# Improved Supplier Selection and Cost Management for Globalized Automotive Production

by

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B.S.E Mechanical Engineering, Princeton University, 2007

Submitted to the MIT Sloan School of Management and the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degrees of

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## Abstract

For many manufacturing and automotive companies, traditional sourcing decisions rely on total landed cost models to determine the cheapest supplier. Total landed cost models calculate the cost to purchase a part plus all logistics costs to transport the part from the supplier to the plant. Although these models can provide a base comparison for suppliers, they do not contain the complete information necessary to make a supplier decision. There are several other factors that must be considered in the sourcing decision process to make a proper decision that considers the risks associated with supplier selection.

The primary focus of the thesis is to improve the sourcing decision methodology for choosing between suppliers by identifying and developing models for the key elements in the decision process. A secondary focus of the project is to identify an inventory policy that reduces the supply chain cost of foreign suppliers.

Four different aspects of the sourcing decisions process are discussed. The first section is the risk of air freight. Air freight risk is important in the context of the global versus local supplier discussion because it creates a major discrepancy when comparing the potential cost of each supplier. The thesis develops a model that provides an expected cost of air freight to measure air freight risk through the use of historical data.

The second aspect discussed is the development of a more comprehensive cash flow model to determine the NPV of cash flows of each supplier that includes the impact of inventory policy and payment terms on net working capital. A more comprehensive model provides the true cash cost, not the accounting cost, of a supplier decision. The model is primarily used to compare local and foreign suppliers.

The third part discussed is the impact of foreign exchange rates on the supplier decision and how certain assumptions can impact or alter the supplier decision. A means of testing how the supplier decision is impacted by foreign exchange assumptions and volatility is discussed. Finally, a dual mode sourcing model that ships parts by both air and ocean freight is developed to reduce overall logistics costs for parts procured from foreign suppliers.

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# 1 Introduction

## 1.1 Company Overview

General Motors Corporation (NYSE: GM) is the world's largest automotive manufacturing company by sales across the world (Galligan, 2012). General Motors (GM), headquartered in Detroit, Michigan, employs over 200,000 people while doing business in 157 countries and producing cars and trucks in 31 countries (General Motors Company Page, 2012). GM offers a variety of cars and trucks from seven different brands such as Chevrolet, Buick, Cadillac, and Opel. GM operates out of five main regions or home bases for design and manufacturing; United States, China, Germany, Korea, and Russia.

General Motors has gone through a major transformation since filing for reorganization under the provisions of Chapter 11 on June 8th, 2009. The company sold and eliminated several brands, received billions of dollars in loans from the U.S. and Canadian governments which became large stakeholders in the company, and set a record for the largest IPO in US history on November 18th, 2010. GM has emerged from bankruptcy with strong results taking over Toyota in 2011 as the largest automotive company by sales with 9.025 million units sold worldwide or 11.9% of global market share (General Motors Company Page, 2012).A big part of GM's success is due to the strength in international markets such as China and Brazil which are the company' first and third biggest markets by sales, respectively.

GM has had tremendous success in China, the company's fast growing market, particularly with the Buick brand. GM operates in China through several joint ventures. GM sales increased 28.8 percent to over 2.3 million units in 2010 and plans to double sales from 2010 to nearly 5 million units by 2015 (The Detroit News, 2011). International markets have become an increasingly important part of GM's success. In 2011, 71.9% of GM sales were outside of the Unites States and Chevrolet, a brand of GM, had more than 15 markets experience record sales all with double digit year over year gains (GM Press Release, 2012). The US market continues to grow with 2.5 million units sold, up 11% from 2010.

GM's subsidiary in Brazil, General Motors do Brasil, is headquartered in Sao Caetano do Sul and has been in operation since 1925. GM only sells the Chevrolet brand in Brazil with a mix of imported vehicles and vehicles assembled in Brazil. Many of the existing vehicles assembled and sold in Brazil share platforms with the Opel brand in Europe. The product portfolio in Brazil is going under a major transformation as legacy vehicles are phased out and new, global platforms are being assembled in Brazil.

## 1.2 Problem Overview

Over the past decade as international demand for automobiles has expended, especially in Asia, South America, and eastern Europe, automotive manufacturers have adopted a "build where you sell" strategy expanding manufacturing operations and establishing joint ventures all over the world. With the global reach, automotive companies have pushed to move towards the use of global platforms.

In the past, many automotive companies would develop a vehicle platform but wouldn't use the same platform across all markets. For example, GM would develop a small pick-up truck for the US market that doesn't share the same styling, parts, and branding as the small pick-up truck offered in Europe or South America. Companies have begun to develop one model which is used globally across all markets sharing the same name, styling, and parts. A recent example of a global platform model is the Chevrolet Cruze. The engineering for the Chevy Cruze was developed in Korea but the Cruze has launched in Korea, Russia, China, Europe, United States, and Brazil.

Although there are minor differences between the vehicles in each region (mostly due to regional safety regulations and consumer preferences), a vast majority of the parts for the vehicle are the same across all regions. Transitioning from regional platforms to global platforms has a significant impact on the company's operations. Global platforms allow for consolidation of engineering and design resources and have a significant impact on sourcing strategy. As a result of the transition to global platforms, companies have begun to alter their sourcing strategy using a single global supplier to supply parts to all the different regions for global platforms. Of course, there are advantages and disadvantages to this strategy, which are discussed in Chapter 2.

The transition to the new strategy impacts each region differently. For GM Brazil, the new sourcing strategy is a vast departure from its previous sourcing strategy. The parts for the global programs are sourced primarily by international suppliers in the Asia-Pacific region going against the historical trend of local suppliers for vehicles assembled in Brazil. The transition to a more prevalent use of foreign sourcing has created several issues for GM such as putting a strain on resources and incurring unanticipated costs (mostly due to unanticipated air freight) testing the belief that pure global sourcing is the cheapest sourcing strategy. As a result, GM Brazil has been pushing to localize more parts and to revisit the business case methodology for sourcing parts.

An important component of the sourcing process is determining the total landed cost of a part. The total landed cost calculation can be executed in many different ways (comprehensive literature review is in chapter 3) but it is a vital first step to be able to compare suppliers for a sourcing decision.

The total landed cost of a part is generally defined as the cost to purchase a part plus all logistics costs to bring the part from the supplier to the plant. Depending on the part and contract specifications, the individual components of the total landed cost may differ but for most cases the total landed cost is comprised of the variable cost of the part from the supplier, inbound logistics costs to bring the part to a port or airport, air or ocean freight costs, insurance costs, import duties, taxes, port fees, inbound logistics costs to bring to a warehouse, warehouse storage costs, inventory holding costs, and transportation from the warehouse to the plant. A precise, accurate, and flexible model is an important asset for making good supplier decisions.

At GM Brazil, the total landed cost of a part is calculated by the Supply Chain Engineering group. The group receives the variable cost per part from the Buyer Group within GM and calculates the other components of the total landed cost. The individual components of GM's total landed cost calculation are proprietary but the calculation is extremely comprehensive and is executed with great precision. GM's method offers great flexibility to determine the total landed cost for suppliers from every area of the world covering several variations of the contracts.

Although GM's total landed cost model is a strength within the sourcing methodology, there are other three areas which required further examination and improvement. First, the model used to estimate the cost of unexpected air freight shows volatile results that do not properly reflect the risk of air freight. The volatile results make it difficult for managers to incorporate the risk of unintended air freight into the sourcing decision. Second, the method of financial analysis to compare suppliers omits important financial elements which can alter the supplier decision. Third, there is no comprehensive approach to understand the impact of foreign exchange forecast assumptions and foreign exchange volatility on the supplier decision.

Beyond the sourcing decision methodology, the inventory policy used in Brazil requires a large amount of safety stock for internationally sourced parts. Examining alternative inventory policies for internationally sourced parts is important to reduce the logistics cost burden for these parts. As a result of these facts, GM needs to develop a more comprehensive set of tools for the supplier decision and examine a variety of inventory policies to reduce overall logistics costs.

## 1.3 Project Objective

The primary focus of the project is to improve the sourcing decision methodology for choosing between suppliers by identifying and developing models for the key elements which should be incorporated into the decision process. Another focus of the project is to identify an inventory policy which reduces the supply chain cost of foreign suppliers. There are three objectives pertaining to the sourcing decision and one objective for the inventory policy.

It is important to note that there are other factors besides those discussed to consider in the supplier decision. The supplier's quality record, capacity, and technological capabilities are important factors among others. It is assumed in this analysis that if a supplier has made it to the point in the decision process that management is requesting quotes, the supplier has met the necessary requirements for the factors stated above.

**Sourcing Decision Methodology:**

- **Air Freight Risk:** The plant's top priority is to keep the assembly line moving to keep producing cars. From the manufacturer's perspective, the cost of stopping the assembly line is prohibitively high. If an issue arises that requires immediate delivery of parts, air freight is utilized to keep the line running. Air freight risk is difficult to assign to the cost of a part because it is hard to know if and how much air freight will be required. Air freight risk is important in the context of the global versus local supplier discussion because it creates a major difference between the potential cost of each supplier. The supply chain is only susceptible to air freight risk under a foreign supplier and air freight could be a significant un-anticipated cost. The first goal of the project is to develop a model which provides an expected cost of air freight to measure air freight risk through the use of historical data.
- **Financial Modeling:** Net present value (NPV) analysis is a key component of the supplier decision. Traditional models compare the total landed cost from each supplier along with tooling cost requirements to develop a cost-based NPV. The second goal of this project is to develop a more comprehensive cash flow model to determine the NPV of cash flows of each supplier that includes the impact of inventory policy and payment terms on net working capital. A more comprehensive model provides the true cash cost not the accounting cost of a supplier decision. The model is primarily used to compare local and foreign suppliers.
- **Foreign Exchange Risk:** Foreign exchange risk is a difficult factor to account for in supplier decisions. Depending on what currency a company uses to make a comparison between suppliers, both local and foreign suppliers are subject to foreign exchange risk. The supplier decision is also subject to certain assumptions based on foreign exchange which can impact or alter the supplier decision. The third goal of the project is to develop a means of testing how the supplier decision is impact by foreign exchange assumptions and volatility.

**Inventory Policy:**

- **Dual Mode Sourcing:** The primary method for sourcing parts from foreign suppliers is by ocean freight. Air freight is used for very small, low volume parts under certain circumstances and in emergency situations when parts need to arrive at the plant to keep the line moving. The fourth goal is to develop a dual mode sourcing model shipping parts by both air and ocean freight to reduce overall logistics costs.

Sourcing decisions from GM Brazil are used as examples to illustrate the benefits of the models and techniques developed for all four goals. For all examples, information has either been altered or omitted in order to protect any proprietary information.

The remainder of this paper is organized as follows. Chapter 2 reviews the issues concerning local versus global sourcing. Chapter 3 provides a comprehensive literature review. Chapter 4 reviews GM's current air freight risk model and describes the proposed air freight risk model. Chapter 5 describes the cash flow model developed to choose suppliers and compares the traditional cost based model to the cash flow model. Chapter 6 discusses the impact of foreign exchange on the supplier decision. Chapter 7 reviews the dual mode sourcing model. Chapter 8 provides a conclusion.

# 2 Local versus Global Sourcing

## 2.1 Introduction

This chapter provides a broad discussion of the advantages and disadvantages of global sourcing based on discussions with GM employees. Regional issues and how they impact the suitability for global or local sourcing are discussed. Brazil is used as an example to highlight the impact of particular regional issues.

## 2.2 Why Global Sourcing?

Utilizing one single global source versus several local sources for global platforms is a difficult consideration, each with its own advantages and disadvantages. After spending time with Global Purchasing and Supply Chain managers in both the United States and Brazil, I found that among individuals in the purchasing department at GM, there doesn't seem to be a complete agreement that there is a single best strategy. Discussions with the GM purchasing department highlighted some of the broader issues they identify as important in the global supplier discussion. The advantages and disadvantages of a global supplier strategy are discussed below.

First, economies of scale can be fully realized under a global supplier policy. Instead of ordering 200,000 parts from five different suppliers, ordering 1 million parts from a single supplier can bring significant volume discounts. It is possible, however, that the corresponding logistics cost to send the part to different regions could offset the volume discounts.

Operating with a single supplier is also an efficient use of resources. Each supplier requires a tooling investment by the manufacturer (i.e. GM) which is a significant fixed cost. Paying for tooling only once as opposed to paying five times is a better use of assets. A single supplier also requires fewer resources devoted to supplier management. If each region needs to coordinate with fewer suppliers, it requires fewer people to manage the process. Communicating design or scheduling changes is also much easier to coordinate with a single supplier.

GM employees also believed that using a global supplier opens the supply chain to a variety of risks. The first risk is concentration risk. With one supplier, the supply chain is vulnerable if any problems arise with the supplier. Many of these potential issues like a worker strike or a natural disaster are completely out of GM's control. Any sudden issues that occur could stop the line for the plants across all regions. Using multiple suppliers reduces this risk and creates flexibility in the supply chain if one supplier has capacity or quality issues.

