landed Cost Models**

Total landed cost models are developed to help businesses make decisions on raw material sourcing from suppliers. When sourcing, businesses are not only responsible for material costs but also for transportation costs. Accordingly, a total landed cost model is developed to calculate both costs together in order to help business select the least costly suppliers.

Then, the idea of considering on the whole supply chain emerged. The concept of total cost of ownership is defined that the company needs to take into account all costs related to purchasing goods and services throughout the entire supply chain. The total supply chain cost

was also defined by the Supply Chain Council as “all the costs associated with acquiring and delivering material, planning and order management, but none of the expenditures associated with Research and Development or sales and marketing.” The Supply Chain Council also provided a set of five cost buckets: acquisition costs, order management costs, inventory carrying costs, information systems costs, finance and planning costs. According to this idea, we found that many businesses put a great deal of effort into reducing inventory holding costs. As a result, many later total landed costs includes the inventory cost, which is a trade-off between transportation costs.

Thomchick (2007) develops a total landed cost model that includes six cost elements. The detail of each cost elements are demonstrated below.

1. Purchase Price: Price paid to seller, payment terms and exchange rates over time
2. Transportation: Foreign inland, local inland, accessories, insurance, packaging
3. Custom and Import: Tariff rate, merchandise processing, harbor maintenance fee, broker fee, and duty drawback
4. Inventory: Cycle stock, safety stock, and in-transit stock
5. Overhead and administration: Sourcing staffs, relationship collaboration, learning curve
6. Risks and compliance: Cost of potential risk of supply disruption and cost of potential risk of damage to reputation health, safety, environment

These six cost elements are presented at a high level. So, Thomchick noted that when applying these frameworks to the business, the cost might be calculated differently and also the calculation needs to be adjusted in order to fit the business. From the total landed cost elements

that we have studied, we obtain the concepts that enable us to consider the cost of ownership and the labor cost associated with purchasing tasks. Next, we review the development and application of the total landed cost model to the business.

Robinson (2006) develops a total landed cost model for an aerospace manufacturer determines to whether to insource, outsource, and integrate vertically. Robinson uses the model to compare various manufacturing locations. This model incorporates four cost elements: labor cost, logistics cost (transportation cost), inventory and taxes. This research summarizes that the landed cost provides the insight into how the four major costs above are linked and shows the better result for make a strategic decision. At the end, Robinson suggests that the more cost elements that can be included in the model, the more accurate the result will be. However, it might be hard to obtain all data because the data is in a different country. Businesses need to make decisions quickly and are likely to use the landed costs to support the assumption. So, Robinson's research concluded that focusing on the main cost elements greatly assures the overall costs fit with the business needs. This conclusion contextualizes our research by focusing on six cost drivers: raw material sourcing, manufacturing, inbound and outbound transportation, inventory holding, warehousing, and taxes.

Morita (2007) creates a total landed cost model for an electric power equipment manufacturing company to make sourcing. The characteristics of this industry is the high the material cost. Because of this, effective sourcing is critical to profitability. The basic idea is to apply a total cost model to analyze whether changing suppliers is beneficial. Morita focuses on comparing the current local supplier with a Chinese supplier. Morita's research includes several financial analyses such as net present value of the future marginal cash flow. Morita compares

the material costs, transportation cost, inventory cost, and labor cost. Also, Morita studies the effect of exchange rates on total costs. Finally, Morita provides some limitations of his model, since it calculated based on the specific annual volume, if the volume changes, the fixed cost also changes. Accordingly, changes in volume may cause the model to not be accurate. Morita suggests that further research should focus on how to incorporate risk factors into the model.

Feller (2008) develops a total landed cost model for an engineering instrument manufacturing company. The purpose of this model is to select the best sourcing options. The model incorporates material cost, transportation cost, and inventory cost. Feller's research uses a continuous review policy to manage the inventory, in which the level of product is monitored closely. For instance, if the safety stock decreases to the re-order level, the company will request products from suppliers. Additionally, Feller's model includes risk analysis for each supplier. The risk data is collected from past experience with suppliers. The risks are identified in five areas: purchasing, inventory, finance, logistics, and suppliers. These risks are converted to metrics and then added to the total landed cost on the normal scenario without risks. Feller notes that understanding both total landed cost and risks to select supplier supports the business to make strategic and financial prudent decisions. We agree that considering supply chain risk is an essential part to total landed cost model in which it makes the model more accurate.

In summary, we found many researchers use total landed cost models to analyze sourcing decisions from suppliers to business. However, we did not see the application of total landed cost model to the overall supply chain (multi-echelon) which are sourcing raw material, manufacturing, and transporting to customers.



## 2.2 Global Supply Chain Risks

Global supply chains are more vulnerable to more kinds of risks more than local supply chains since the distance between supplier and customers are extended. Accordingly, our literature review focuses on the research, articles and surveys produced during the last two decades in order to be a guideline for firms.

Levy (1995) shows that the risk on supply chain varies by country. Levy studied the geographical location of the suppliers and proposed location-specific factors. The location-specific factors is the model to quantify risks of each supplier based on the potential factors of those locations such as wages, production costs, political and economic stability.

Meixell and Gargeya (2005) demonstrated the complexity of a global supply chain due to geographic distance. Longer distances not only increase transportation costs but also create complexity in forecasting demand and lead time, thereby raising the inventory level. Additionally, Tomlin (2006) also shows that longer distances create difficulties in communication across the supply chain. Tomlin's research shows that ineffective communication causes the inaccurate information. This also contributes to the complexity in forecasting demand.

Jain (2009) uses a risks analysis framework to study each supplier. The main objective for Jain's model is to evaluate the risks and assess the costs between local supplier and international supplier and also between selecting low-cost and long-term suppliers. The risk factors affecting supplier selections are classified into eight categories: political, natural disasters, financial stability of supplier, economic, security and terrorism, logistics, supplier relationships and reliability risks. The research result shows that, under high risk conditions,

distant, global suppliers with relatively lower contract costs can exceed cost budgets as well as the cost of domestic sourcing. Jain's research provides an initial methodology to our thesis related to quantifying the total costs. However, Jain's research calculates the total cost on the supplier side only. Our research shows the impact to the whole supply chain from raw material to the final distribution to the customer.

A McKinsey Global Survey (2006) conducted a research on global supply chain risks by surveying the opinion for 3,000 top executives from firms across a full range of industries. Two-thirds of respondents accepted that risks to their supply chain have increased over the past five years. Forty-three percent of the respondents agree that the most critical concerns are labor cost and labor quality. More importantly, the survey shows that many companies do not put a lot of effort into studying and mitigate risks carefully. The survey from McKinsey illustrates that firms should study risks related to labor costs intensively. In this research, we apply the concept of volatility in labor cost to our total landed cost. By doing so, we can quantify the impact of labor cost risks to the firm global supply chain operation.

## **CHAPTER 3 A TOTAL LANDED COST MODEL DEVELOPMENT**

This chapter introduces the total landed cost model that we created. The chapter begins by analyzing the supply chain of Tyco Electronics. Then, the cost factors associated in each supply chain part are reviewed. Next, the chapter shows the calculation and the mathematical formula used in the total landed cost model. The complexity and the problems in assessing the cost function are addressed. Later, the chapter presents the development process and infrastructure of the total landed cost model.

### **3.1 Total Landed Cost Components**

In order to understand how to build a total cost model, we need to comprehend the underlying supply chain and the product movement. Figure 3.1 shows a schematic of the supply chain for Tyco Electronics.

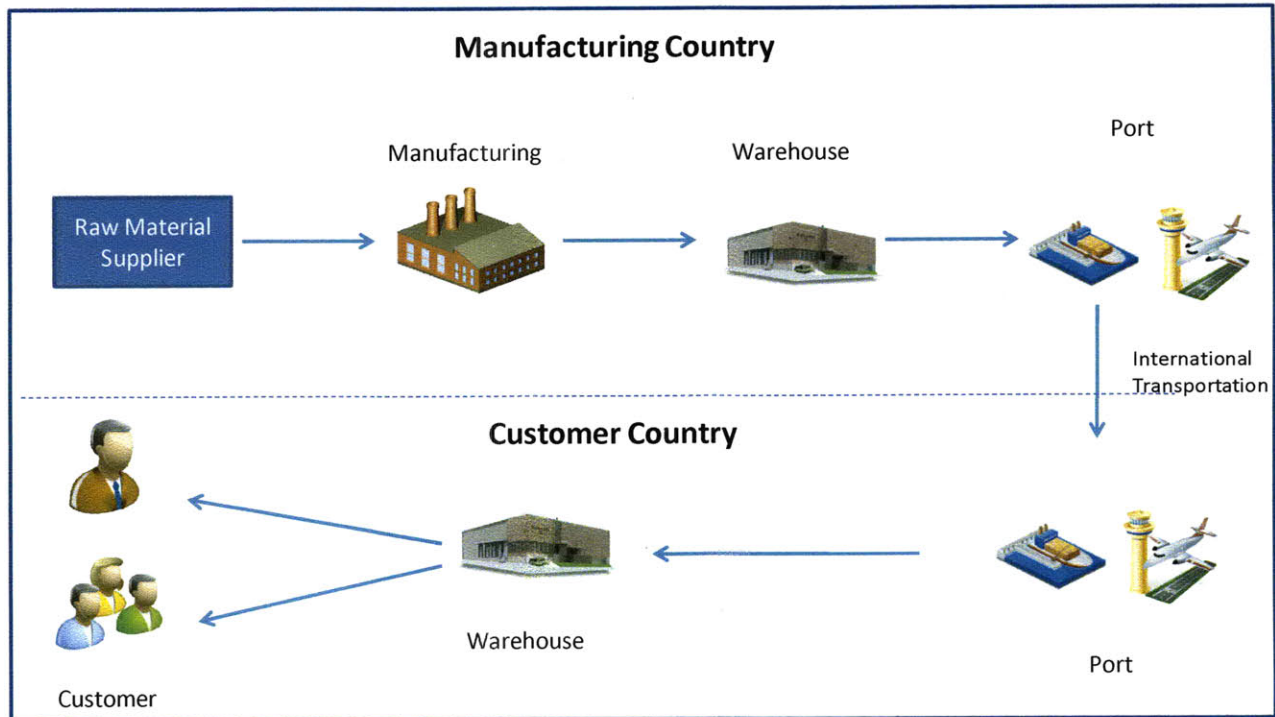


Figure 3.1 Tyco Electronics global supply chain

The Figure 3.1 demonstrates the supply chain from manufacturing to final distribution to customer. The first process is to source raw materials such as sands, steels or plastics for producing finished goods. Raw materials are procured from Brazil, Germany, United States, and China. The raw material is stored at the manufacturing plant. The next process is the manufacturing, which produces connectors (finished goods). Tyco Electronics categorized plants according to the production types which are manual, semi-automatic and automatic manufacturing plant. Then, the finished goods are transported to store at a local warehouse then to the port in order to send to customer country. Finished goods are kept at the customer country's warehouse to wait for the final distribution to customers. We model six cost components: raw materials sourcing, manufacturing, warehouse, transportation, inventory

holding, and taxes. These costs form the basis of the total landed cost model. The total landed cost model is summarized in the Figure 3.2.