Another risk is air freight risk which has been previously discussed. A single distant supplier creates the risk of air freight for regions with long ocean lead times. Using multiple local suppliers can reduce the risk of air freight since more regions use a local supplier and will not require air freight. Obsolescence can also be costly and the risk is increased with a single supplier. Obsolescence occurs when a part must be discarded, usually with no salvage value, because of quality or specification changes. In general, the longer the ocean lead time, the higher the potential cost of obsolescence. If there is a quality problem or a design change for a part, the pipeline inventory coming by ocean will become obsolete. A longer ocean lead time means more pipeline inventory which generates a higher cost of obsolescence.

Although there are gains in efficiency from using a single supplier, communication between the suppliers and each region can be difficult. Several GM employees from both the United States and Brazil commented that communicating with a supplier half-way around the world is difficult from a timing and language perspective. Coordinating with the supplier to make changes (scheduling, part alterations, etc…) quickly is difficult because of time zone differences. In some regions, as the GM team is getting into work, the supplier team is leaving and vice versa. As a result, much of the communication is done over e-mail increasing the time to implement changes. English is often used for communication between suppliers and General Motors. Communicating complex issues related to design changes for parts is difficult when a GM employee in Brazil who speaks English as a second language and an employee from the supplier in Korea also speak English as a second language. Employees commented that communicating with a local supplier is often easier and more efficient because there is no language barrier. During my time at GM, I did not see a metric which assigned a cost to the inefficiencies resulting from a foreign supplier.

## 2.3 Regional Issues

Regional issues play an important role in the discussion of global sourcing as each region faces different barriers. These varying challenges influence if a particular region is better suited for a local or global supplier. Different laws, infrastructural capabilities, and regulations are major factors which impact the total landed cost and risk of importing parts from a global foreign supplier. Although there are advantages to a single global supplier as discussed in the previous section, a hybrid strategy of a global supplier providing parts to some regions and while using local suppliers for those same parts in other regions could be an optimal strategy. Brazil presents an interesting case for the hybrid strategy because it is a country which adds significant cost and risk for imported parts due to port congestion and bureaucracy and a protectionist import policy.

Brazil has six main ports which are located in the south and southeastern regions of the country. The demand on the ports has grown significantly over the past few years as Brazil's consumer base and trade have grown as the economy has flourished. A 2011 Q1 Brazil Shipping Analysis report by the glObserver noted that the Business Monitor International (BMI) believes that the Brazilian ports have not yet developed the infrastructure needed to handle the projected growth in demand at the ports (glObserver, 2011). The Brazilian ports also ranked 126$^{th}$ out of 133 nations surveyed in the World Economic Forum's 2010 Global Competitiveness Report (glObserver, 2011).

Based on conversations with managers in Global Purchasing and Supply Chain at GM Brazil, there were three major concerns with the Brazilian ports. The first is the port congestion as discussed above. The second is the risk of strikes at the port. Managers are concerned that at any moment there could be a strike at the port and the imported material would be held at the port for an undetermined amount of time potentially stopping the assembly line. The third issue is the general bureaucracy of the port administration and procedures. If a form is not filled out properly or the wrong color of ink is used on a particular form, material can get held up at the port. All three issues heavily influence the inventory policy for imported material which requires a higher level of safety stock than other regions.

The protectionist stance of the Brazilian government also acts as a barrier for the use of foreign suppliers in Brazil. The Brazilian government passed a measure in September, 2011 that would increase the tax on imported parts and vehicles into Brazil. The measure increases Brazil's industrialized products tax for vehicles that have less than 65 percent of local content and are manufactured outside Mexico or the South American Mercosur trade region (Leahy, 2011). Depending on the size of the engine of the vehicle being produced, the tax rises from between 7 and 25% to up to 55% (Leahy, 2011). In order to avoid the tax increase, companies must meet six of 11 requirements. The requirements are related to where the chassis is assembled and where the engine and transmission are manufactured (Leahy, 2011). The tax increase really puts pressure on manufacturing companies to source more than 65% of the vehicle through local suppliers making a pure global supplier strategy less cost competitive. The change to the port and import tax issues is important because it provides a strong example of the risks of choosing a global supplier strategy that are very difficult to quantify.

## 2.4 Conclusion

This chapter offered a broad summary of many of the advantages and disadvantages for global sourcing from GM's perspective. The port congestion, bureaucracy, and protectionist policies in Brazil provided examples of the barriers which make importing material from global suppliers into Brazil difficult. Overall, it is important to note that unique laws, regulations, and infrastructural challenges of different regions create challenges in the local versus global sourcing discussion.

# 3 Literature Review

## 3.1 Introduction

This chapter provides a brief review of literature related to the components involved in the supplier selection process. Models developed to determine the total landed cost and total cost of ownership are reviewed. Risk mitigation and supplier selection models are also examined. Literature related to foreign exchange and operational hedging is covered in Chapter 6.

## 3.2 Total Landed Cost

A key element of the supplier decision is a cost system which can be used to compare suppliers. A commonly used cost method for supplier comparison is the total landed cost model. The total landed cost model aims to determine the total cost to procure a part from the supplier and bring it to the plant or warehouse. Understanding the total landed cost of materials procured from international sources is critical to making intelligent supplier choices (Staff, 2008). Many initial cost models were relatively simple including only the cost per part from the supplier plus transportation costs. These initials models left out key components of the total landed cost.

Over time, cost models have become more and more sophisticated adding other components to better account for the cost of procuring the part. Many past Leaders for Global Operations theses have explored the total landed cost model. Todd Robinson developed a total landed cost for Honeywell Aerospace that provided a framework for estimating and incorporating labor, logistics, inventory, and taxes associate with a product within a particular supply chain (Robinson, 2006).

Similarly, Brian Feller developed a total landed cost model for PerkinElmer Inc (PKI) which provided detailed cost estimates for packing, tooling, and potential finance charges along with the basic elements covered in previous models. Feller's model also provided analysis for 19 different risk factors for the supplier and supply chain. Risks ranging from currency volatility to geo-political risk were considered and quantified when examining a particular supplier (Feller, 2008).

There isn't firm consensus as to which factors need to be included in the total landed cost model nor is there any evidence of one model performing better than all other models. Some argue that there are four main areas which play an important part in the total landed cost model which must be considered in order to have an effective global sourcing strategy: material costs, transportation costs, inventory carrying cost, and trade compliance costs (Feller, 2008). The Center for Supply Chain Research at Penn State identified a six category model which provides the foundation for total landed cost models (Staff, 2008).

The six categories are purchase price, transportation and logistics, customs and imports, inventory costs, overhead and administration, and risk and compliance.

As total landed cost models and technology have been more sophisticated, software solutions are available which can determine total landed cost for a particular supply chain. As previously mentioned, GM's total landed cost model is quite sophisticated and flexible. The model considers variables which are unique to GM's supply chain with tremendous accuracy.

Another model proposed for the supply decision is the Total Cost of Ownership (TCO) model. The TCO model examines the cost of the part or product from a life cycle point of view incorporating the cost of quality, maintenance, and other that are beyond the initial price perspective. The TCO model allows supply managers to understand and measure the cost impact of the activities associatde with the purchase (Ferrin & Plank, 2002). TCO models are not as widely used in the supplier decision process which could be due to the vast amount of additional costs that need to be estimated and calculated. Total landed cost models have grown in sophistication and have shown to be a preferable method for determining the cost of a part or product.

## 3.3 Supply Chain Risk and Supplier Selection

Many companies are restructuring themselves to operate on a global scale in order to reduce costs (Waart, 2006). Global supply chains provide access to cheap labor, larger product markets, and financial incentives from foreign governments to attract new business (Mentzer & Manuj, 2008). Although there are advantages to global supply chains, they require a high level of coordination of goods, services, information, and cash flows within and across different countries (Mentzer & Manuj, 2008). Outsourcing manufacturing operations and using global suppliers has extended supply chains increasing the risk of supply chain disruptions (Waart, 2006). Supply chains are subject to many risk including economic, political, logistical, and others. These risks can be completely out of the control of the different stakeholders in the supply chain. Recent events such as the SARS epidemic, hurricanes Rita and Katrina, and the Japanese tsunami have shown that an event impacting one part of the supply chain may interrupt the operations of the other members in the supply chain (Mentzer & Manuj, 2008).

Assessing the supply chain risk of a supplier is a critical part of the supplier selection. There is a significant amount of literature proposing different models for risk management and mitigation as well as supplier selection. De Waart offers an approach which measures and prioritizes the risk of sourcing raw materials, components, and subassemblies. De Waart calls the approach "SMART" for the acronym which describes the five stages of the approach (Waart, 2006). The "SMART" approach looks to first identify and measure supply chain risks so that mitigation initiatives can be identified and started. It is important to identify the sources required for the risk mitigation and prioritize those initiatives based on resource constraints.

Once priorities are identified a time phased actionable plan is implemented to mitigate the corresponding risks. An important component of De Waart's approach is how to prioritize specific risks. De Waart classifies risks along two different dimensions through a risk impact matrix; the probability of the adverse event occurring and the impact of the event. In this thesis the only supply chain risk examined is the risk of air freight. Air freight risk is important to examine because it can have a high probability of occurring depending on certain factors and has a major impact of costs when it occurs. There are number of other supply chain risks that can be examined and quantified as seen in Brian Feller's thesis. Air freight risk is examined in this thesis because it presents a significant difference between the risk of local and foreign suppliers.

There are a variety of supplier selection models which focus on the price differential and associate risks of each supplier to make the supplier choice. Sarkis and Talluri believe that supplier selection and relationships based only on price are not effective for organizations and suppliers that wish to practice the latest innovations in supply chain management (Sarkis & Talluri, 2002). Sarkis and Talluri introduce a strategic decision model which incorporates strategic and operational factors in the supplier decision such as the supplier's process capability, design competency, equipment and labor flexibility, and others. Their frame-work for supplier selection is based on the Analytical Network Process (ANP) which is a more generalized form of Analytical Hierarchy Process (AHP).

AHP is also a popular form for supplier selection. The technique allows managers to categorize the preferences for supplier selection, quantify those preferences, and then aggregate them to make a decision (Sarkis & Talluri, 2002). Sarkis and Talluri take a very different approach to the supplier selection process as described in this thesis. As previously noted in Chapter 1, there are other factors besides those discussed in this thesis to consider in the supplier decision, many of which Sarkis and Talluri highlight in their model. It is assumed in this thesis that if a supplier has made it to the point in the decision process that management is requesting quotes, the supplier has met the necessary technical and strategic requirements to be an effective supplier.

## 3.4 Dual Mode Sourcing Optimization

Dual mode sourcing models all operate under the same principle. A part is procured from two separate sources which when used strategically in combination offer lower overall logistics costs than if only one of the sources were used. Dual mode sourcing models break down into one of two main categories: 1. two separate suppliers or plants, a low cost supplier or plant with long lead times and a high cost supplier or plant with short lead times, are the two sources for procurement 2. Two modes of transportation from a single supplier, ocean freight and air freight, are the two methods of procurement. During the literature review process, a majority of the dual mode sourcing models followed the first category.

Allon and Van Miegham offer a tailored base-surge (TBS) sourcing policy that captures the tradeoff between the cost and responsiveness in the sourcing problem (Allon & Mieghem, 2008). Under the TBS policy, inventory is replenished at a constant rate from an offshore source and production occurs at a near shore plant when inventory goes below a certain target. Veeraraghavan and Scheller-Wolf offer a dual sourcing model that considers a single-stage, capacitated, manufacturing location which is facing stochastic demand (Veeraraghavan & Scheller-Wolf, 2008). In the model, the manufacturer can order through a regular channel at a specified cost per unit and through an expedited source at a premium per unit. The model also assigns a penalty for any unsatisfied demand.

Schimpel explores how a fast and expensive second supplier can mitigate the impact of the stochastic lead time of the primary and cheaper supplier (Schimpel, 2010). Schimpel present a model which has a separate review period and order quantity for each supplier and establishes a framework for a periodic review policy which can handle stochastic lead times and stochastic demand.

The dual mode sourcing models with two different suppliers and two different modes of transportation can be applied in similar ways. Both models have cost differences for the two sources of procurement (productions costs for the different suppliers and transportation costs for the different modes of transportation). Both models also have lead time differences for the two sources of procurement. From this perspective, the models described above could have been applied to the model developed in Chapter 7. In order to provide a more flexible model for GM, the model needed to contain the ability to alter packaging inputs, specifically the packaging size, weight, and parts per pack. The packaging variable does not present itself in the previous models and therefore they do not translate well to applications for GM. As a result, the models described above were not considered for GM.

Do presents a more detailed and applicable model for GM in his LGO thesis. Do's model determines the optimal review period and safety stock levels for a manufacturer which can source parts through ocean freight and air freight (Do, 2009). Do's model was most applicable and adaptable to GM's policies. The model used in this thesis is an adaptation of Do's model. Chapter 7 provides more insight into the dual mode sourcing model.

## 3.5 Conclusion

This chapter reviewed previous literature related to the supplier selection process. Two different total cost models were examined as well as approaches to risk mitigation and supplier selection. Many of the models discussed in this chapter take a different approach and consider other variables for supplier selection than the tools described in this thesis.

# 4 Air Freight Cost

## 4.1 Introduction

This chapter provides background on the use of air freight in the transportation of parts and the dynamics of unanticipated air freight costs. GM's model for estimating the cost of unanticipated air freight is reviewed and critiqued. Three alternative models for estimating the cost of unanticipated air freight are proposed. The first proposed model is offered as a replacement to the current GM model and is directly compared to the GM model through a series of tests. The second and third proposed models serve as more generic models to account for air freight risk that can be applied to any company.

## 4.2 Air Freight Background

Air freight is not a prominently used method of transportation for automotive manufacturers. Small sized parts with low annual volumes are often transported by air freight but it is rarely used as a method of planned transportation. The vast majority of air freight is unplanned and is used when parts need to be expedited to a plant to keep the assembly line running.

The cost of shipping a package by air freight is dependent on two main factors which determine the chargeable weight: the weight of the packaging and the volume adjusted weight. The chargeable weight is the greater of the weight of the package and the volume adjusted weight. The volume adjusted weight is determined by multiplying the volume of the packaging by a fixed density factor. To ship a small but very heavy package, the weight of the packaging is used to determine the shipping costs. To ship a large but very light box, the volume adjusted weight is used to determine the shipping costs. This dynamic is very important because there a certain parts which are very costly to send by air due to their size but not weight.

Overall, the amount of air freight required tends to be binary; air freight usage for a given part will be either very low or very high, especially for suppliers with long ocean lead times. If there is a quality problem, scheduling change, or change to the product specifications, parts need to be air freighted into the plant to keep the line running. If the part has been altered then the pipeline inventory from the ocean freight is obsolete and air freight will need to be used for an extended period of time to keep the line running while pipeline inventory is built up through ocean freight. On the other end of the spectrum, air freight costs can be minimal if there are no major issues with quality or part specifications.

## 4.3 Approaches for Determining Air Freight Costs

### 4.3.1 Current GM Model

The current GM model focuses on historical data to determine the cost of air freight per part. GM's method examines several different parameters depending on what historical cost information is available over a rolling 24 month period. The historical data is grouped in three areas: 1. supplier 2. Region where the supplier is located 3. part category. Similar parts are grouped together to form a specific category or classification of parts. For example, all glass parts are grouped together in one category. Historical cost information for the windshield is grouped together with the driver side window because they fall into the same group of parts. The historical cost is then used to determine a cost per part based on the supplier, group the part is classified in, and the future production volume of the part.

Although there are many different methods to examine historical data which can be judged on a subjective basis, GM's method produces extreme results which hinder the value of the air freight cost estimation and the effectiveness of the sourcing decision process. Figure 4.1 shows the distribution of the ratio of the air freight cost of a part to the price of the part from the corresponding supplier for 125 parts covering different vehicle platforms, areas of the vehicle, cost, and size.

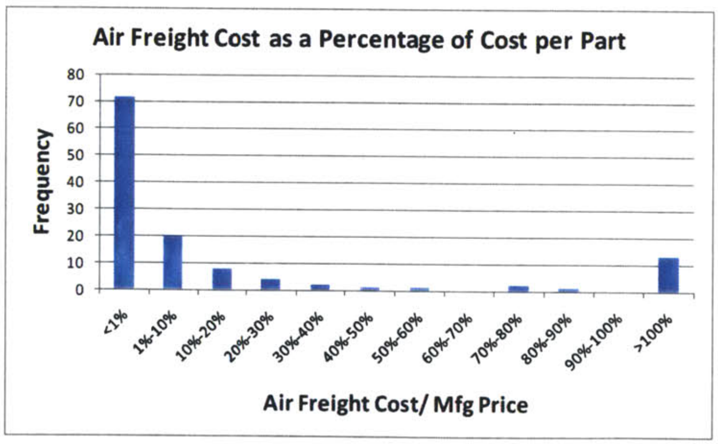


**Figure 4.1: Air Freight Cost as a Percentage of Cost per Part from the Supplier**

The figure shows that in the majority of cases (57.6%) the air freight cost is less than 1% of the price of the part from the manufacturer. In 10% of the cases, the cost of air freight is greater than the price of the part from the manufacturer.

The extreme values of the air freight cost estimation mirror the general behavior of air freight costs because GM's method attempts to directly track historical cost for a specific set of parts on a supplier by supplier basis. The binary nature of the cost of air freight increases the difficulty of assigning an accurate prediction of the future or expected cost (risk) of air freight. The main criticism of GM's method is that assigning a very low or very high cost of air freight to a particular part does not properly account for risk of air freight and negatively impacts the ability to make the best supplier choice in the sourcing decision process.

Assigning a very low cost of air freight does not properly account for the risk of air freight. It is equivalent to assuming that there is almost a zero probability that parts will be air freighted. This provides a distinct advantage to foreign suppliers in the sourcing decision. Assigning a very high cost of air freight has the opposite effect. Foreign suppliers are at a disadvantage relative to local suppliers due to the high cost of air freight. The high cost assumes that air freight will occur and likely occur for a significant period of time.

Analyzing historical data of parts grouped together and not on an individual part by part basis also has a negative impact on the sourcing decision. GM's method uses historical data in a way that the cost of air freight is assigned to a whole group of parts. If part A and part B are in the same group of parts, they will each be assigned the same expected cost of air freight. This is problematic when parts assigned to the same group have drastically different weights and dimensions because the cost of shipping each item would be drastically different. For example, shipping a small piece of glass for the rear passenger window is less costly than shipping the windshield.

Another issue with the GM model is the general use of historical costs. Both ocean and air freight costs will change over time. When making a sourcing decision for a product launch three to four years in the future historical costs could drastically under estimate the cost of both ocean and air freight.

### 4.3.2 Proposed Model

#### *4.3.2.1 Model Development*

The proposed model uses historical data but in a different form to determine the expected percentage of annual volume of a part to be air freighted each year. The annual percentage is then converted to a cost per part using annual volume and shipping cost information. The goal of the new model is to offer less extreme air freight costs so that the estimations for expected air freight cost provide better information in the sourcing decision. If air freight is similar to flipping a coin with a 50% chance of 0 (low cost) and 50% chance of 1 (high cost), the GM model produces either a value very close 0 or very close to 1 which creates biases in the sourcing decision as previously discussed. The goal of the model is to produce a result closer to the expected value of ½ than to the extreme values of 0 and 1.

The model uses a two-tier system which assigns an expected percentage of annual volume to all parts and a larger percentage to a specific set of parts which are deemed more likely to require air freight. The two-tier system is created by dividing the reason for each instance of air freight or reason code into one of two categories: those that impact all parts and those that impact a select group of parts. For example, air freight may occur because of an increase in demand which would impact every imported part. Air freight may also occur because of an engineering change or change in specifications of the part. Historically, there are certain parts in which engineering changes are much more common than other parts. An engineering change is an example of a reason code which impacts only certain parts.

The expected annual percentage of yearly volume for all parts is calculated from reason codes only classified for All Parts. The expected annual percentage of volume for Select Parts is the percentage for All Parts plus the additional annual percentage of volume from reason codes classified just as Select Parts. The percentage for Select Parts will always be greater than or equal to the value for the All Parts.

In order to determine the expected percentage of annual volume shipped, each reason code is analyzed to determine the average annual percentage of volume that was shipped due to that specific reason code. A weighted average of the annual percentage of volume shipped by air freight for each reason code is calculated based on the distinct number of parts. This method represents a general approximation for calculating the weighted average and is shown in equation 4.1. For equations 4.1 through 4.3, RC = reason code, PN = part number, E[] = expected value, and % of Ann Vol = percentage of annual volume.

$$E[\%\ of\ Ann\ Vol] = \sum_{\{RC=A,B,C,\ldots\}} \left( \left( \frac{Vol\ AF\ for\ RC}{\sum_{\{PN=1,2,3\ldots\}} Ann\ Vol\ of\ PN\ for\ RC} \right) * \left( \frac{No.of\ PNs\ in\ RC}{Total\ No.of\ Imported\ PNs} \right) \right) \quad (4.1)$$

The proper method for determining the weighted average is shown in equation 4.2. The weighted average is based on the annual volume of all part numbers which fall under a particular reason code.

$$E[\%\ of\ Ann\ Vol] = \sum_{\{RC=A,B,C\ldots\}} \left( \left( \frac{Vol\ AF\ for\ RC}{\sum_{\{PN=1,2,3\ldots\}} Ann\ Vol\ of\ PN\ for\ RC} \right) * \left( \frac{\sum_{\{PN=1,2,3\ldots\}} Ann\ Vol\ of\ PN\ for\ RC}{\sum_{\{PN=1,2,3\ldots\}} Ann\ Vol\ of\ PN} \right) \right) \quad (4.2)$$

Equation 4.2 simplifies to equation 4.3 which states that the expected percentage of annual volume is simply the volume of parts air freighted for all reason codes divided by the annual volume of part numbers for all reason codes.

$$E[\%\ of\ Ann\ Vol] = \sum_{\{RC=A,B,C\ldots\}} \left( \frac{Vol\ AF\ for\ RC}{\sum_{\{PN=1,2,3\ldots\}} Ann\ Vol\ of\ PN} \right) \quad (4.3)$$

Equation 4.1 is used as an approximation for equation 4.2 because obtaining accurate information on the annual volume of for all parts can be very difficult. Automotive companies have tens of thousands of parts for several different vehicle platforms and the information for these parts can change fairly frequently.

Equation 4.1 uses the number of distinct part numbers contained within each reason code to weight the percentage of annual volume among all reason codes. Under the two tier system, the reason codes used in the summation of equation 4.3 will differ. When analyzing All Parts, the summation is reason codes that relate to All Parts. When analyzing Select Parts, the summation is across all reason codes.

| No. of Imported Parts | 1800 |
|---|---|

| Reason Code | Classification | % of Annual Volume Shipped by Air Frieght | No. of Distinct PNs | Contribution to E[% of Vol of AF] |
|---|---|---|---|---|
| RC A | All Parts | 9.40% | 200 | 1.0% |
| RC B | Select Parts | 11.50% | 80 | 0.5% |
| RC C | All Parts | 7.00% | 70 | 0.3% |
| RC D | Select Parts | 18.00% | 40 | 0.4% |

| | |
|---|---|
| All Parts | 1.3% |
| Select Parts | 2.2% |

**Figure 4.2: Expected Annual Percentage of Volulume Calculation**

Figure 4.2 above shows an example of the calculations. Reason code A is classified as a code for All Parts. Historical data showed that an average of 9.4% of the annual volume was shipped by air freight for parts which required air freight due to reason code A. Reason code A contains 200 distinct parts out of the total of 1800 imported parts, therefore the weight given to Reason Code A is 1.0% or (.094)*(200/1800). The same calculation is executed for reason codes B, C, and D.

The expected annual percentage of volume for All Parts is the sum of the weighted percentages for all reason codes classified as All Parts. The expected annual percentage of volume for Select Parts is the sum of the weight percentages for all reason codes. In figure 4.2, the percentage for All Parts and Select Parts is 1.3% and 2.2%, respectively. Once the expected percentage of annual volume for a part is determined, equation 4.4 is used to calculate the number of parts expected to be air freighted.

$$Expected\ Vol\ to\ Air\ Freight = (Ann\ Vol) * (E[\%\ of\ Ann\ Vol]) \tag{4.4}$$

Classifying which parts fall into which tiers would vary for each manufacturer and require some analysis. A particular reason code for GM may impact all part but for Ford it may only impact select parts. For General Motors, parts previously classified as high supply chain cost parts were placed in the higher percentage tier. These parts historically had the highest logistics costs primarily because of the size of the part.

If the annual volume of a part classified as All Parts is 50,000, as shown in figure 4.3, then the expected number of parts to be air freighted is 650.

| Example Part Number | |
|---|---|
| Annual Volume | 50,000 |
| Classification | All Parts |
| Parts per Pack | 24 |
| Cost of AF per Pack | $ 750 |

**Figure 4.3: Specifications for Example Part Number**

Equation 4.5 shows how to determine the cost for air freight per part. Using the numbers from figure 4.3, the cost of air freight is equal to $0.406 per part. The cost of air freighting each pack can be determined with either current rates or with a forecasted future rate during the lifetime of sourcing the part.

$$AF\ Cost\ per\ Part = \frac{\left(\frac{Vol\ of\ AF}{Part\ per\ Pack}\right) * (Cost\ of\ AF\ per\ Pack)}{Ann\ Vol} \tag{4.5}$$

For a company with global operations, the model should be used to analyze each region independently using air freight data into each country. Engineering changes, forecast changes, and lead times will vary in Brazil, the Unites States, and other areas of the world. Analyzing each country's historical data independently would produce the most accurate results. If a company chose to use a single expected percentage for all regions, the cost per part of an individual part would still vary by region. Shipping 650 parts from Thailand to Brazil and Thailand to the United States will not be the same and therefore the cost per part will not be the same.

#### *4.3.2.2 GM and Proposed Method Comparison*

Although it is difficult to present a clear, quantifiable measure which can compare the two methods, the proposed method solves many of the critiques of the GM model. The model offers significantly less variation for the expected cost of air freight, produces a cost per part for each individual part, and utilizes more recent shipping cost information to determine the cost per part.