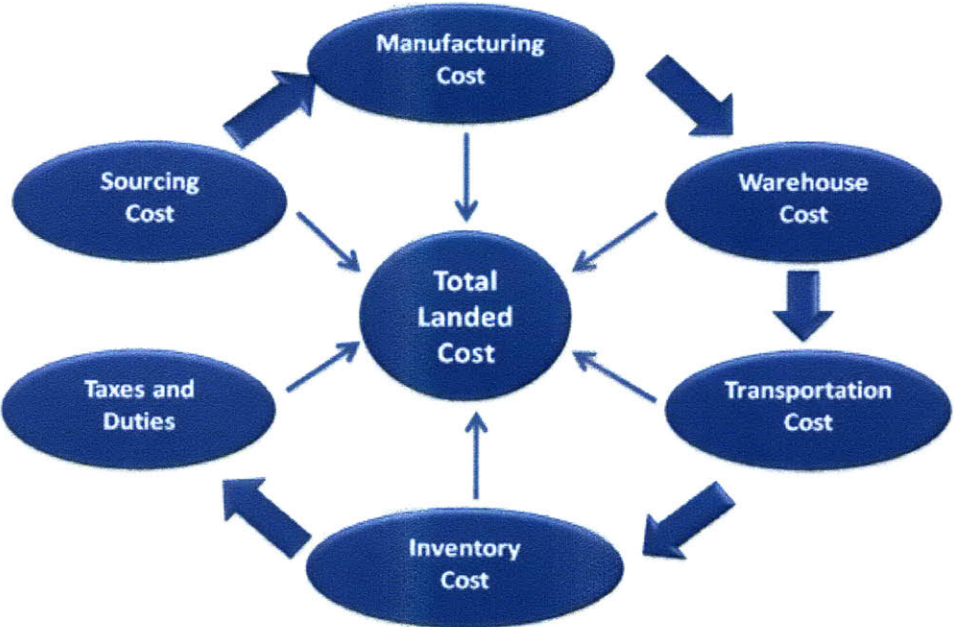


Figure 3.2 Six cost factors of a total landed cost model

Next, we study each cost bucket and also demonstrate the methodology to assess these six costs. We begin with raw material sourcing cost, manufacturing cost, warehouse cost, transportation cost, inventory holding cost, and, taxes.

### 3.2 Raw Material Sourcing Cost

The sourcing cost is the cost associated with raw material procurement. Raw material can be procured from local suppliers in the manufacturing country or from international suppliers depending on availability and cost. For our sample five SKUs, raw materials can be procured from Brazil, USA, Germany and China.

To assess the total raw material cost, we analyze the raw material purchasing. The sourcing decision depends on the production quantity, the availability in that country, market prices, and overall demand. Raw materials are usually purchased by weight or by pieces. In addition, each end item requires a different ratio of raw materials. For instance, one unit of product A requires ten grams of raw material 1000 and five pieces of raw material 0001. Accordingly, in this thesis, we called this ratio as *Used\_Ratio*. We develop the equation to calculate the total raw material cost as below.

$$\text{Total Raw Material cost} = \sum_{a=0}^n D * \text{Used\_Ratio}_a * \text{Raw material cost}_a$$

*where*

D = Finished goods annual demand (pieces)

Used\_Ratio = Ratio of required raw material a to produce one unit of finished good

Raw material cost = Costs of raw material a (\$/kg or \$/piece)

a = Raw material number

n = Total number of require raw materials

In some instances, supplier offer a volume discount if a firm purchases a minimum quantity. This discount is a mutual benefit to both suppliers and customers. Suppliers want to sell a large amount at the same time in order to gain economies of scale. The buyer also benefits since they get a reduced cost per unit. However, the buyer might later face higher inventory costs. We calculate the order quantity in order to check the purchase volume per review period.

$$Q = D * R$$

Due to the volume discount, the raw material cost is defined by

$$\text{Raw material cost} = \begin{matrix} m & \text{if} & Q > p \\ n & \text{if} & Q < p \end{matrix} \quad \text{or}$$

*where*

D = Finished goods annual demand (pieces)

Q = Order Quantity per review period (pieces)

R = Review period (times)

p = amount of volume to obtain a discount (grams or pieces)

m, n = unit price (dollars) ;  $n > m$

In addition to raw material cost, we include the transportation and import taxes as part of raw material procurement. For local supplier procurement, raw materials are transported by truck which we assume is paid by the supplier. For international procurement, Tyco Electronics is responsible for the associated international transportation and import taxes. The transportation

cost might be straight forward: however, the import taxes are more complex. The percentage of import duties for each manufacturing country is different. In addition, some countries waive import duties for raw material if they are used in the manufacturing process within that country. We create the equation to assess the transportation and taxes as below.

Raw material transportation cost

$$= \sum_{a=0}^n D * Used\_Ratio_a * Raw\ Material\ Weight_a * Transportation\ Cost_a$$

Import Taxes

$$= \sum_{a=0}^n (Material\ cost + Raw\ material\ Transportation\ Cost) * duties\ rate$$

*where*

D = Finished goods annual demand (pieces)

Used\_Ratio = Ratio of required material to produce one unit of finished good

Raw Material Weight = Weight of the raw material (kg.)

Raw material cost = Costs of raw material a (\$/kg or \$/piece)

Transportation Cost = Cost of raw material transportation (\$/kg.)

duties rate = import duties of manufacturing country (percent)

a = Raw material number

n = Number of raw material



From the discussion above, we found that the total sourcing cost can be derived from

Total sourcing cost = Raw material cost + Raw material transportation cost + Import taxes

In summary, the total sourcing costs are cumulative cost of raw materials, transportation, and taxes and duties. Even though sourcing from local suppliers does not have taxes and transportation cost associated, international sourcing often more cost-efficient due to lower material costs and the waiving of taxes if the import parts are involved in the later process.

### **3.3 Manufacturing Cost**

Manufacturing costs cover such factors as labor, equipment operation, and the general overhead for the facility. Tyco Electronics production processes comprised of plating, stamping, molding, and assembling. Facilities are either automated or manual. Each process needed to calculate separately since each process has different production time, labor used, and production cost. In addition to the manufacturing cost, which is the direct variable cost, we also include the plant facility cost and damaged cost.

Plant facility cost is the sum of indirect production costs which are administrative labor, machine cost, electricity cost and plant depreciation cost. The method to allocate the facility cost to each finished goods is sophisticated since each product has different value and different production time. We assess the plant facility cost by divide the interested finished goods' product value to total product value of the plant proportionally.

Damaged costs are also included in the total production cost. Damaged product can create drawbacks to the whole process since the company not only suffers from the defected product

but they also lose production time and material resources to produce additional product. Damage costs can play a role in selecting manufacturing locations. Automated plants have lower damaged rates than manual plants. However, production costs are higher. Accordingly, a company faces a trade-off between production and damage costs. To calculate the damaged cost, we multiply the damaged ratio for each five plant with annual demand and product value. The definition of product value can be the sale price or the manufacturing cost plus raw material cost. In this thesis, we use the latter. As a result, the product value of each production country will be different since the manufacturing cost and raw material sourcing cost are different. We defined the manufacturing cost formula as below.

$$\text{Manufacturing cost} = \text{Production cost} + \text{Facility cost} + \text{Damage cost}$$

We develop the formula as below

$$\text{Production cost} = D * \text{Hourly Labor Salary} * \text{Performance}$$

$$\text{Facility cost} = (\text{Admin. cost} + \text{Mfg. overhead cost}) * (\text{Production cost} / \text{Total production cost})$$

$$\text{Damage cost} = (D * v * \text{Percentage of damage goods})$$

*where*

$$D = \text{Finished goods annual demand (pieces)}$$

$$\text{Hourly Labor Salary} = \text{Labor cost for each plant for each process (\$/hr)}$$

$$\text{Admin. cost} = \text{Total administrative cost for each plant (\$/year)}$$

$$\text{Mfg. overhead cost} = \text{Total plant overhead cost for each plant (\$/year)}$$

Performance = Production Performance for each plant (pieces/hr)

Production cost = Cost for each production process for each plant (\$/hr)

v = Product value (\$)

Percentage of damage goods = Percentage of damaged goods for each plant (percent)

In summary, the total manufacturing cost is the function of finished goods manufacturing costs, plant facility cost, and damaged costs. These three costs need to be calculated together otherwise it might not represent the actual manufacturing costs for each plant. For instance, some plants may have low labor cost; however, the damaged ratio and the facility cost is high. The total manufacturing cost may be equal to the plant that has high labor cost but has low damaged rate and facility cost.

### **3.4 Warehousing Costs**

After manufacturing, all finished goods are transported to the closest warehouse where Tyco Electronics uses both automatic and manual operations. The costs associated with warehousing are the handling and storing finished goods product. Warehouse cost can be divided into handling, administrative and facility costs.

The handling cost is the labor cost of handling finished goods from enter warehouse, store the products in the right position, record product's data in the warehouse computer system, and load finished goods to the truck. To assess the handling cost, firstly, we convert all demand in pieces to be the number of packages. However, five SKUs that we focused have different

package size. So, we need to know how many finished goods can be placed in one package. Secondly, we estimate how many finished goods packages can be handled in one hour. Then, we find the number of employee involved and the salary in each country. We obtain the equation below.

Total Handling cost

$$= (D/\text{Carton size}) * \text{Number of labor involved} * \text{Avg. salary per hour} * \text{Performance}$$

*where*

D = Finished goods annual demand (pieces)

Carton size = Size of carton (pieces/carton)

Number of labor involved = Number of employees to deal with moving cartons (people)

Avg. salary per hour = Labor cost salary for one hour (\$/hr)

Performance = Number of cartons can be move within one hour (cartons/hr)

Next, we also consider the administrative and facility cost in the same way as we calculated the manufacturing cost. The administrative cost the indirect labor cost in the warehouse. However, we realized that the facilities cost is different from that of manufacturing part. For instance, Tyco Electronics outsources warehouse function to other logistics companies. Or, Tyco Electronics rents the warehouse of other companies. So, we need to include this cost when calculated the facility cost. We calculate both facility and administrative cost as below

Administrative cost per carton

= Annual warehouse administrative cost / number of packages per year

Facilities cost per package

= Annual warehouse facilities cost / number of packages per year

Due to the time constraint, we cannot obtain all the facility and administrative data for every five manufacturing countries. However, we have the average warehouse cost per each carton for each warehouse. This average warehouse cost includes labor cost, administrative cost, and facility cost. Therefore, we develop a new formula to assess warehouse cost.

Warehouse cost = (D/Carton size) \* Avg. warehouse cost

D = Finished goods annual demand (pieces)

Carton size = Size of carton (pieces/carton)

Avg. warehouse cost = the average cost of dealing one carton (\$/carton)

In summary, warehousing cost is mainly a cost of handling product from enter to exit warehouse. The main factor which determines the warehouse cost is the labor cost and the number of labor involved in the warehouse process. In some warehouse which operated by an automatic system, the handling cost may low but the facility cost is higher since Tyco Electronics has to bear higher electricity and maintenance cost. Actually, we did not include the damaged cost in the warehouse since the number of damaged package is fairly low. So, the damaged cost might be marginal when comparing with the handling cost.

### 3.5 Transportation Cost

The definition of transportation cost in this model is the finished goods transportation from manufacturing plant to local customers or to international customers. For the raw material transportation cost, we consider it in the raw material sourcing cost. We separate transportation cost into domestic and international. The domestic transportation paths are from 1) manufacturing plants to warehouses and 2) warehouse to customer or to airports or ocean ports. The international transportation paths are the transportation from manufacturing country to customer country. Tyco Electronics uses trucks for domestic moves and air or ocean mode for international moves. In practice, Tyco Electronics uses Third Party Logistics (3PL) providers to manage both domestic and international transportation.

To calculate the transportation cost, we study the transportation management practice of Tyco Electronics. For ground and ocean transportation, transportation cost is charged per truck or per container. Tyco Electronics transports many SKUs within one shipment. Therefore, in this total landed cost model, we assume that all transportation containers or trucks are full. The transportation cost will be calculated proportionally from the carton's size of interested finished goods to the maximum size of truck or ocean container. We use the equation below to calculate the transportation cost. The transportation costs from the manufacturing countries to the customer countries are provided by Tyco Electronics. We used the data to form the equation below.

$$\text{Truck Transportation Cost} = [D/(\text{Carton size}) / \text{Cap}_{\text{Max}}] * \text{Tcost}_{\text{Truck}}$$

$$\text{Ocean Transportation Cost} = [D/(\text{Carton size}) / \text{Cap}_{\text{Max}}] * \text{Tcost}_{\text{Ocean}}$$

*where*

D = Finished goods annual demand (pieces)

Carton size = Size of carton (pieces/carton)

Cap<sub>Max</sub> = Maximum capacity for truckload or ocean container (cartons per container)

Tcost<sub>Truck</sub> = Truck transportation cost from manufacturing country to the customer country (\$)

Tcost<sub>ocean</sub> = Ocean transportation cost from manufacturing country to the customer country (\$)

Air transportation, unlike ocean and ground, charges by weight. Accordingly, we cannot use the equation above to calculate the air transportation. We revise the equation by weight. Firstly, we need to know the weight of each five product SKUs in order to calculate the total weigh. We use the formula below to calculate.

$$\text{Transportation Cost}_{\text{Air}} = D * \text{Weight} * \text{Tcost}_{\text{Air}}$$

D = Finished goods annual demand (pieces)

Weight = Product Weight (grams/pieces)

Tcost<sub>Air</sub> = Air Transportation from manufacturing country to the customer country (\$)

There is also a per order cost that applies regardless of the size of the shipment. This covers the 3PL's administrative, communication, and monitoring tasks. The equation to calculate the transportation cost is demonstrated below.

$$\begin{aligned} \text{Annual ordering cost} &= \text{Ordering cost} * (\text{Number of replenishment orders placed per year}) \\ &= \text{Ordering cost} * (1 / R) \end{aligned}$$

*where*

$$R = \text{Review period or period to make an order (times)}$$

$$\text{Ordering cost} = \text{a fixed cost of each ordering (dollars)}$$

In summary, the transportation cost is cost of movement finished goods from manufacturing country to local customers or to customer countries. We assume that all containers are full. The truckload and ocean transportation are charged regarding to the container size and distance. However, the air transportation is charged regarding to product weight and distance.

### **3.6 Inventory Holding Cost**

Inventory Holding cost is composed of three parts:

1. Cycle stock
2. Safety stock
3. In-transit stock or pipeline stock



Cycle stock is the stock of products to serve the demand during the review period. Cycle stock varies according to the length of review period and the annual demand.

Safety stock is the quantity of finished goods maintained at a location to buffer against unexpected demand. Theoretically, safety stock is defined as extra units of inventory carried as protection against stock outs. Businesses usually held the safety stock when the business cannot accurately predict demand and lead time for the product. By having an adequate amount of safety stock on hand, a company can meet a sales demand which exceeds the demand they forecasted without altering their production plan.

In-transit inventory is the inventory stock during transportation. We did not calculate in-transit inventory for raw materials because Tyco Electronics did not take ownership of raw materials during transportation. However, if Tyco Electronics takes ownership of raw materials, we have to calculate in-transit inventory of raw material. Accordingly, the total cost may be higher if the lead time is longer.

In this thesis, since we analyze the supply chain cost from the raw material to customer hand, we need to calculate the inventory holding cost of both finished goods and raw materials. We realized that the equation to assess those costs is different and we divided it into two categories which are finished goods inventory holding cost and raw material inventory holding cost.

### 3.6.1 Finished Goods Inventory

Finished goods are stored in both the manufacturing and customer countries. In addition, finished goods are on the ocean or in the air during the transportation.

We analyze the inventory holding at the manufacturing country warehouse. The finished goods usage pattern drops according to the Figure 3.3 if it has an order. A large amount of finished goods will be transported at one time and then the finished products from manufacturing will be replenished. So, we should consider the safety stock to hold this inventory.

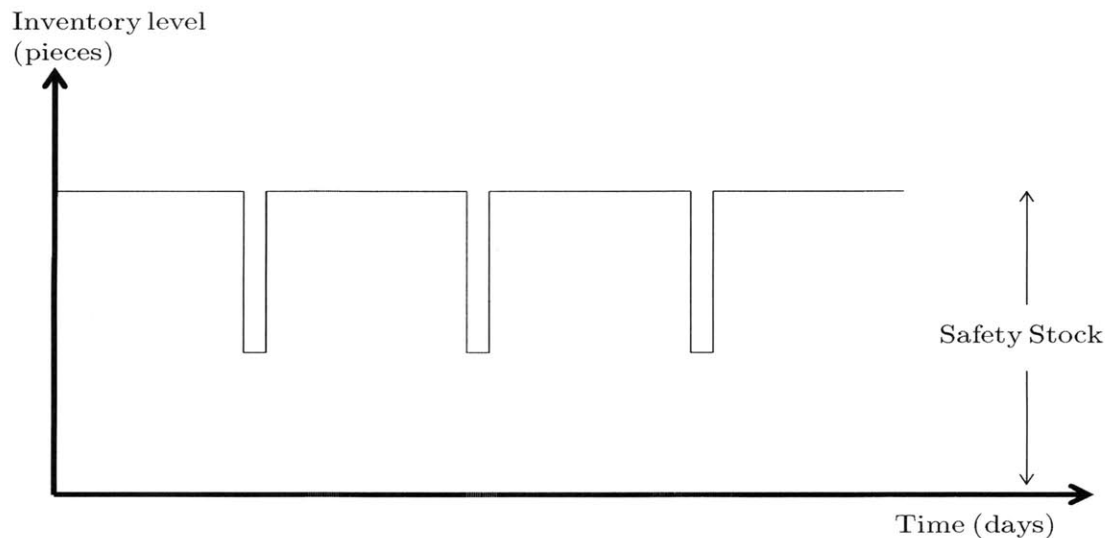


Figure 3.3 Finish goods inventory pattern at manufacturing's country warehouses

Tyco Electronics uses the fixed inventory policy which means each warehouse set the level of finished goods to cover the forecasted demand during certain period. For instance, the 30 days inventory policy and means thirty multiply with daily forecasted demand. So, we use the equation below to calculate the safety stock cost

$$\text{Safety stock level} = \text{Fixed inventory policy for each plant}$$

$$\text{Safety stock cost} = \text{Safety stock level} * v * r$$

where

D = Finished goods annual demand (pieces)

R = Period to make an order (times)

v = Product value (\$)

r = Inventory holding cost of capital; we set as 0.25

Next, we analyze the finished goods inventory pattern at customer country warehouse.

The usage pattern is shown on the Figure 3.4.

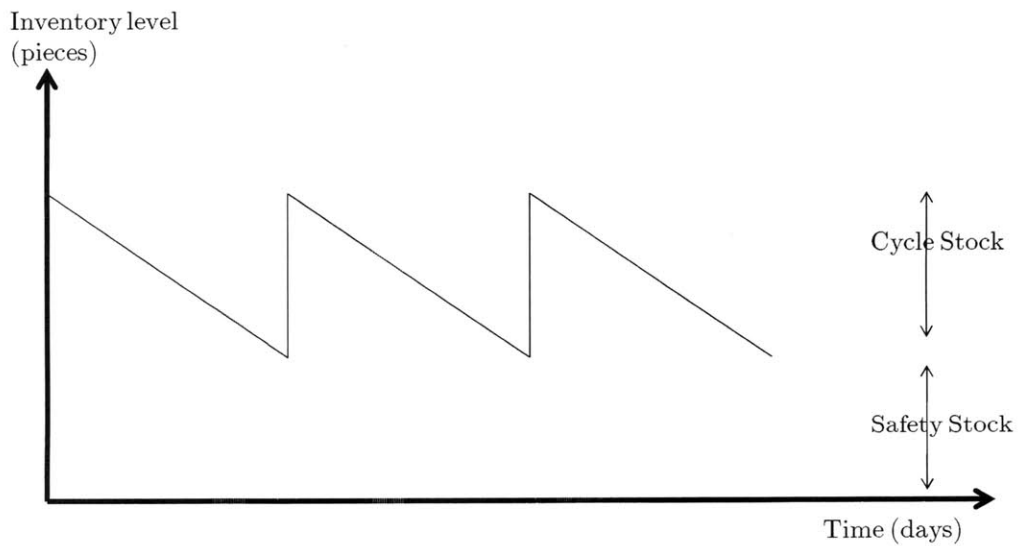


Figure 3.4 Finish goods inventory pattern at customer's country warehouses

We use equation below to calculate cycle stock cost and safety stock cost

$$\text{Cycle stock level} = (D * R) / 2$$

$$\text{Cycle stock cost} = \text{Cycle stock level} * v * r$$

$$\text{Safety stock level} = k * \text{Sigma over lead time}$$

$$\text{Safety stock cost} = \text{Safety stock level} * v * r$$

where

D = Finished goods annual demand (pieces)

R = period to make an order (times)

v = Product cost (\$)

r = Inventory holding cost of capital

Then, we analyze the in-transit inventory pattern. The amount of in-transit inventory stock depends on the lead time of transportation. The Figure 3.5 demonstrates the in-transit stock. We use the example of ocean and air transportation. The shorter lead time, the lower in-transit stock cost.