Figure 4.4 below shows a comparison between the two methods. As mentioned in section 4.3.1, 125 parts covering different vehicle platforms, areas of the vehicle, cost, and size were tested to compare the two methods. The figures below shows the distribution of the ratio of the air freight cost per part of each method to the purchasing price of the part from the supplier. The GM method has 72 of 125 or 58%

of the tests below 1% and 13 of 125 or 10% of the tests above 100%. Of the 13 above 100%, 11 were above 200%. These results show that the GM method produces extreme results for air freight cost estimations.

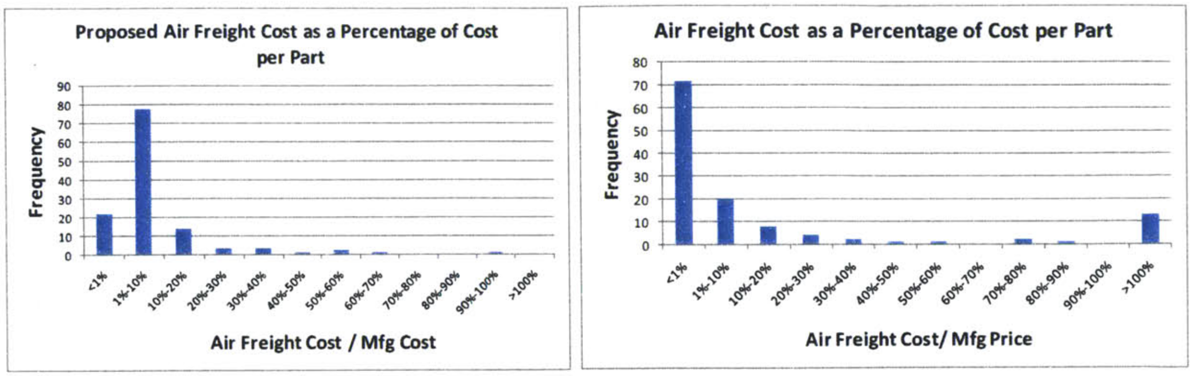


**Figure 4.4: Comparison of Proposed and GM Method for Determining Expected Air Freight Costs**
**Proposed Method** **GM Method**

The proposed method shows much less variation for air freight costs overall. 4 of the 125 tests are above 50% with no test higher than 100% compared to 17 of 125 above 50% for the GM Method. 17.6% of the parts are under 1% compared to 57.6% for the GM method. The proposed method follows the shape skewed but uni-modal curve centered around 1%-10%. Under the proposed method 80% of the tested part numbers fall under the 20% value. This is a significant result because the proposed method does not produce very extreme results allowing for a more appropriate estimation for the expected cost of air freight.

Another advantage to the proposed model is each individual part has a different air freight cost. Under the GM model, parts placed in the part group were given the same air freight cost because of how the historical data was grouped. Each part may have the same expected percentage of volume air freighted but the cost to ship the items will be different. Because the model examines the historical number of items shipped and not historical costs, it incorporates the most recent shipping cost information. If necessary, forecasted shipping rates could be used for programs being sourced several years in the future.

Both models are heavily impacted by the general life cycle of the product portfolio. If several of the vehicles in the product portfolio are towards the end of their production lifecycle or are at the launch phase, it can alter results. During the end of a production lifecycle, the use of air freight should be minimal as it is unlikely to have engineering changes or any surges in demand. During the launch phase of the production cycle, the use of air freight should be more common. Air freight is required to source the small volume of parts for pilot runs and launches rarely go as planned requiring air freight to keep the line running. Engineering changes typically occur as the plant ramps up production increasing the risk for air freight.

If the makeup of the historical and future production life cycle of the product portfolio don't match, each model will be less accurate and effective. This was an important issue for the operations at GM Brazil as the composition of the production cycle of the product portfolio shifted from 2010 to 2011. In 2010 the product portfolio was weighted towards the end of the production cycle while in 2011 two new vehicles were launched and preparations began for several future launches in 2012 and 2013.

Since 2011 was a better representation of the future composition of the production life cycle of the product portfolio than 2010, the proposed model used air freight data from the first half of 2011 for the testing of the 125 parts. 2010 data was also analyzed to better understand the impact of the of the production life cycle mix. The expected percentage of annual volume for 2010 for All Parts was 75% of that for 2011. For select parts, 2010 and 2011 were nearly identical.

### 4.3.3 Other Possible Models

Given access to an array of data, it is possible to develop other models which could be used to determine the potential cost of air freight for parts. This section reviews two alternative models; the distribution model and the break-even demand method.

#### *4.3.3.1 Distribution Model*

The distribution model uses historical shipping information to determine a distribution for the percentage of annual volume to be air freighted for an imported part. Instead of producing a single expected cost per part of air freight, the model provides an expected mean and standard deviation which can be used to quantify the risk of air freight measured by cost per part.

For simplicity, assume that the distribution curve for all imported parts follows a normal distribution with a mean 1.5% of annual volume and a standard deviation 0.5%. Also assume a part has an annual production volume of 100,000 and a cost of $2,000 to ship 100 parts by air. Based on the distribution, there is a 50% chance of yielding a cost of $0.30 per part or less to ship the part by air freight.

When comparing a local supplier and a foreign supplier, the distribution model can be used to determine how the risk of air freight impacts the sourcing decision. For example, assume the total landed cost of the part for a local supplier is $0.10 per part greater than the foreign supplier. $0.10 per part is equivalent to $10,000 of air freight which is the cost to ship 500 parts or 0.5% of annual volume. For the distribution above, 0.5% of annual volume is two standard deviations below the mean so the probability that the cost of air freight will be greater than $0.10 per part is 97.7%. Given the high probability that air freight costs will exceed $0.10 per part, the local supplier is the better choice.

Unlike the GM and proposed model, the distribution model does not provide a single cost of air freight per part. The goal is assess the risk of the cost of air freight and understand how the potential risk impacts the supplier decision. There is no concrete evidence to support the normal distribution assumption but it serves as a simple example. Before using this methodology, past historical data would need to be studied to determine an appropriate distribution, mean, and standard deviation.

#### *4.3.3.2 Break-Even Demand Method*

The break-even demand method does not produce an expected cost but produces a flexible measure to determine the significance of air freight risk when deciding between two suppliers. The method is a useful tool when comparing two suppliers for a sourcing decision to better understand how air freight risk impacts the sourcing decision.

The method determines the number of weeks of demand that would be required to be air freighted for one supplier versus another such that the supplier decision would be altered. The number of weeks of demand is compared against a previously determined scale which would provide a measure of how air freight influences the sourcing decision. For example, a break-even demand of zero to one month could be considered high risk because zero to one month of demand air freighted would alter the supplier decision. One month to two months would be considered moderate risk and greater than two months low risk. The scale would vary from company to company and require the company to execute analysis to determine the scale.

The example below outlines how the method is executed. Suppose there is a foreign supplier, Supplier A, and a local supplier, Supplier B. The yearly demand for the part being sourced is 50,000 parts per year and the total landed cost differential between the two suppliers is $0.20 per part. Given the yearly demand, Supplier A would cost $10,000 less per year than Supplier B but Supplier A has the risk of air freight because it is a foreign supplier. Using shipping cost information, it is determined the 5,000 parts can be shipped by air freight for $10,000. Given a yearly demand of 50,000 parts, 5,000 parts represents five weeks of demand.

If more than five weeks of demand needs to be air freighted under Supplier A, Supplier B would become the least expensive option. Under the scale described above, five weeks of demand would represent moderate risk. Although this method does not produce a tangible number to quantify air freight risk, it is simple to execute and is very useful for understanding the potential air freight for the sourcing decision.

## 4.4 Conclusion

This chapter reviewed the current GM model for estimating unanticipated air freight showing through testing that the model produces extreme results. Estimating the cost of air freight as either extremely low or extremely high with respect to the price of the part does not properly account for the risk of air freight. The proposed model showed more stable and consistent results when compared to the GM model. The proposed model better accounts for the expected cost and therefore risk of unanticipated air freight. Two other generic models are proposed which take a different approach to understanding the risk of air freight. The models provide a easy way to measure and understand how the risk of air freight impacts the supplier decision. Air freight can be a significant cost so it is vital that the risk of air freight is properly accounted for in the supplier decision as it is one of the major differentiators between local and foreign suppliers.

# 5 Cash Flow Analysis

## 5.1 Introduction

This chapter outlines two approaches to financial analysis to make a supplier decision. The first model is a cost based net present value analysis commonly used by manufacturing companies. The second model is a cash flow model developed during the internship at GM. The two models are compared through a series of supplier decision tests which show different results for the supplier recommendation.

## 5.2 Cost Based Net Present Value Analysis

When considering a potential investment, a common method to determine if an investment should be made is net present value (NPV) analysis. The investor determines the timing of the cash flows in and cash flows out discounting them at an appropriate weighted cost of capital. The investment is made if the NPV of all cash flows is greater than zero. If a company can choose only one project amongst a set of projects, it will choose the project with the highest NPV.

NPV analysis is typically used in sourcing decisions but is utilized in a slightly different way. Many companies use a cost-based NPV analysis which compares the total cost of purchasing the parts and direct capital expenditures of each supplier but does not consider all areas which impact cash flows out. The method used to determine the total cost of purchasing a part is the total landed cost. As described in previous sections, the total landed cost factors in the piece price plus all logistics costs to bring the part to the plant. Since this analysis considers only costs, the supplier with the lowest, not the highest NPV is chosen.

Consider two suppliers to source a widget for a three year vehicle program with an annual volume of 20,000 parts. The total landed cost of Supplier A is $5.50 and the total landed cost of supplier B is $5.60. Both suppliers require new tooling which must be paid for as soon as the contract is signed. Supplier A charges $5,000 for tooling and supplier B charges $4,000 for tooling. Assuming a cost of capital of 18%, supplier A costs $3,348 less than supplier B and would therefore be chosen to supply the widget. Figure 5.1 shows the detailed analysis.

| | Supplier A | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Tooling | $ 5,000 | $ - | $ - | $ - |
| Total Landed Cost per Part | $ - | $ 5.50 | $ 5.50 | $ 5.50 |
| Volume | - | 20,000 | 20,000 | 20,000 |
| Total Cost | $ 5,000 | $ 110,000 | $ 110,000 | $ 110,000 |
| PV(Total Cost) | $ 5,000 | $ 93,220 | $ 79,000 | $ 66,949 |
| NPV | $ 244,170 | | | |

| | Supplier B | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Tooling | 4,000.00 | - | - | - |
| Total Landed Cost per Part | - | 5.60 | 5.60 | 5.60 |
| Volume | - | 20,000.00 | 20,000.00 | 20,000.00 |
| Total Cost | 4,000.00 | 112,000.00 | 112,000.00 | 112,000.00 |
| PV(Total Cost) | 4,000.00 | 94,915.25 | 80,436.66 | 68,166.66 |
| NPV | 247,518.57 | | | |
| **DIFFERENCE** | 3,348.55 | | | |

**Figure 5.1: Cost Based NPV Comparison between Supplier A and B**

The advantage of this analysis is that it is very simple and fast to execute requiring a minimal amount of information. The most difficult piece of information to determine is a precise and accurate total landed cost per part for each supplier. But as previously discussed, total landed cost models have become very sophisticated and widely used among manufacturing companies. Manufacturers make supplier decisions on thousands of parts so it is important to be able to quickly execute a comparative analysis to make a supplier decision.

The major disadvantage of utilizing this analysis is that it does not consider how the supplier choice impacts the cash flows of the firm. Differences in inventory policy due to supplier location and payment terms impact net working capital and are not considered in this basic model. Payment terms are incorporated into many total landed cost models but are often calculated without incorporating the timing of how inventory moves from the supplier to the factory. This methodology is discussed in later sections. Most companies require standard payment terms across all suppliers but this can vary from company to company. Payment terms can also be first sources of negotiation so it is important to have a tool which can help a firm understand the direct impact to cash.

Depreciation of tooling is also not directly considered. Depreciation has a greater impact on the supplier decision if there is significant difference in the capital expenditure requirements for different suppliers. Incorporating cash flow analysis as opposed to a cost based NPV analysis helps a firm better understand how a supplier impacts true costs and not accounting costs to the firm.

## 5.3 Supplier Selection: Cash Flow Analysis

This section describes each component of the model developed to more accurately show the impact of a supplier on a firm's cash flows. The model determines the free cash flows to the firm over the life of the product discounted at an assumed cost of capital.

Since the model examines the impact of cash flows to the firm, the total landed cost of a part from traditional models ($TLC_o$) may need to be adjusted. One component of the total landed cost is the inventory carrying cost related to holding and storing inventory. The carrying cost represents an opportunity cost to the firm and is a non-cash charge. As a result, the total landed cost used in the cash flow model ($TLC_{CF}$) is the total landed cost of a part without the inventory carrying cost.