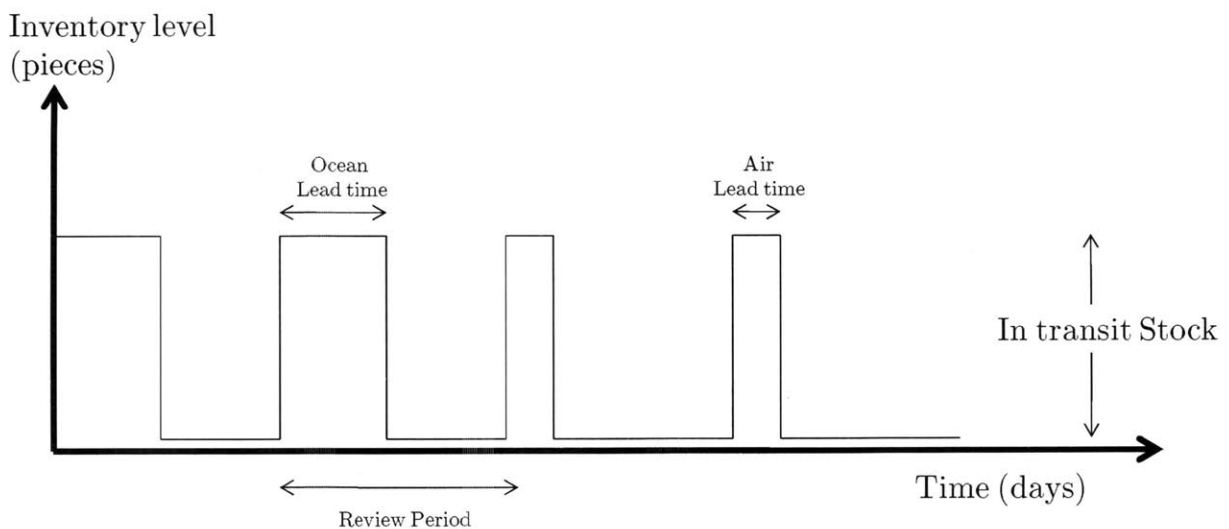


Figure 3.5 In-transit finish goods inventory pattern

$$\text{In-transit level} = (D \cdot R) = Q$$

$$\text{In-transit cost} = (D \cdot R) * (\text{Transportation lead time}) * (\text{Number of replenishment orders placed per year}) * v * r$$

where

D = Finished goods annual demand (pieces)

R = period to make an order (times)

Q = Order Quantity per ordering period (pieces)

v = Product cost (\$)

r = Inventory holding cost of capital

Transportation lead time = days of transportation from manufacturing country to customer (days)

### 3.6.2 Raw Materials Inventory

The raw material is held at the manufacturing plant in order to supply the production process. The lack of raw materials can lead to a disruption in the supply chain. For Tyco Electronics, raw materials are transported by suppliers to their manufacturing plants. Tyco Electronics does not take ownership of raw materials and so in-transit safety stock cost is zero. However, if Tyco Electronics takes ownership of raw materials at source, we have to calculate in-transit inventory. So, it has cycle stock and safety stock at the plant. The raw material usage pattern is demonstrated in Figure 3.6.

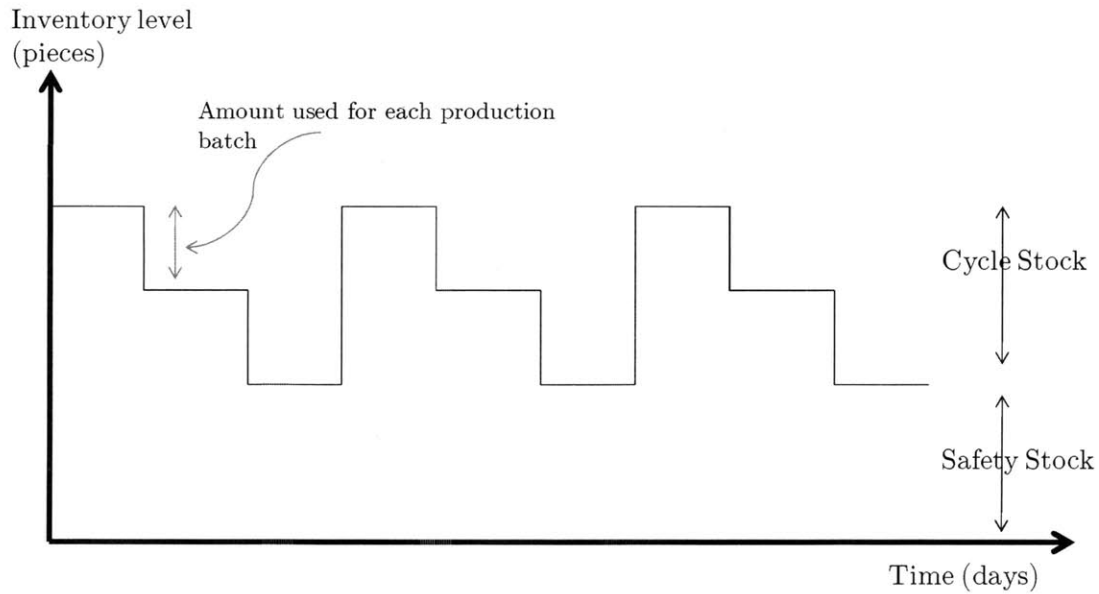


Figure 3.6 Raw materials inventory pattern at manufacturing plant

The amount of raw material used depends on the size of the production batch. We use the equation below to calculate the inventory holding cost.

$$\text{Cycle stock level} = (D * R) / 2$$

$$\text{Cycle stock cost} = \text{Cycle stock level} * v * r$$

$$\text{Safety stock level} = k * \text{Sigma over lead time}$$

$$\text{Safety stock cost} = \text{Safety stock level} * v * r$$

where

D = Finished goods annual demand (pieces)

R = period to make an order (times)

v = Product cost (\$)

r = Inventory holding cost of capital

In summary, the inventory holding cost is the cost associated from the stock of finished goods and raw materials. The main factor to determine the cycle stock is the review period. For the safety stock and in-transit stock, the factor to determine is the lead time or the mode of transportation. The longer lead time leads to the higher safety stock. The equation above show the trade-off between the transportation cost and inventory cost. Intuitively, if the companies select to save cost from using slower transportation, they will face higher inventory cost.

### 3.7 Taxes and Duties

Tyco Electronics pays the import tax to final destination government when Tyco Electronics imported products (raw materials and finished goods) from other countries. Tyco Electronics receives a discount tax rate if these raw materials or finished goods involved in the production process within the final destination country.

We develop the formula as below

$$\text{Import taxes} = D * (v + \text{transportation cost} + \text{insurance cost}) * (\text{duties rate})$$

*where*

$$D = \text{Finished goods annual demand (pieces)}$$

$$v = \text{Product value (\$)}$$

$$\text{Transportation cost} = \text{Transportation cost from the section 3.5}$$

$$\text{Insurance cost} = \text{Finished goods insurance cost (\$)}$$

duties rate = Import duties set by customer country government (percent)

### 3.8 Total Landed Cost Infrastructure

The total landed cost model was created in Microsoft Excel and has four components, which are

- 1. Input: Receive input from users
- 2. Calculation: Perform six cost factors calculation
- 3. Database: Store data for each plant, transportation mode, sourcing location, warehouse, and import tax.
- 4. Output: demonstrate total landed cost for each scenario to user