Another adjustment to total landed cost is made for payment terms. If the total landed cost model does not include the impact of payment terms, it should be added to the total landed cost. The payment terms model used for the cash flow analysis is described later in this section. Given these two adjustments, the total landed cost of a part for a cash flow model ($TLC_{CF}$) is the total landed cost of a part minus inventory carrying cost plus payment terms as shown in equation 5.1.

$$TLC_{CF} = TLC_o - \ Inventory\ Carrying\ Cost + Payment\ Terms\ Adjustment \qquad (5.1)$$

The primary purpose of the cash flow model is to compare two or more suppliers from different regions of the world. The inventory policy of a local supplier versus a foreign supplier has a significant impact on net working capital which isn't properly captured in traditional models. Although a foreign supplier may have a lower total landed cost, the cash impact of the inventory policy may impact the supplier decision. The cash flow model determines the free cash flow to the free using the equation 5.2 below. The free cash flow is determined by adding depreciation and subtracting capital expenditures and increases in net working capital from the after tax EBIT (earnings before interest and taxes).

$$FCF_F = EBIT(1-T) + \ Dep'c - Cap\ Expenditures - \ Increases\ in\ Net\ Working\ Capital \qquad (5.2)$$

### 5.3.1 Earnings Before Interest and Taxes (EBIT) and Depreciation

Unlike the cost based NPV model, the cash flow model assumes that a particular part contributes to the price or revenue from selling a vehicle. The model assumes that the contribution to price (R) of the part is 110% of the higher $TLC_{CF}$ of the two suppliers. The concept of the contribution to price is that each part in the vehicle contributes to the actual price of the vehicle. This is used as a means to determine the profit from buying and selling the particular part which goes into a vehicle. The assumed contribution to price does not impact the supplier decision because we are comparing the two suppliers on a relative basis. The contribution to price does

The equations above show mathematically that the value of L or the contribution to price does not impact the supplier choice. The contribution to price only impacts the absolute values of the respective NPV calculations. The EBIT is calculated as shown in equation 5.3 below.

$$EBIT = \mu_{Monthly} * (R - TLC_{CF}) - Depreciation \tag{5.3}$$

The source of depreciation is from tooling required to produce the parts. There are a variety of depreciation methods that can be used. The model assumes a 5 year straight-line depreciation with no salvage value at the end of the 5 years. The model also assumes a 35% tax rate to determine the after-tax EBIT.

### 5.3.2 Capital Expenditures

Capital expenditures are related to tooling and other costs paid by the company to the supplier. It is assumed that all tooling is paid immediately in both the cost based NPV model and the discounted cash flow model. As a result, capital expenditures do not produce any differences between the two models.

### 5.3.3 Changes in Net Working Capital

Net working capital is defined as the difference between current assets and current liabilities. Current assets are assets that are reasonably expected to be converted into cash within one year. This includes cash, inventory, marketable securities, accounts receivable, and other liquid assets. In the context of a supplier decision, the most relevant current assets are the dollar value of inventory. Therefore, the inventory policy for each supplier impacts net working capital and net present value of the supplier.

Current liabilities are liabilities that due within one year. These include short term debt, accounts payable, and other types of short term obligations. In the context of a supplier decision, the most relevant liabilities are accounts payable. The payment terms of each supplier impacts the cash liabilities to the firm and therefore the net working capital. The impact of payment terms on supplier choice is accounted for in the payment terms model described in the next section. As a result the net working capital model only considers average inventory levels.

The net working capital model calculates the change of the value of the average inventory for each supplier during each month of production. Average inventory is determined by adding the safety stock, cycle stock, and in-transit inventory. During the production cycle, inventory levels follow three phases: 1. Ramp-up 2. Steady state 3. Final Ramp-Down. The model assumes that production is constant for each month during the life of production.

The ramp-up phase occurs during the launch of production. It is common practice to keep higher levels of inventory during the launch phase of a new product to ensure that production continues. The model assumes average inventory levels during the first month of production are 15% and 25% higher than steady state levels for the local and imported supplier, respectively. The ramp-up levels are to protect against any problems during the launch phase that may cause the line to stop temporarily. The steady state begins one month after the launch until the ramp down phase near the end of production. During this phase, average inventory levels remain constant and changes in net working capital are zero. The average inventory for each supplier is the average daily demand multiplied by the total inventory days including pipeline, safety stock, and cycle stock.

The ramp-down phase occurs near the end of production but is dependent on the specific inventory policy required for each supplier. Typically, for imported suppliers average inventory levels will slowly decrease towards the end of production because safety stock and pipeline inventory can be used to fill demand instead of ordering new parts. This creates a reduction in net working capital over the last phase of production. The local supplier's net working capital will remain unchanged.

For the last phase of the production, the model determines when the ramp down phase for supplier begins. During each month, the model compares the remaining months of accumulated demand plus a half month of demand to the current average inventory level. If the remaining accumulated demand plus half month of demand is greater than the current average inventory level, the average inventory level remains the same. The use of an additional half month of demand is meant to act as safety stock. A more precise method could be used to determine if less or more than a half month of demand should be used. The model is flexible to incorporate this change.

If the remaining accumulated demand plus half month of demand is not greater than the current average inventory level, then one would stop ordering inventory and use the remaining cycle, safety, and pipeline stock to meet the demand requirement. If this is the case, the model approximates average inventory for that month to be the average of remaining accumulated demand plus a half month of demand and the remaining accumulated demand for the next month. The equations below show the expressions described above.

$$Remaining\ Accumulated\ Demand = \omega$$
$$= (Final\ Month\ of\ Production + 1 - Current\ Month) * Monthly\ Demand + Half\ Month\ of\ Demand$$

$$If\ \omega > (Total\ Invetory\ Days) * (Daily\ Demand)$$

$$Avg\ Inventory = (Total\ Inventory\ Days) * (Daily\ Demand)$$

$$If\ \omega < (Total\ Invetory\ Days) * (Daily\ Demand)$$

$$Avg\ Inventory = \frac{(Month_{Final}+1-Month_{Current})*\mu_{monthly}+.5*(\mu_{monthly})+(Month_{Final}-Month_{Current})*\mu_{monthly}}{2}$$

Overall, suppliers which require a greater number of total inventory days because of location have larger increases in net working capital during the ramp up phase and larger decreases in net working capital at the ramp down phase than suppliers with a fewer number of total inventory days. As a result, there will be a net present value advantage to suppliers with a fewer number of total inventory days due to net working capital.

It is important to note that the differences between the net working capital approach described above and the inventory carrying cost typically used by manufacturing companies. The inventory carrying cost method calculates the carrying cost of holding inventory by multiplying the average yearly dollar value of inventory by a cost of capital. A foreign supplier which requires a higher average inventory value has a higher inventory carrying cost which is factored into the supplier decision for traditional models.

The main problem with the carrying cost method is the use of average inventory. During the ramp-up, steady state, and final ramp-down phases inventory levels deviate from the average. During the ramp-up phase, inventory levels are significantly higher than the average. In the steady state phase, inventory levels are very close to the average inventory. In the final ramp-down phase, inventory levels are lower than the average inventory. The average inventory level isn't reflective of the differences between the two suppliers because of timing differences. Inventory levels are higher than the average at the beginning of the program and should be weighted from a present value perspective more than the inventory levels towards the end of the program. As a result, the inventory carrying cost model underestimates the true cost of the differing inventory levels between two suppliers.

### 5.3.4 Payment Terms

A traditional payment term model compares the number of days required for payment from each supplier and determines the corresponding impact on net working capital. Brian Feller explores this analysis in his thesis, "Development of a Total Landed Cost and Risk Analysis Model for Global

Strategic Sourcing". Figure 5.2 below provides a simple, high-level example of payment terms from Brian's thesis for his internship with PerkinElmer (PKI).

| | | | |
|---|---|---|---|
| Annual Borrowing Rate | 7.3% | | |
| Daily Borrowing Rate | 0.02% | | |
| | ***Supplier A*** | ***Supplier B*** | ***Supplier C*** |
| Payment Terms | Net 30 | Net 45 | Net 60 |
| Invoice Due (days) | 30 | 45 | 60 |
| "Best Case" Terms for PKI | 60 | 60 | 60 |
| Difference (Best – Actual) | 30 | 15 | 0 |
| Annual Invoice | $1,000,000 | $800,000 | $900,000 |
| Impact on Working Capital (using Difference) | $6,000 | $2,400 | $0 |
| Impact Over Three (3) Year Contract | $18,000 | $7,200 | $0 |

**Figure 5.2: Payment Term Impact (Feller, 2008)**

In the example above, Supplier C presents the best payment terms, requiring 60 days for payment. As a result, choosing Supplier A or B requires earlier payment producing an impact on net working capital of $6,000 and $2,400, respectively. The impact of cash is determined by using the following formula: Annual Invoice * Daily Barrowing Rate * Difference in Days compated to Best Alternative.

Unlike the payment terms model described above, the model used in the comparative cash flow analysis incorporates inventory policy to determine the number of days difference of when cash outflows are made to each supplier. This is accomplished by mapping the procurement and payment cycle of a part to determine when cash outflows occur. Figure 5.3 shows an example of the inventory policy and payment terms for an imported supplier and local supplier.

| | IMPORTER | LOCAL |
|---|---|---|
| Safety Stock (Days in Warehouse) | 20 | 2 |
| Days at Port | 5 | 0 |
| Days in Transit | 50 | 3 |
| Payment Days (Upon Arrival) | 45 | 30 |

**Figure 5.3: Inventory Policy of Imported vs Local Supplier**

The imported supplier has a significantly longer total lead time due to the longer transit time and safety stock which is a result of the longer transit time. Based on the inventory policy and payment terms, it is possible to determine the timing differences of cash out flow and the resulting impact on net working capital.

Assume that the production schedule of the vehicle is independent of the supplier choice. A part meant for production on day 100 will follow a different timeline and therefore different cash outflow depending on supplier choice and payment terms. Using the policies from figure 5.3 we can determine at which stage in the process of procurement and payment a part is currently in. For example, if a part from an imported supplier is scheduled to be used in production on day 100, it will arrive at the warehouse on day 80 or 20 days prior to production. Figure 5.4 shows on which day the part arrives at each phase of procurement.

| | IMPORTER | LOCAL |
|---|---|---|
| Day of Production | 100 | 100 |
| Day to Arrive at Warehouse | 80 | 98 |
| Day to Arrive at Port | 75 | - |
| Day of Shipping from Supplier | 25 | 95 |
| Day of Cash Outflow | 120 | 128 |

**Figure 5.4: Part Arrival Schedule**

In the example above, the cash outflow to the local supplier would occur on day 128 versus on day 120 for the imported supplier, producing an 8 day cash advantage. The cash advantage occurs even though the payment terms for the local supplier require payment 30 days after the arrival of the part instead of 45 days for the imported supplier. This is a significantly different result than traditional payment term models which would give the imported supplier a 15 day cash advantage due to the difference in payment terms.

The resulting impact on net working capital for the 8 day difference is determined using the same formula described in Brian Feller's thesis. Assuming a daily cost of capital of .04% and an annual invoice of $1,000,000, the impact on working capital would be $3,200.00. The model applies the cost of working capital by dividing the impact on working capital by the yearly production volume. In this case the price of the part of the imported supplier would be adjusted but the price of the part of the local supplier would not change.

## 5.4 Comparison of Cost Based NPV Model & Free Cash Flow Model

In order to better understand the impact of the free cash flow model versus the cost based NPV model on the supplier decision, the two models are compared varying several parameters under certain assumptions for a set of supplier decisions. The tests compare a local supplier to a foreign supplier using assumptions common to the global versus local supplier analysis for production in Brazil.

First, the part has a production cycle of three years. Second, the foreign supplier is located in the Asia Pacific with an inventory policy which mirrors GM's policy for suppliers from the region. Third, the local supplier is located within Brazil with an inventory policy (review period and inventory levels) which mirrors GM's policy for suppliers located in Brazil. Fourth, both suppliers require tooling with identical cost. Fifth, the payment terms of each supplier are the same. Although payment terms can have an impact on the supplier decision, the payment terms are kept equal to make the analysis simpler and show the big picture impact of on the supplier decision of the cash flow model. Sixth, the foreign supplier's total landed cost is less than or equal to the total landed cost of the local supplier. Any of these assumptions can be altered in the model.

There are two goals for the testing; 1. Understand which inputs impact the differences in the cash flow and cost based NPV models 2. Test of a range of inputs to see when the cash flow model alters the supplier decision under the cost based NPV model. Before discussing the test results, it is important to review how the supplier decision is made under each model.

Under the cost based model, the supplier with the lowest NPV is chosen. The cost based NPV differential is defined as the NPV of the local supplier minus the NPV of the foreign supplier. If the differential is greater than zero, the foreign supplier is the best supplier choice. If the differential is less than zero, the local supplier is the best supplier choice. Under the sixth assumption stated above, all tests should show the cost based differential greater than or equal to zero making the foreign supplier the best choice under all scenarios. The purpose of this assumption is to test under what conditions the cash flow model recommends a different supplier.

| **Cost Based Model** | **Cash Flow Method** |
|---|---|
| NPV(Local) | NPV(Foreign) |
| - NPV(Foreign) | - NPV(Local) |
| Cost Based NPV Differential | Cash Flow NPV Differential |
| If > 0 foreign supplier better choice | If > 0 foreign supplier better choice |
| If < 0 local supplier better choice | If < 0 local supplier better choice |

**Figure 5.5: Cost Based and Cash Flow NPV Differential**

Under the cash flow model, the supplier with the highest NPV is chosen. The cash flow NPV differential is defined as the NPV of the foreign supplier minus the NPV of the local supplier. Supplier choice is made under the same parameters as the cost based model, if the differential is greater than zero, the foreign supplier is the best supplier choice. If the differential is less than zero, the local supplier is the best supplier choice. Both definitions are shown in figure 5.5.

The cost based NPV differential and cash flow NPV differential are analyzed in two different ways in the tests. First, examine how the difference of the two model differential changes with varying inputs. For example, under a certain set of conditions the cost based NPV differential shows that the foreign supplier is $1,000 less expensive than the local supplier but the cash flow NPV differential shows that the foreign supplier is $200 less expensive than the local supplier. The two model differential in this case is $800. The equation below defines the two model differential.

$$Two\ Model\ Differential = Cost\ Based\ NPV\ Differential - Cash\ Flow\ NPV\ Differential$$

The second method for testing is to examine under which inputs the models recommend different suppliers (cost based NPV differential greater than zero, recommending the foreign supplier, and the cash flow NPV differential less than zero, recommending the local supplier). These two methods help to better understand the impact of the cash flow model on supplier decisions.

Figures 5.6 through 5.9 illustrate the first analysis showing the two model differential plotted against the total landed cost differential between the two suppliers over four different annual volumes. Each figure shows the results for a different total landed cost ranging from \$5.00 to \$65.50. Figure 5.6 shows the first set of tests. The NPV differential between the two models is plotted while varying the total landed cost differential from \$0.00 to \$0.50 over a yearly production volume of 10,000, 50,000, 100,000, and 200,000 for a part with a total landed cost of \$5.00.

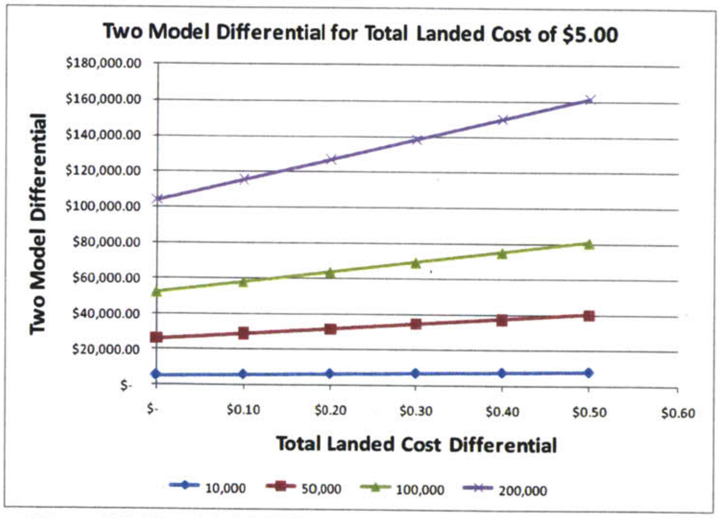


**Figure 5.6: Two Model Differential for Total Landed Cost of \$5.00**

Figure 5.6 shows two interesting results. The two model differential grows linearly as the yearly production volume increases. Therefore, the cash flow model has a greater impact on the sourcing decision for parts with large production volumes. The two model differential also grows as the total landed cost differential grows. This is a significant because it shows the cash flow model could alter the supplier decision even with large total landed cost differentials between the foreign and local suppliers.

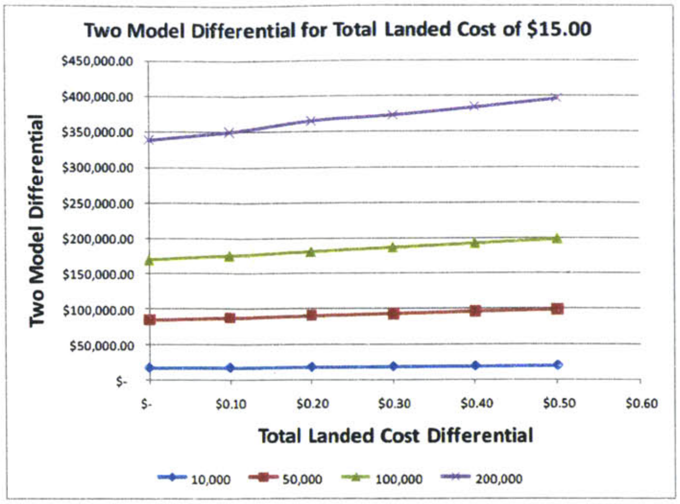


Figure 5.7: Two Model Differential for Total Landed Cost of $15.00


Figure 5.8: Two Model Differential for Total Landed Cost of $35.00

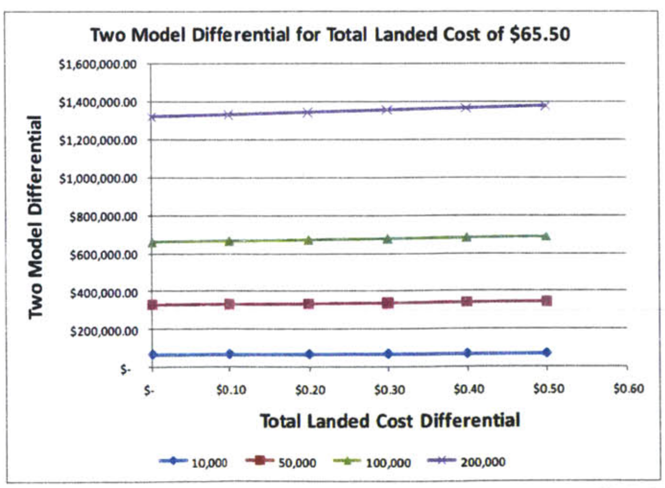


Figure 5.9: Two Model Differential for Total Landed Cost of $65.50

Figures 5.6 through 5.9 also show another trend. The two model differential increases as the total landed cost of the part increases. Overall, the two model differential is largest and would have the biggest impact on the supplier decision for high value, high volume parts.

Figures 5.10 and 5.11 show how the cash flow model impacts supplier decisions. Figure 5.10 shows the NPV differential under each model for a part with a total landed cost of $5.00 and an annual volume of 100,000 parts. This example highlights how the cash flow model can impact the supplier decision. The cost based NPV model recommends the foreign supplier (the NPV differential is positive) under all cases. The cash flow model recommends the local supplier if the total landed cost differential is $0.30 or less.

If a company were deciding between a foreign and local supplier for a part with an annual volume of 100,000 parts with a total landed cost of $5.00 and $5.30 respectively, the cost based model would show that the foreign supplier's NPV is $65,000 less than the foreign supplier and should be chosen to supply the part. Under the cash flow model, the local supplier's NPV is $3,700 more than the foreign supplier and should be chosen to supply the part. This example shows the importance of working capital considerations, most notably the inventory levels, in the supplier decision.

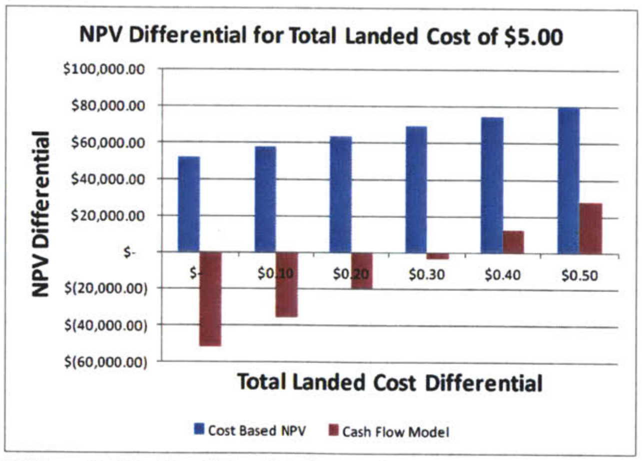


**Figure 5.10: NPV Differential for Total Landed Cost of $5.00 for Cost Based and Cash Flow Models**

Figure 5.11 shows a slightly different result than in figure 5.10. When the value of the part is increased to $65.50, the results are more drastic. In all cases, the cost based NPV model recommends the foreign supplier and the cash flow model recommends the local supplier.

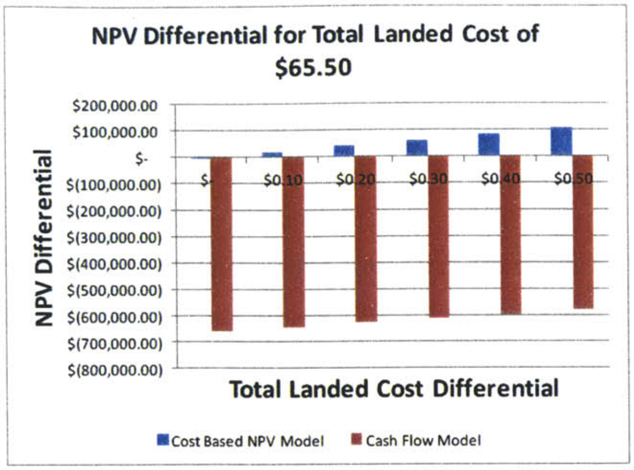


**Figure 5.11: NPV Differential for Total Landed Cost of $65.50 for Cost Based and Cash Flow Models**

If a company were deciding between a foreign and local supplier for a part with an annual volume of 100,000 parts with a total landed cost of $65.50 and $66.00 respectively, the cost based model would show that the foreign supplier's NPV is $107,000 less than the foreign supplier and should be chosen to supply the part. Under the cash flow model, the local supplier's NPV is $581,000 more than the foreign supplier and should be chosen to supply the part.

Higher annual volumes and value of the part produces more extreme differences between the models and can have a major impact on the supplier decision. If it is too burdensome to use the cash flow model for all parts, it should be used for the parts and packages of parts with the highest annual volumes and total landed cost.

## 5.5 Conclusion

This chapter showed that using a cash flow model versus a cost based NPV model for supplier financial analysis yields drastically different results for the supplier decision. Incorporating the impact of inventory policy and payment terms on net working capital creates timing differences in cash flows that impacts the respective cash flows of the suppliers. The cost based NPV gives an advantage to foreign suppliers by not taking into account changes in net working capital. Through a series of tests, it was determined that high volume and high value parts produced the largest NPV differential between the two models.

# 6 Foreign Exchange Risk

## 6.1 Introduction

Foreign exchange (FX) risk is one of the most difficult aspects of the supplier decision. Often the supplier is not providing parts for several years in future and therefore payments are not due for several years making predicting future costs due to FX fluctuations difficult. This chapter provides background on foreign exchange risk and highlights two main issues with FX in the supplier decision. 1. Understanding how to account for potential deviations from forecasted FX rates and how that impacts supplier choice. 2. Implementing hedging strategies to reduce or eliminate the foreign exchange risk due to supplier choice. Operational hedging strategies are also discussed.

## 6.2 Background on Foreign Exchange – Source of Exposure

FX risk is a key component of the supplier decision. FX risk is a difficult issue because there is no one perfect way to manage the risk within the context of the supplier decision. FX risk occurs when the currency required to pay the supplier is not the regional currency used by the company for its operations. For example, an operation in Brazil holds the Brazilian Real (BRL) at a local bank to make payments for employees, taxes, and other operational costs. If the Brazilian operation chooses a supplier in Japan that requires to be paid in Yen (JPY), the operation has risk to exchange rate movements between the Yen and the Real.

Assume that the operation agrees to have a supplier in Japan provide navigation systems for 44 million JPY per year for a vehicle to be assembled in two years in Brazil. The Brazilian operation needs to exchange BRL to pay the Japanese supplier in JPY two years from now. Assuming a current BRL/JPY exchange rate of 44.00 (1 BRL = 44.00 JPY), the Brazilian operation must exchange 1 million BRL into 44 million JPY to pay the supplier. If the exchange moves from 44.00 today to 40.00 two years from now when the payment is due, the operation must exchange 1.1 million BRL to pay the supplier 44 million JPY. The Japanese supplier has become 100,000 BRL more expensive than when the supplier was chosen. If the decision makers knew that the actual cost of the supplier is 1.1 million BRL instead of 1 million BRL, it might have chosen a different supplier. Management does not know in which direction the FX rate will move and even the best currency forecasters have trouble predicting the direction of future rates with reasonable certainty. Many manufacturing companies pick a forecasted rate based on a variety of methodologies to be used for all business decisions which involve foreign exchange risk.

There are two main issues for a global automotive manufacturer that relate to the uncertainty of FX rates in the future. The first issue is to understand how to account for potential deviations from forecasted FX rates and how that impacts supplier choice. The second issue is to implement hedging strategies to reduce or eliminate the foreign exchange risk due to choosing suppliers from around the world. This chapter focuses on the first issue but does go into moderate depth on the second issue.

As the example above shows, local sourcing is one way of avoiding foreign exchange risk for an operation within a global manufacturing company by matching the currency of revenues and costs. If the Brazilian operation receives BRL for selling cars in Brazil and pays workers, suppliers, taxes, and other costs in BRL then the appreciation or depreciation of the BRL is not important to the Brazilian operation but is important in context of the global manufacturing company. This issue is discussed in more detail in section 6.6.

## 6.3 Foreign Exchange in Total Landed Cost

The previous section outlined the basics of how foreign exchange risk is embedded into the supplier decision. The issue is actually more complicated because typically suppliers are compared on a total landed cost basis. The landed cost includes all aspects of the logistics costs including transportation, fees, taxes, and others which can be paid in different currencies. An additional complication is that many automotive companies choose one currency to compare all suppliers against. For example, GM converts all components of the total landed cost into US Dollars (USD) to compare all suppliers. If there is a local supplier in Brazil and a foreign supplier in Asia, all components of the landed cost are converted to USD and compared on that basis.