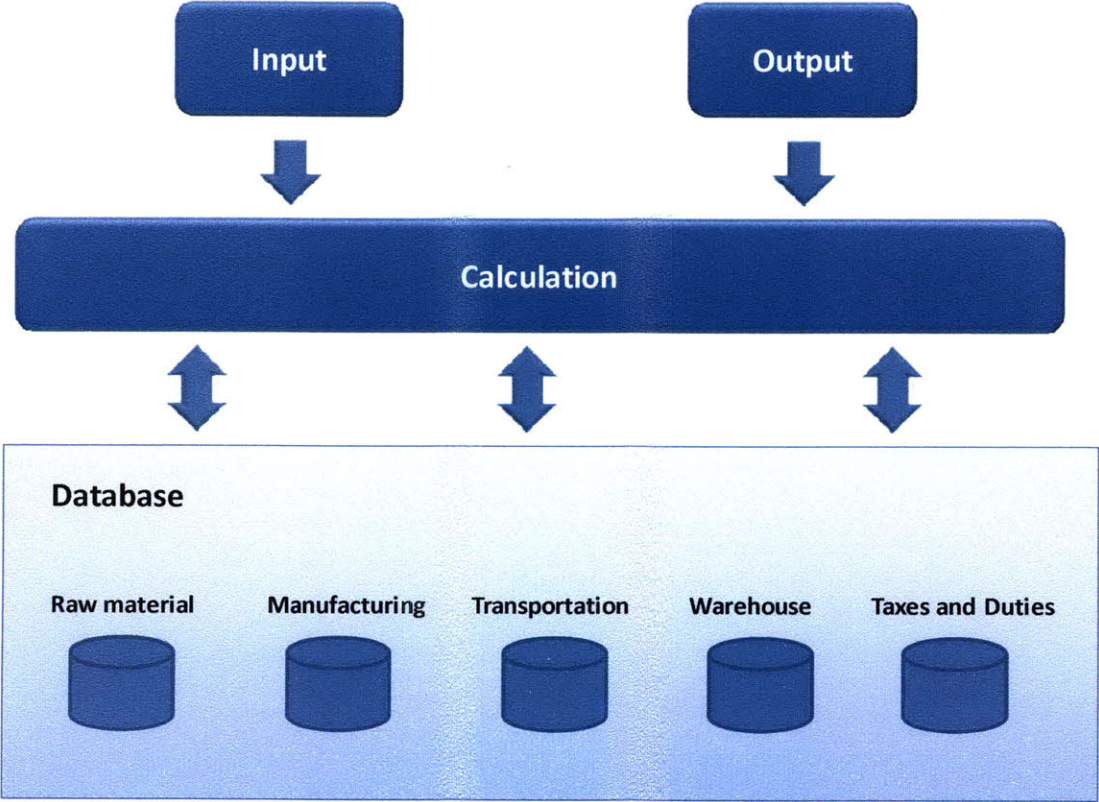


Figure 3.7 A total landed cost infrastructure



### 3.9 The Total Landed Cost Model

#### 3.9.1 The Sample Input Page

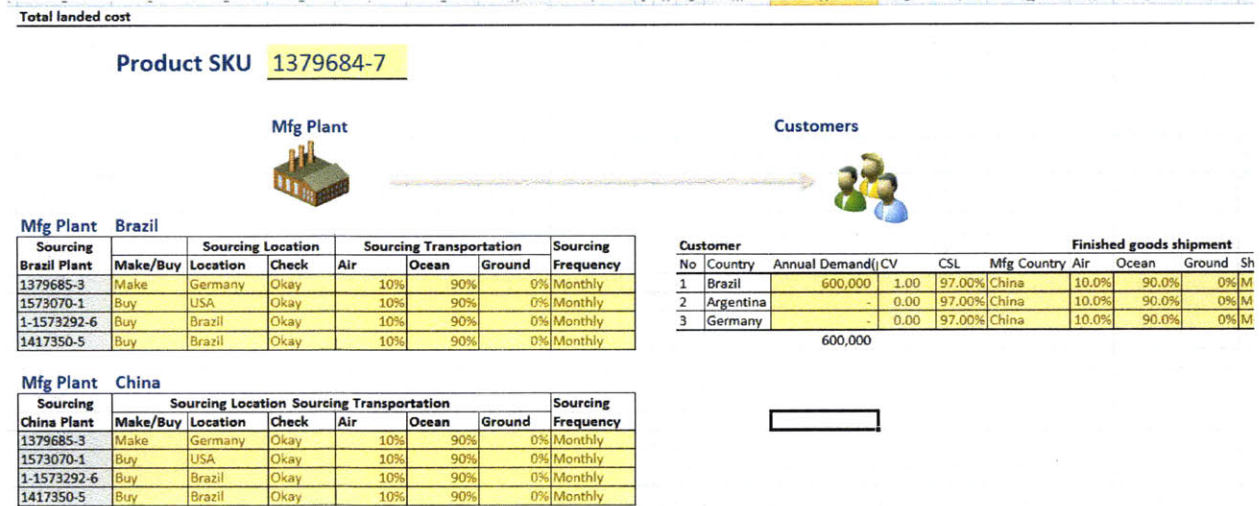


Figure 3.8 The total landed cost sample input screen

The Figure 3.8 shows the sample total landed cost input screen in the Microsoft excel software. Users can select two manufacturing countries and three customer countries. The raw material sourcing option and transportation sourcing mode can be selected. On the customer side, users can set demand coefficient of variation and required customer service level for each customer country. The finished goods international transportation mode can be selected.

### 3.9.2 The Sample Output Page

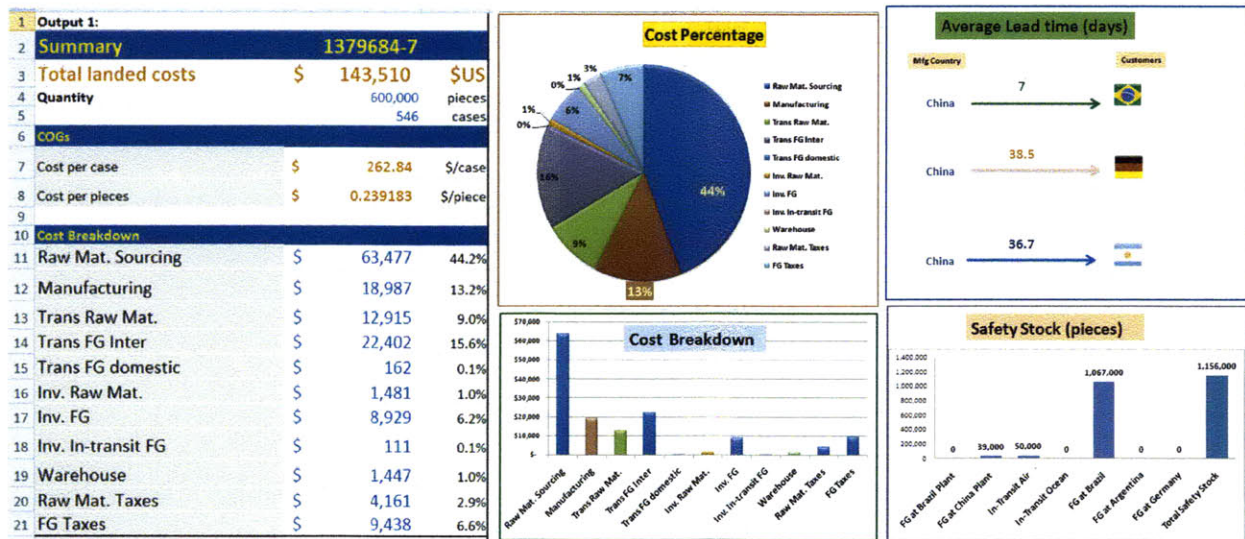


Figure 3.9 The total landed cost sample output screen

Figure 3.9 shows the sample total landed cost output screen in the Microsoft excel software. The total landed cost and each six cost bucket details for the input scenario are displayed. The output also shows the cost percentage, average lead time and required safety stock level.

# CHAPTER 4 ANALYSIS AND RESULT

This chapter uses the total landed cost model to analyze select manufacturing location, international mode of transportation. Next, this thesis uses the total landed cost to study the impact of global supply chain risks; increasing labor cost and increasing oil price.

## 4.1 Analysis Introduction

We used the total landed cost model to analyze Tyco Electronics global supply chain. We studied five product SKUs, which have different characteristics in term of demand, demand variability, weight, product value and customer service level. We tested these five products with five manufacturing countries and three customer countries. However, we are unable to disclose the result of the analysis due to the confidentiality reasons.

Accordingly, in this thesis, we selected one product as an example to be analyzed. The data for this product are realistic but not real. We tested this sample product with five manufacturing countries and one customer country, Brazil. The characteristics of the sample product are demonstrated in Table 4.1.

<b>Product A Characteristics</b>	
Demand:	600,000 pieces

Weight	3 grams
Annual demand coefficient of variation (CV) :	1.0
Customer service level:	97%
Manufacturing countries:	Brazil, China, Mexico, Czech Republic, and India
Customer country:	Brazil
Raw material sources:	Germany, Brazil, China
Inventory policy	Periodic review
Review period	One month
International Transportation	80% of finished goods by ocean transportation 20 % of finished goods by air transportation

Table 4.1 Sample product characteristics

In practice, since the demand often fluctuates, we use annual demand coefficient of variation to measure the demand fluctuation. Annual demand coefficient of variation represents the ratio of the standard deviation to the mean or normal annual demand. The mathematical formula is represented below.

$$\text{Coefficient of variation} = \text{Standard deviation} / \text{Mean}$$

In this experiment, we set demand coefficient of variation equal 1.0. So, the standard deviation equal 600,000.

Customer service level in a supply chain is a function of several different performance indices. The first one is the *order fill rate*, which is the fraction of customer demands that are met from stock. *Stockout rate* is the complement of fill rate and represents the fraction of orders lost due to a stock out. Another measure is the *backorder level*, which is the number of orders waiting to be filled. In this experiment, we used the order fill rate. Accordingly, ninety seven percent customers service level means a firm need to hold safety stock in order to meet the ninety seven percent of demand variation and have three percent stock out.

Additionally, we assume some scenarios such as demand variability and customer service level in order to demonstrate the impact to our result. The result can provide guidance for a firm to select manufacturing location and distribution strategies.

More importantly, we study the impact of global supply chain risk to our total landed cost. Obviously, overseas production has more exposure to several risks and uncertainties than local production. Accordingly, risks should be considered before making a decision to pursue a global strategy. In this analysis, we assume two risk scenarios; the rising of labor cost and increasing oil price. We chose these two factors because they have a high likelihood of occurring.

## 4.2 Which Manufacturing Locations Should Be Selected?

We tested production of product A across five manufacturing countries. The analysis result showed the total landed cost, cost breakdown, average lead time, and safety stock. Clearly, we want to identify the trade-off between manufacturing and transportation, inventory and taxes in oversea production. Therefore, the objective of this analysis is not to make a final decision but to demonstrate overall factors in order to help a firm make a better decision.

There are some assumptions that we used.

- Product A can be manufactured in all manufacturing countries.
- The fixed cost of each plant does not change by producing product A
- For the production overseas, 80% of Product A are transported by ocean and 20 % by air
- Raw materials are procured from the current suppliers.
- Inventory holding cost of capital is 25 percent.

The result is shown in Figure 4.1.