Since several automotive companies compare suppliers on a USD basis, many suppliers in China, Korea, and Thailand provide cost quotes in USD. Even though the cost of the part is quoted in USD, the other components of the total landed cost are in other currencies depending on the final location of the part. If the part is being sent to Brazil, foreign suppliers will have a component of the USD based total landed cost be dependent on the USD/BRL exchange rate. Of course, local suppliers in Brazil will have the USD based total landed cost completely dependent on the USD/BRL exchange rate.

Figure 6.1 below outlines the different components of the total landed cost and the conversion required to make a USD to USD comparison of a local supplier in Brazil and a foreign supplier in Korea. It is important to note that in the example, the Korean supplier quotes the price of the part in USD. The example shows that both the local and foreign supplier have USD/BRL exchange risk but to varying degrees. A majority of the components of the local supplier's total landed cost, including the manufacturer's price, is quoted in BRL so those components must be converted to USD. A few of the logistics components of foreign supplier are quoted in BRL but overall the total landed cost is less sensitive to changes in the USD/BRL exchange rate than the local supplier. If the foreign supplier quoted the cost per part in Korean Won (KRW) then the total landed cost would be dependent on the USD/BRL and USD/KRW exchange rate making the USD conversion more complex.

| **Foreign Supplier** | | | **Local Supplier** | | |
|---|---|---|---|---|---|
| **Price from Manufacturer** | **USD** | | **Price from Manufacturer** | BRL | USD |
| **Logistics** | | | **Logistics** | | |
| Inland at origin | USD | USD | Inland at origin | BRL | USD |
| Transportation Freight | USD | USD | Transportation Freight | BRL | USD |
| Insurance | USD | USD | Insurance | USD | USD |
| Port Taxes | BRL | USD | Port Taxes | BRL | USD |
| Port Fees | BRL | USD | Port Fees | BRL | USD |
| Importing Duties | USD | USD | Importing Duties | USD | USD |
| Inland to Warehouse | BRL | USD | Inland to Warehouse | BRL | USD |
| Inventory carry cost (ICC) | BRL | USD | Inventory carry cost (ICC) | BRL | USD |
| Warehouse Cost | BRL | USD | Warehouse Cost | BRL | USD |
| **Total Logistics** | | **USD** | **Total Logistics** | | **USD** |
| **Total Landed Cost** | **USD** | | **Total Landed Cost** | **USD** | |

**Figure 6.1: Foreign Exchange Conversions for a Local and Foreign Supplier**

From the example above it is clear the forecasted USD/BRL rate used to develop the total landed cost of each supplier is a very important component of the supplier decision. The forecasted rate, which has no guarantee of accuracy making it an essentially arbitrary number, can drastically alter the supplier decision. If the forecasted exchange rate is significantly higher than current rates (a weaker BRL than the current rate), it produces an advantage to the local supplier. If the forecasted rate is significantly lower than current rates (a stronger BRL than the current rate), it produces an advantage to the local supplier.

When management is presented with the supplier decision, they make the decision based on the information presented to them which is reliant on certain assumptions. All of the assumptions about transportation costs, fees, taxes, and others are all altered by the forecasted rate chosen which can produce an inherent bias in the decision. It is important to know if a supplier is chosen because of the FX forecast assumption or if that is the correct decision. A good way to understand if the forecasted FX rate is impacting the decision is to use sensitivity analysis. The next section provides an example of how sensitivity analysis can be used to understand the impact of the forecasted rate on the supplier decision.

## 6.4 Foreign Exchange Risk in Supplier Decision

Sensitivity analysis is a straight forward and simple way to measure the impact of a variable on the output of a model. In the context of the supplier decision, varying the forecasted FX rate by some measure to see the impact on the supplier decision is an effective way to make a more thorough decision. One challenge with sensitivity analysis for the forecasted FX rate is to decide how much to vary the rate to adequately test the supplier decision. A simple solution is to use a fixed percentage (i.e. 15%) above and below the forecasted rate for all currencies and see how the supplier decision is impacted, but that presents some issues. Not all currencies are the same as some are more volatile than others. A 10% move in either direction may be more likely for one currency versus another.

There are several measures of volatility which can be used to determine the range for the sensitivity analysis. Historical volatility is among of the best to use because it is easy to determine and uses actual data to calculate the volatility. The historical volatility of a currency is the realized volatility over a specified period of time and is calculated by determining the standard deviation of daily returns over the specified period. Historical volatility is not the perfect solution because past volatility is not a predictor of future volatility but it can be used as a benchmark for expected volatility in the future for the purposes of the supplier decision.

The historical volatility is unique to each currency making it a useful measure in the supplier decision. If a supplier decision requires sensitivity analysis on two different currencies but one currency is more volatile than other, the same fixed percentage in the sensitivity analysis for each currency would not be the best method. For example, the one year historical volatility for USD/JPY rate as of January 26$^{th}$, 2012 was 8.6% while the one year historical volatility for USD/BRL rate on the same date was 14.7% (Goldman Sachs Portal, 2012). For a supplier decision between a local supplier and a foreign supplier in Japan, the historical volatilities above versus the same fixed percentage for each currency would be a good source for the bounds for the sensitivity analysis.

In conducting the sensitivity analysis, the goal is to see how the supplier decision is impacted by the deviations from the forecasted exchange rates but also consider forecasted rate and deviations relative to the current exchange rate. For example, assume the current USD/BRL exchange rate is 1.60 (1 USD = 1.60 BRL) and the forecast rate for two years from today when the first supplier payment is due is 2.00. After conducting sensitivity analysis, results show that the supplier decision is altered if a forecast rate of 2.20 is used instead of 2.00. A 10% deviation above the forecasted rate is not a significant deviation but a USDBRL rate of 2.20 in two years requires a 37.5% appreciation of the BRL. The probability of the appreciation occurring depends on many factors but the historical volatility can be helpful in gauging the likelihood of the event occurring. Without considering how deviations from both the forecasted rate and the current rate impact a supplier decision, managers can not get a full understanding of how FX movements impact the supplier decisions.

Figure 6.2 shows an example of similar sensitivity analysis for a group of four parts sourced for a vehicle in Brazil. The foreign supplier quoted the cost of the part in USD so the only FX exposure is related to the USD/BRL exchange rate. The figure shows the total landed cost (TLC) of the local supplier as the percentage of the total landed cost of the foreign supplier as a function of three different USDBRL rates. If the value is greater than 100%, the foreign supplier is cheaper and therefore the better supplier choice. If the value is less than 100%, the foreign supplier is more expensive and therefore the better supplier choice.

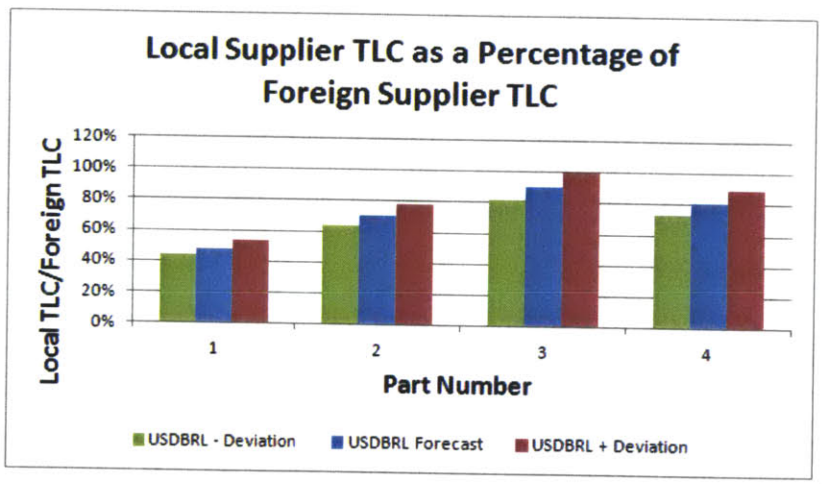


**Figure 6.2: Comparison of Total Landed Cost as a Function of USDBRL FX Rate**

The supplier decision is analyzed at three different exchange rates. The first is the forecasted USD/BRL rate for when the vehicle program begins. The second and third are the forecasted rate plus and minus the deviation from the historical volatility, respectively. In this particular example, the deviation between the forecasted rate and the current or "spot" rate at the time was minimal so a comparison between the deviations and the spot rate was not necessary.

Figure 6.2 shows that for part numbers 1, 2, and 4, the local supplier is the better choice. The figure also shows that the assumed forecasted rate does not impact the supplier decision; therefore, the supplier decision is not subject FX risk. Of course there is still FX risk for reasons previously described but the choice of the supplier is not dependent on FX rate movements. Part number 3 shows a different result. For the assumed forecast rate and the forecasted rate minus the deviation, the local supplier is the better choice. For the assumed rate plus the deviation, the local supplier and foreign supplier have the same total landed cost in USD terms. In this case the choice of the supplier is dependent on the FX rate so FX volatility creates risk in the supplier decision. Ultimately, it is impossible to know the exchange rate in two years but it is important to understand that deviations on the assumed rate can change the supplier decision.

## 6.5 Hedging Foreign Exchange Risk

The previous sections focused on understanding how to account for potential deviations from forecasted FX rates and how those deviations impact the supplier choice. This section provides a brief overview of hedging strategies to directly hedge FX risk from a supplier decision.

Forward contracts are one of the most widely used financial products for hedging FX risk. FX options are also used but this section focuses on forward contracts. A forward contract is an agreement between two counterparties to exchange a specified amount of currencies at a previously specified rate on a specified date in the future. Forward contracts can be used to hedge FX risk because the FX rate to exchange in the future is predetermined. In the previous example from section 6.2, the Brazilian operation needed to pay the Japanese supplier 44 million JPY two years in the future. The operation can enter into a forward contract to receive (buy) 44 million JPY two years from today in exchange for (sell) a specified amount of BRL. The amount of BRL exchanged depends on the exchange rate agreed to on the future contract. If the agreed rate is 45.00 (1 BRL = 45 JPY) then 977,778 BRL will be exchanged for 44 million JPY two years in the future. By entering into the forward contract, the operation knows exactly how many BRL it costs to procure the parts from the supplier. The cost of procuring the parts is no longer dependent on how the BRL/JPY exchange rate moves.

The forward contract could be a valuable tool for parts such as part number 4 from section 6.4, which have FX risk in the supplier choice. For part number 4, the supplier choice was dependent on the forecasted rate. The local supplier is the better choice for the forecasted rate and the forecasted rate minus the deviation. The foreign supplier and local supplier have equal total landed cost for the forecasted rate plus the deviation. In this type of scenario, using the forward contract rate as the assumed forecast rate solves the uncertainty of the supplier selection. If you can enter into the contract at a pre-determined USD/BRL rate, the total landed cost of the local supplier relative to the global supplier is known and a supplier decision can be made.

Assume the USDBRL forward rate is equal to the forecasted rate minus the deviation. In this case, the local supplier is the better choice. Management can choose the local supplier, enter into the forward contract, and know the exact cost of the supplier choice. Entering into the forward contract can have a cost depending on the currencies and date of the forward contract. The forward rate for the contract will be either above or below the current spot rate based on the interest differentials between the two countries. The differential between the spot rate and the forward creates a potential carry cost.

Since manufacturers make thousands of supplier decisions a year, the forward contract approach is not practical for every supplier decision. Cases which involve high volume, high cost parts where the supplier choice is subject to assumptions of the forecasted FX rate are best suited for this method. These parts make up a majority of the cost of the vehicle and would therefore make up the majority of added costs due to currency fluctuations.

## 6.6 Operational Hedging

Beyond hedging for a particular supplier decision, global companies must examine the broader foreign exchange risk impacting the company. Outside of the supplier decision, a global manufacturing company needs to examine how foreign exchange rates impact the cost of operations and revenues across the different regions of the world. If the BRL appreciates dramatically, the operational cost in USD terms become more expensive but the revenue received from selling vehicles in Brazil is also more valuable in USD terms. The concept of operational hedging is to set up a large scale manufacturing network which can be used to naturally hedge against different cost uncertainties, particular foreign exchange volatility.

Don Rosenfield explores different models which look to understand how to tradeoff extra capacity and flexibility to handle the different uncertainties in a global environment (Rosenfield, 1996). The general strategy is to use an operational approach by using manufacturing facilities differently in each period by cutting back at the most costly ones. Rosenfield argues that the operational approach is richer than mixing investments and the effects of the approach go beyond those used in traditional portfolio theory (Rosenfield, 1996).

Through the use of several numerical models, Rosenfield shows that an increased number of plants with excess capacity can be utilized to hedge uncertainty by cutting back variable production at the most expensive plants and shifted to lower cost facilities reducing costs below the level of cases with no uncertainty. Rosenfield notes in his analysis that European and Japanese automobile companies developed manufacturing sites in the Unites States during the 1980s and 1990s which helped those companies operationally hedge. The devaluation of the dollar during the period enabled them to hedge currency risk by increasing production in the United States and exporting cars to Japan.