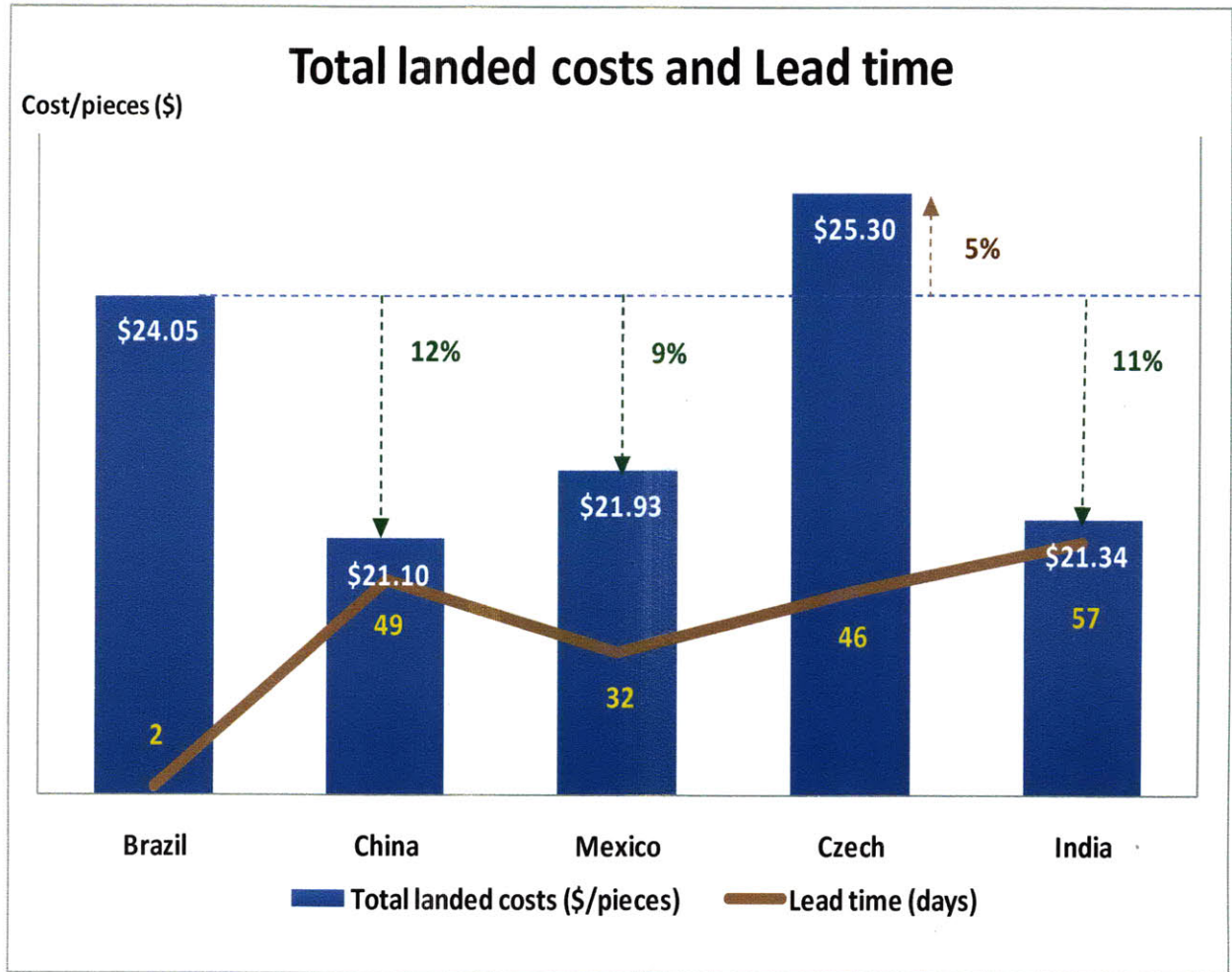


Figure 4.1 Comparing total landed cost and lead time in five manufacturing countries

The result in Figure 4.1 shows that China offers the lowest landed cost which is \$21.10 per piece or 12 percent lower than cost that of Brazil. India is the second lowest landed cost which is \$21.34 per piece or 11 percent lower than that of Brazil. Mexico is the third lowest landed cost. However, in term of lead time, production in China and India has the long lead times which are 49 days and 57 days respectively.



Cost Breakdown	Brazil	China	Mexico	Czech	India
Raw material	56%	64%	60%	49%	71%
Manufacturing	36%	15%	22%	28%	10%
Transportation	0.1%	5%	3%	3%	4%
Warehouse	0.4%	1%	1%	2%	1%
Inventory	8%	9%	8%	11%	9%
Imported Taxes	0%	6%	7%	7%	6%

Table 4.2 Total landed cost breakdown

The result in Table 4.2 shows the costs breakdown of the total landed cost in Figure 4.1. The Table 4.2 also demonstrates the trade-off in supply chain. The global supply chain strategy might help a firm reduce manufacturing cost but a firm faces higher inventory cost and international transportation cost and taxes.

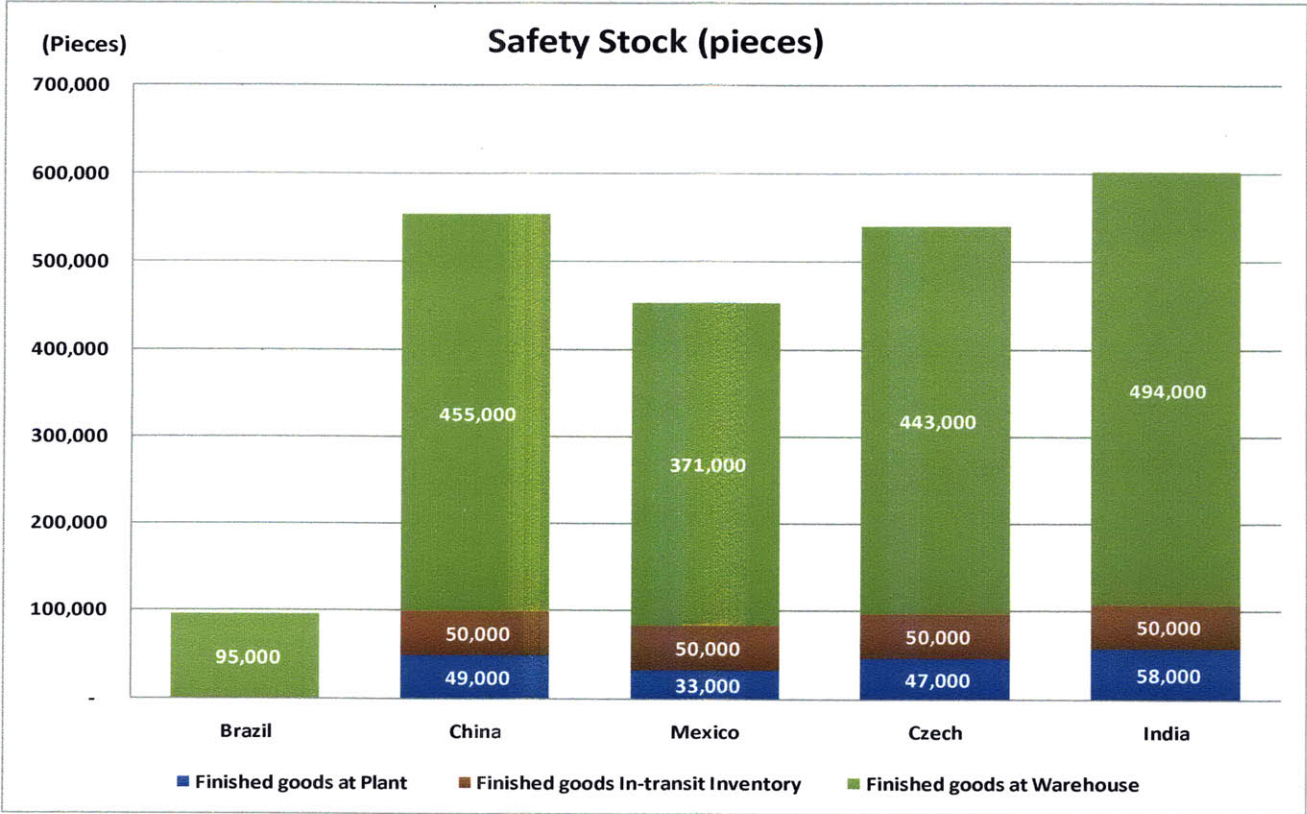


Figure 4.2 Comparing safety stock in five manufacturing countries



The Figure 4.2 shows the required safety stock for each manufacturing country if a firm wants to maintain the same customer service level.

### **4.3 Which Modes of Transportation Should Be Used?**

We studied which mode of transportation, either air or ocean should be used for transporting product A. Obviously, ocean transportation offers a more competitive transportation cost. However, transporting by ocean means a longer transportation time and also more lead time variability than air transportation. As a result, a firm needs to hold higher safety stock when using ocean in order to maintain the same customer service level. The higher inventory cost, safety stock and in-transit stock, sometimes may outweigh the cost-savings offered by ocean transportation and, therefore, air transportation may be suitable. Accordingly, the objective of this analysis is to show when the transportation cost will be less than the inventory holding cost and taxes.

The result from analyzing the five electronics products that we focused on shows that the total landed cost of shipping by ocean is less than by air. We found that shipping by air has shorter lead times and requires less amount of safety stock. However, the cost-savings from lower inventory levels did not outweigh the increasing transportation costs. We realized that it might be because of the characteristics of the connector product that has low value and light weight (3 grams). So, we suggest that, for electronics industry, a firm should use the ocean mode.

### 4.4 When Should Air Transportation Be Used?

We come to the question of when air transportation be used. The advantage of air transportation is that it helps a firm lower their inventory levels and response faster high demand variability. Therefore, demand variability and customer service level plays a role in determining transportation mode. To validate the hypothesis, we test product A with different levels of demand variation. We select the case where manufacturing is located in China and the customers are in Brazil. By varying the coefficient of variation of demand, we can estimate the break-even point where modes are equal.

We use demand coefficient of variation in the analysis. The result is shown in Figure 4.3.

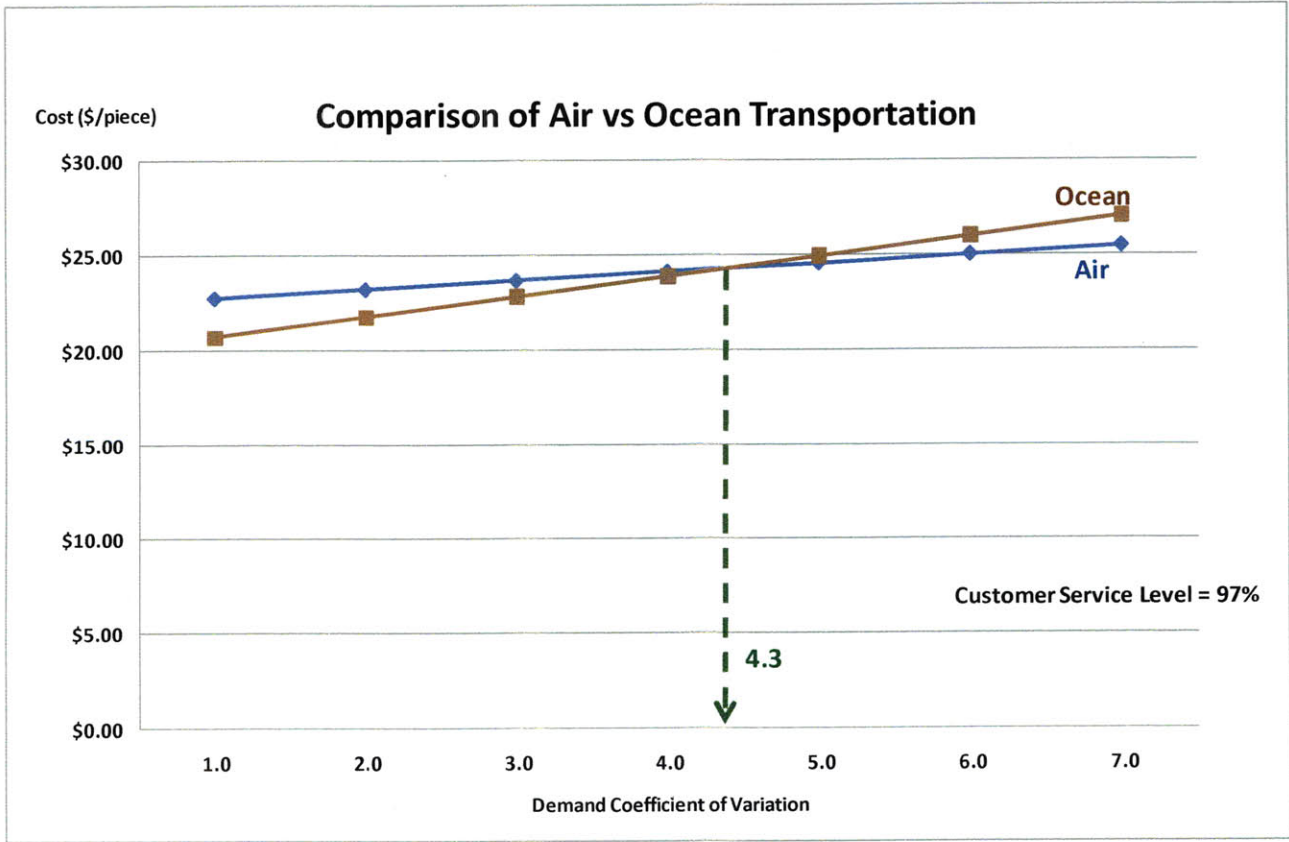


Figure 4.3 Sensitivity analyses in demand coefficient of variation

The result shows that if the demand coefficient of variation of product A is higher than 4.3, the total landed cost will be lower for air transportation than for ocean transportation. Accordingly, if product A has demand coefficient of variation more than 4.3, the firm should transport by air not only because lower total landed cost but also shorter lead time.

In general, it can be concluded that, when demand variation increases, it makes more sense to ship by air because the slope of ocean is steeper than air transportation. The reason is that higher demand variation requires higher safety stock, thereby increasing the inventory cost.

On the above analysis, we study only one level of customer service (95%). Next, we study the impact of different customer service levels; 95%, 97%, 98%, 99%, and 99.99%. The recommendation for each combination of customer service level and demand variability is displayed in the Table 4.3.

CSL	Demand CV.				
	1.0	2.0	3.0	4.0	5.0
95%	Ocean	Ocean	Ocean	Ocean	Ocean
97%	Ocean	Ocean	Ocean	Ocean	Air
98%	Ocean	Ocean	Ocean	Air	Air
99%	Ocean	Ocean	Air	Air	Air
99.99%	Ocean	Air	Air	Air	Air

Table 4.3 Transportation mode for the demand coefficient of variation and customer service level.

For the connector products, air transportation help reduce the total landed cost if the product has high demand variability and high customer service levels. The result shows that higher customer service level requires higher safety stock and therefore, it makes more sense to transport by air.

## **4.5 Impact of Increasing Labor Cost**

The next analysis examines the impact of increasing labor cost within the supply chain. Many companies decided to locate manufacturing facilities in developing countries because of low-labor costs. However, labor costs in the developing countries are like to increase due to high economics growth rate. Accordingly, we perform an analysis in order to address the question of how much the increasing of labor costs impact to the total landed cost of a firm and when it should move the production back to the local country.

The complexity in assessing the impact of labor cost is that each country has different performance level and different production systems such as automatic and manual production. Therefore, increasing labor cost in that country may not proportionally raise the manufacturing cost. To determine the manufacturing cost, we need to consider labor cost, plant performance, and percentage of labor use at the same time. For instance, the labor-based production plants experience increased labor cost at a higher rate than machine-based production plants in a comparable labor market. In the same way, the plant that has higher performance has less negative impact than the plant that has lower performance.

More importantly, we wish to address the assumption that labor cost will affect only manufacturing cost so we can assess the impact directly. However, by using the total landed cost model we found that this is not true. When the manufacturing cost increases, the import taxes

and duties increase since the product value is higher. In addition, the inventory holding cost also increases since the inventory cost is calculated based on product value. Thus, the business needs to consider every cost factor together.

To perform an analysis, we set the scenarios as below

1. Raise the labor cost increase 100 percent from the current position.
2. Study product A for manufacturing in 5 countries and 1 customer in Brazil.
3. Ship 80% of finished goods by ocean and 20% by air.

The result is displayed Figure 4.4.

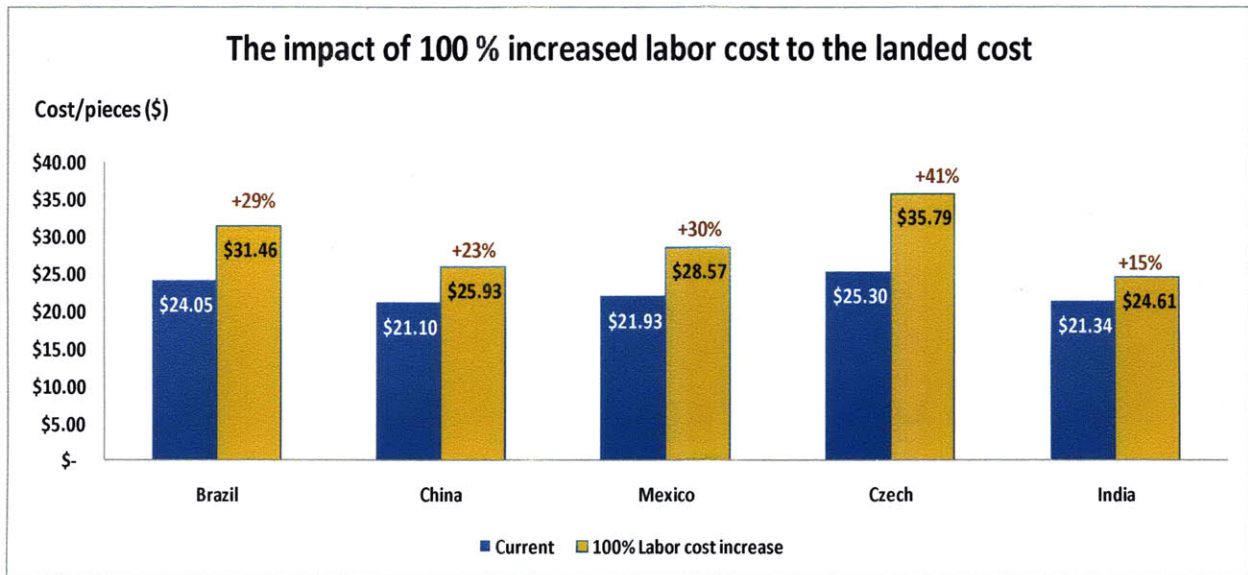


Figure 4.4 The impact of increased labor cost to the total landed cost

From the Figure 4.4, we found that Czech Republic experiences the greatest impact from increasing labor costs. India experiences the least impact. We also tested the result with other



level of increasing labor cost. The result is linear. So, we can use the percentage of impact to the total landed cost shown above to assess.

### 4.6 If Labor Cost Keep Rising, When Should A Firm Move Production Back?

Next, since we comprehend the level of impact of labor cost, we calculate if the labor cost is rising from the current position, when a firm should move the production back.

To perform an analysis, we raised the labor cost 10 percent every step. The result is displayed in Figure 4.5.

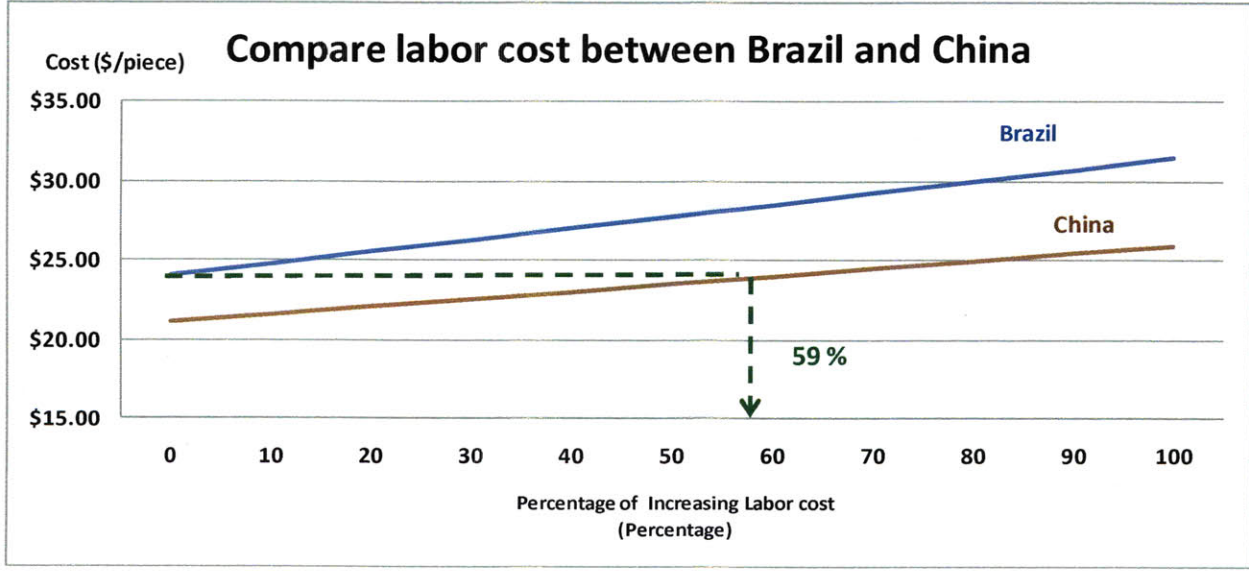


Figure 4.5 Sensitivity analysis to increasing labor cost

The analysis shows that if the labor cost of China rose 59 percent and the labor cost of Brazil is stable, the total landed cost will be the same. Therefore, a firm may consider moving production back to Brazil.

## 4.7 Impact of Rising Transportation Price

We study the impact of the rising transportation price to a firm's global supply chain operation. The oil price greatly impact to the international transportation cost. We need to consider the impact for both the finished goods transportation and raw material transportation. Additionally, the rising of transportation cost also increase the import taxes because the import taxes calculate from the product value and transport cost.

To perform an analysis, we test the scenarios below;

1. Raise the transportation price 100 percent from the current position.
2. Study product A for manufacturing in 5 countries and 1 customer in Brazil.
3. Ship 80% of finished goods by ocean and 20% by air.

The result is displayed in Figure 4.6.

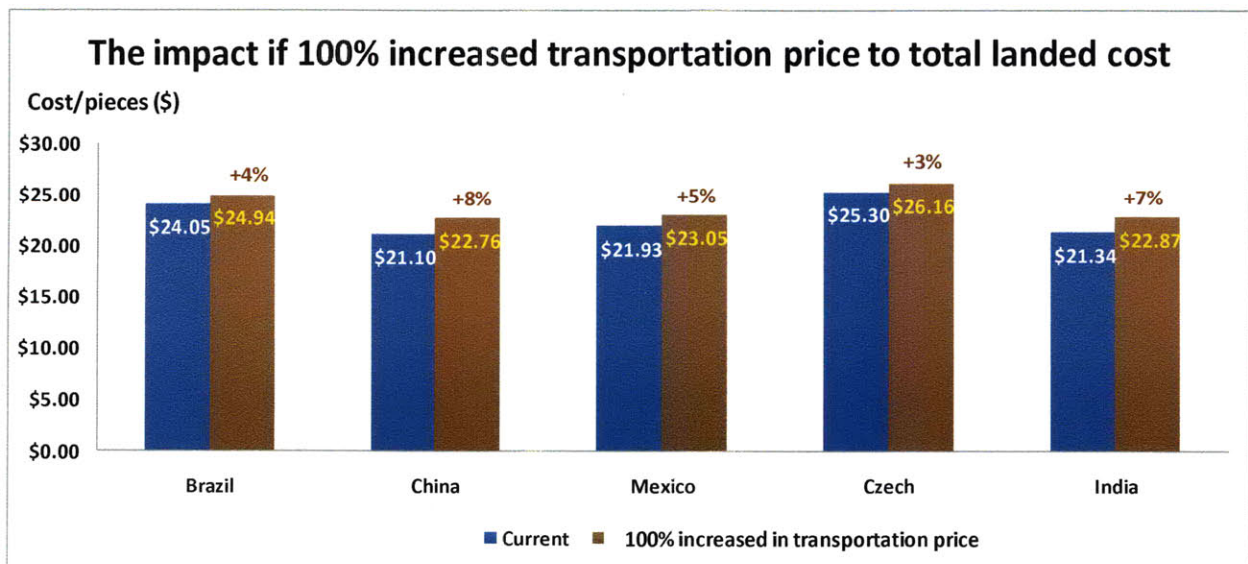


Figure 4.6 The impact of increasing oil price to the total landed cost

From the Figure 4.6, we found that China is impacted the most from the increasing transportation cost. The Czech Republic is impact least. China experiences the greatest impact because the distance to customer is longer than any other countries. We also tested the result with other level of rising oil price. The result is linear. So, we can use the percentage of impact to the total landed cost shown above to assess.

However, unlike the labor cost, the impact of transportation cost is between 3 – 8 percent. The reason is because the weight of the connectors is light and manufacturing costs account for approximately 40 percent of total cost. So, we might conclude that the connector product is more sensitive to labor cost.

#### **4.8 If Transportation Price Keeps Rising, When Should A Firm Move Production Back?**

Next, we address the question of when a firm should move production to the customer country. We use same method as above to analyze this effect. We raise the transportation cost 20 percent every step. The result is displayed in Figure 4.7.



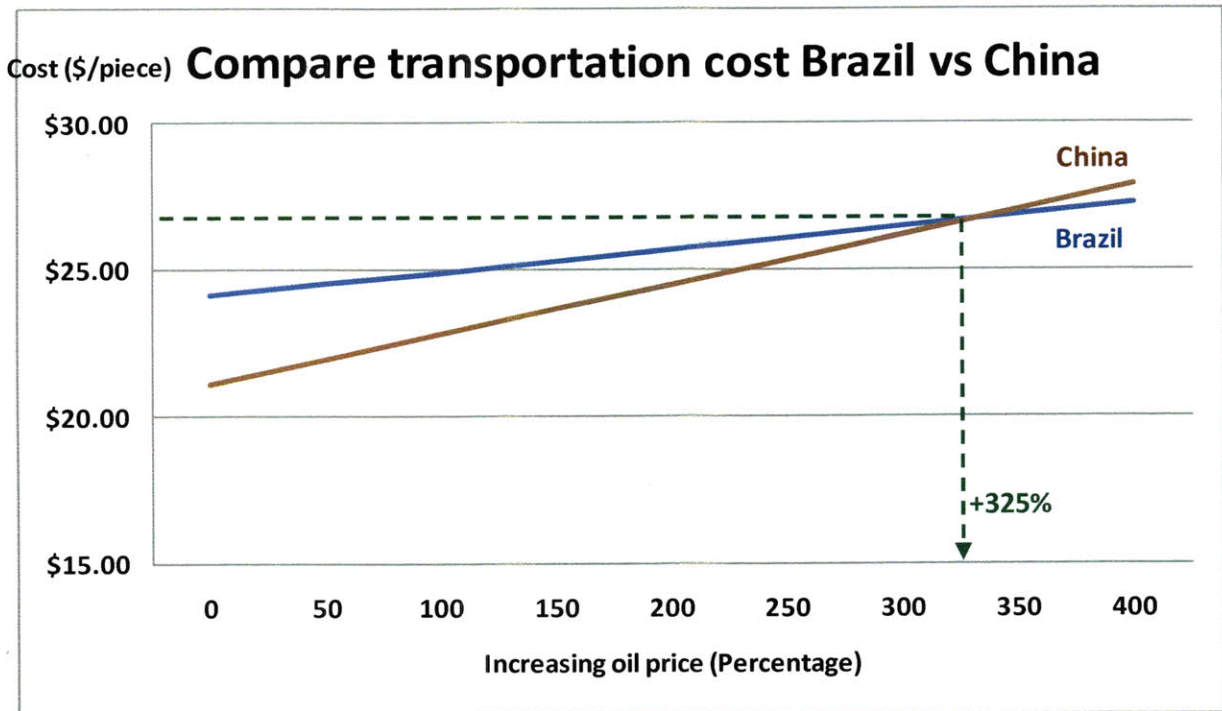


Figure 4.7 Sensitivity analysis to the increasing transportation cost

The analysis shows that if the oil price rise 325 percent, the total landed cost will be the same. Therefore, a firm may consider moving production back to Brazil.

## **CHAPTER 5 THESIS SUMMARY**

This chapter summarizes using a total landed cost model to foster global logistics strategy in the electronics industry. This chapter reviews the result by applying total landed cost model to the business case. The final part of the chapter discusses the further research opportunities that can be extended from this thesis.

### **5.1 Conclusion**

To begin with, this thesis focused on developing a total landed cost model for electronics industry and on applying this landed cost model to help businesses develop a global logistics strategy. We chose one sample electronics business, Tyco Electronics, which has manufacturing facilities and customers around the world. This total landed cost model is built based on Tyco Electronics' sourcing, manufacturing and distributing business practice. The total landed cost model is formed by six cost buckets; raw material sourcing, manufacturing, domestic and international transporting, warehousing, inventory holding and duties. This model can change such variable as percentage of air and ocean transportation across countries, desired customer service level, demand coefficient of variation, and inventory review period. The scope of thesis is to study

- 1) Five manufacturing countries; Brazil, China, Czech, Mexico, and India
- 2) Three customer locations; Brazil, Germany, and Argentina

3) Five product SKUs, which has different characteristics in term of annual demand, demand variability, weight, and product value.

The first objective of this thesis is to estimate total landed cost for manufacturing in each five country to serve each three customer country. The next objective is to study the impact of increasing labor cost and oil price to the total landed cost. The result of this study demonstrates the lowest landed cost of manufacturing country and mode of transportation for each customer and each five product SKU.

We tested these five products with five manufacturing and three customer countries for both air and ocean international transportation. We obtained the lowest landed cost for each manufacturing and customer country for each five product SKUs. However, the results of the analysis are not allowed to disclose due to the confidential reasons. Accordingly, in this paper, we selected one sample product, Product A. The annual demand, demand variability, and customer service level for product A are generated for academic purpose. We tested this sample product with five manufacturing countries; Brazil, China, Czech, Mexico, and India, and one customer country, Brazil.

The analysis result shows that product A should be manufactured in China since production in China has the lowest landed cost. For international transportation, product A should be transported by ocean. Air transportation should be used if the product A has high demand coefficient of variation or if a firm require high customer service level. The detail is demonstrated in Table 4.3.

Next, we tested the impact of increasing labor cost and oil price. We found that electronics products are more sensitive to the increasing labor cost. However, the increasing oil price does not much increase the total landed cost.

Overall, the result from the total landed cost model shows the trade-off in global supply chain that 1) although a firm can save the manufacturing cost by moving production to low-labor cost country, a firm face higher international transportation cost, higher safety stock level and increasing import taxes. and 2) ocean transportation cost offers lower transportation cost than air transportation; however, a firm need to hold higher safety stock in order to maintain the same customer service level. Importantly, to be successful in lowering total supply chain cost by manufacturing in low-labor cost country, a firm need to accurately understand these trade-offs. Our total landed cost model can show this trade-off, which can help firm decide whether the oversea productions in some country reduce firm's total costs.

In summary, the total landed cost model can be used as a quick tool to analyze the associated costs in global supply chain from sourcing raw material, manufacturing finished goods, distributing to customer hand. The total landed cost model's output help a firm make a better global logistics design decision in term of selecting a manufacturing location, choosing distribution strategies and studying the impact from global supply chain risks.

## **5.2 Future Research**

Our thesis has also uncovered the fixed costs of manufacturing, and warehousing. Since our total landed cost model is designed to be a quick tool to show landed cost for each manufacturing location and mode of transportation, we consider only variable cost. We assume

that the product can move to produce anywhere without affecting the total fixed cost of each plant. However, in the real practice, by moving production from one country to another country, the fixed cost will be allocated to other products. Accordingly, the total plant cost (fixed cost and variable cost) per unit changes. To use this total landed cost model intensively, the fixed cost needs to be included in order to obtain the more accurate result.

In addition, the further research should incorporate lead time variability of international transportation to the model. Theoretically, the higher lead time variability in the international transportation requires higher safety stock. However, in this thesis, we did not include the lead time variability when calculating the safety stock level and safety stock cost.

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