## 6.7 Conclusion

This chapter outlined how foreign exchange risk is embedded in the supplier decision and offered techniques to understand how forecasted foreign exchange rates and deviations impact the supplier decision. Utilizing sensitivity analysis by varying the forecasted foreign exchange rate based on the historical volatility over the appropriate period is a good method to understand how deviations from the forecast rate impact the supplier decision. It is also important to examine the differential between the current spot rate and the forecasted rate to see if the forecasted rate creates an inherent bias in the supplier decision. The use of operational hedging as a means to hedge broader foreign exchange risk for a global manufacturing company was also discussed.

# 7 Dual Mode Sourcing Optimization

## 7.1 Introduction

This chapter provides a detail description of a dual mode (combination of ocean and air shipping) sourcing optimization model which recommends the optimal safety stock levels and review period to reduce overall logistics costs. Specific examples are discussed to show the potential costs savings under dual mode sourcing. The chapter also discusses which parts and regions are best suited for dual mode sourcing.

## 7.2 Dual Mode Sourcing Overview

Ocean freight is the primary mode of transportation for an automotive supplier to import parts from long distances across the globe. Ocean freight is reliable, has tremendous capacity, and is significantly cheaper than shipping parts by air. The primary disadvantage of ocean freight shipping is the long lead times. Bringing a part from Asia into Brazil or the Unites States by ocean freight can take up to 60 days or more. The part needs to travel in-land from the supplier to the port, travel by ocean to the Brazilian port, wait at customs at the port, and then travel in-land from the port to the warehouse at the plant. The long lead times increase safety stock levels and reduce supply chain flexibility. The safety stock in ocean mode is held to cover the variable demand while the mean demand is supplied by the ocean shipments.

The goal of a dual mode sourcing model is to reduce overall logistics costs by using a mix of ocean and air freight. Instead of holding large amounts of safety stock, a company can use air freight to supply some or all of the variable demand. There is an obvious trade-off between the cost savings from inventory reductions and the added cost of air shipping. The dual mode sourcing optimization model developed here details this trade off and others that develop under a dual mode sourcing policy.

The model described below is based on a dual mode sourcing model previously developed by Wondong Do's "Development of International Supply Chain Strategies to Support Global Sourcing and Manufacturing". Mr. Do's model was used as a framework but there were several changes made to his model. The new model incorporates a more precise calculation for the cost of air and ocean freight and the cost of warehouse space is included in the cost savings calculation. The model described below also uses different numerical techniques to solve for different components of the optimization model.

## 7.3 Model Development

This section provides a thorough description of the development and calculations of the optimization model. The model inputs, decision variables, and objective function are discussed in detail. The methods to calculate key components of the model are also discussed. The goal of the model is to recommend a specific review policy and safety stock level which reduces overall logistics costs.

### 7.3.1 Model Inputs, Decision Variables, and Objective Function

This section outlines the inputs to the model, the decision variables which set the inventory policy, and the objective function which determines the cost savings of the dual mode sourcing model.

#### *7.3.1.1 Model Inputs and Data*

Part Parameters

- Total landed cost of part
- Packaging Dimensions
- Parts per Pack

Demand

- Mean of weekly demand in units ($\mu_i$)
- Standard deviation of weekly demand in units ($\sigma_i$)

Other

- Ocean lead time ($L_O$)
- Air freight lead time ($L_A$)
- Inventory holding cost
- Desired service level ($z$)
- Ocean freight shipping cost structure
- Air freight shipping cost structure

#### *7.3.1.2 Decision Variables*

There are two decision variables under the dual mode sourcing model: review period (R) and safety stock SS ($z\sigma_i\sqrt{L_A} + \beta$), where $\beta$ is the additional safety stock. These variables are altered to maximize the cost savings under the dual mode sourcing model.

#### *7.3.1.3 Objective Function*

The model's objective is to determine the optimal review period and safety stock levels under dual mode sourcing which maximizes the supply chain savings compared to single source, ocean shipping. The supply chain cost savings is calculated below and is discussed in depth in section 7.3.2.3

**Supply Chain Cost Savings** = Safety Reduction + Cycle Stock Increase + Pipeline Inventory Reduction + Warehouse Space Reduction – Air Shipping Increase + Ocean Shipping Decrease

### 7.3.2 Calculations

The model calculations are comprised of three critical parts: 1. Determining the probability that stock-out occurs during a single cycle such that air freight is required to ship parts. 2. Determining the average number of parts shipped by air freight given air freight occurs. 3. Calculating each component of the objective function to determine the cost savings from the dual mode sourcing policy.

#### *7.3.2.1 Probability of air shipment, P(AS)*

In order to determine the probability of a stock out, the demand required to cause a stock out is needed. If a stock out occurs due to high demand during the period, it would occur due to demand during the period between the most recent regular shipment arrival and $L_A$ days before the next regular order shipment. Assuming air freight is an option with a lead time, $L_A$ , the minimum threshold for ordering new inventory would be $\mu_i L_A + z\sigma_i\sqrt{L_A}$ . Once the shipping threshold is hit, a certain number of units should be ordered to cover any volatility during the period. With a minimum safety stock of $\sigma_i\sqrt{L_A}$ due to the availability of air shipment, the average inventory on hand is $\mu_i R + z\sigma_i\sqrt{L_A}$, where R is the review period for ordering.

In order for the air shipment threshold to be hit, the demand must exceed the difference between the air shipping threshold ($\mu_i L_A + z\sigma_i\sqrt{L_A}$ ) and the average inventory held at the beginning of the period ($\mu_i R + z\sigma_i\sqrt{L_A}$ ) or $\mu_i R - \mu_i L_A$ over the period which is $R - L_A$ days long. Figure 7.1 below shows the probability density function for the accumulated demand over the period. Assuming that daily demand is independent and follows a normal distribution, the accumulated demand distribution has a mean of $\mu_i * (R - L_A)$ and standard deviation of $\sigma_i * \sqrt{R - L_A}$ .

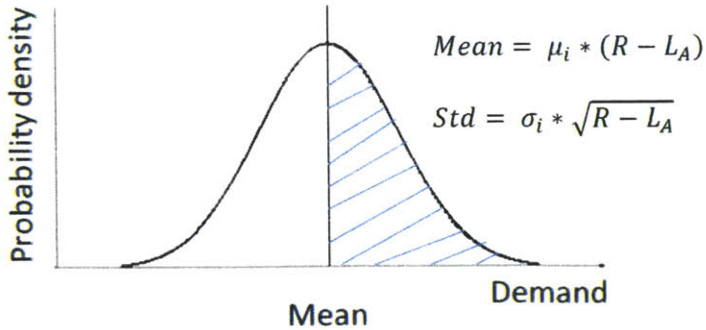


**Figure 7.1: Probability density function with no additional safety stock (Do, 2009)**

Since the demand threshold is $\mu_i * (R - L_A)$ and the mean of the accumulated demand distribution is $\mu_i * (R - L_A)$, there is a 50% probability of air shipment. The analysis above is based on keeping a minimum safety stock level of $z\sigma_i\sqrt{L_A}$ . If the minimum safety stock is increased from $z\sigma_i\sqrt{L_A}$ to $z\sigma_i\sqrt{L_A} + \beta$, where $\beta$ is additional safety stock, it decreases the probability of air shipment. Increasing the level of safety stock increases the demand required to break the threshold. With additional safety stock β, the demand required to break the threshold increases from $\mu_i * (R - L_A)$ to $\mu_i * (R - L_A) + \beta$. Figure 7.2 shows the accumulated demand probability density function with the new demand requirement.

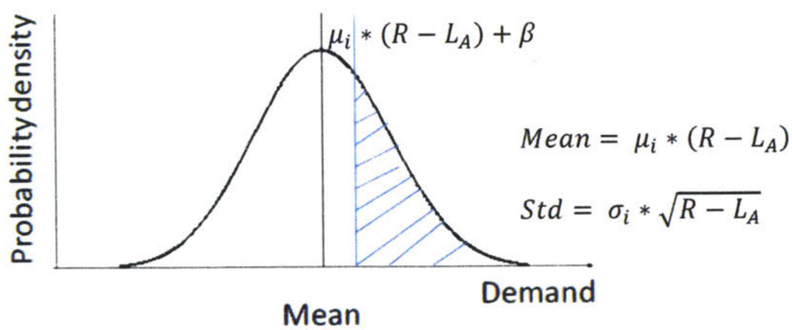


**Figure 7.2: Probability density function with additional safety stock (Do, 2009)**

As β and overall safety stock increases, the probability of air shipment decreases. The choice of β impacts the probability of air shipment which impacts the average amount of air shipment, cost of air shipment, and inventory holding costs. The probability of air shipment, P(AS), is shown below.

$$P(AS) = 1 - \Phi\left(\frac{\mu_i * (R - L_A) + \beta - \mu_i * (R - L_A)}{\sigma_i}\right)$$

#### 7.3.2.2 *Average number of units shipped by air per cycle, $S_A$*

Anytime during the period between the last regular order and $L_A$ days before the next regular shipment, the air shipment threshold can be crossed depending on demand. If demand during the beginning of the period is extremely high, the threshold would be reached very early in the period. If demand during the beginning of the period is extremely low, the threshold would be reached later in the period.

In order to determine the average number of units shipped by air per cycle, the probability that the air threshold is crossed N days into the period and the air shipment order amount if the threshold is crossed N days into the period need to be determined. The air shipment order amount must cover the accumulated demand and safety stock during the period from the air shipment arrival to the next regular ocean shipment. If the demand threshold is crossed four days after the regular shipment period the air shipping order amount is $\mu_i * (R - L_A - 4) + z\sigma_i\sqrt{R - L_A - 4}$ . For N days into the period, the air shipping order amount is $\mu_i * (R - L_A - N) + z\sigma_i\sqrt{R - L_A - N}$ .

One might think that the air shipment amount is to protect over the period of R – N not $R - L_A - N$. Since you lose the lead time for the air freight period, you are only protecting for the period of $R - L_A - N$. If $\geq R - L_A$ , there will be no air shipment because the parts would arrive either after or on the same day was the regular shipment, negating the need for air freight.

The probability that the demand threshold is crossed on the n-th day into the period is based on a conditional probability and can be written as $P(N = n|\, AS)$. The idea is to find the probability that the threshold is reached on the n-th day ($P(N = n)$), given that the air shipment (AS) threshold has been reached. Since the period is $R - L_A$ days long, N = n must be less than $R - L_A$ and greater than 1. The probability can be re-written as shown below. Since the event $N = n$ occurs once the air shipment threshold has been crossed, the $P(N = n \cap AS) = P(N = n)$. The calculation for $P(AS)$ is discussed previously in this section.

$$P(N = n|\, AS) = \frac{P(N=n \cap AS)}{P(AS)} = \frac{P(N=n)}{P(AS)}$$

In order for the demand threshold to be reached on the n-th day, it can not be reached during the prior n – 1 days. Therefore, the probability that the demand is reached on n-th day is based on the probability that the demand threshold is broken on the n-th day and that the accumulated demand over the previous n – 1 days did not reach the demand threshold. The $P(N = n)$ can be rewritten as below.

$$P(N = n) = P(N = n \; and \; N \neq n-1) = P(N \neq n-1) * P(N = n \,|N \neq n-1)$$

The $P(N \neq n-1)$ is based on the probability that the accumulated demand over the previous n-1 days does not reach the demand threshold. The accumulated demand over n – 1 days is assumed to be a normal distribution with mean of $\mu_i * (n-1)$ and standard deviation of $\sigma_i * \sqrt{n-1)}$ as shown in figure 7.3 below.

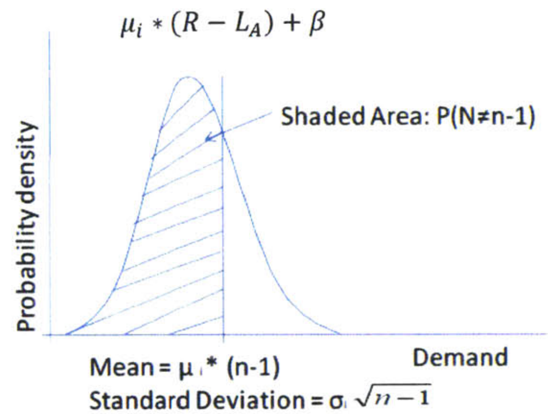


**Figure 7.3: Probability density function for accumulated demand (Do, 2009)**

The $P(N \neq n-1)$ can be rewritten as below where $PDF(x)_{n-1}$ is the probability density function of the accumulated demand shown in figure 7.3.

$$P(N \neq n-1) = \int_{x=0}^{\mu_i*(R-L_A)} PDF(x)_{n-1} dx$$

As the additional safety stock increases, the demand threshold increases making the shaded area larger and therefore increasing the probability of $(N \neq n-1)$ . Effectively, increasing the safety stock decreases the probability that the demand threshold will be reached on the n-th day. The other component to determining $P(N = n)$ is $P(N = n \,|N \neq n-1)$. The idea is determine the probability that the demand on the n-th day given the accumulated demand over the previous n – 1 days. If the demand threshold is $\mu_i * (R - L_A) + \beta$ and the accumulated demand over the previous n – 1 days is X, then demand on the n-th day must exceed $\mu_i * (R - L_A) + \beta - X$. Figure 7.4 illustrates below.

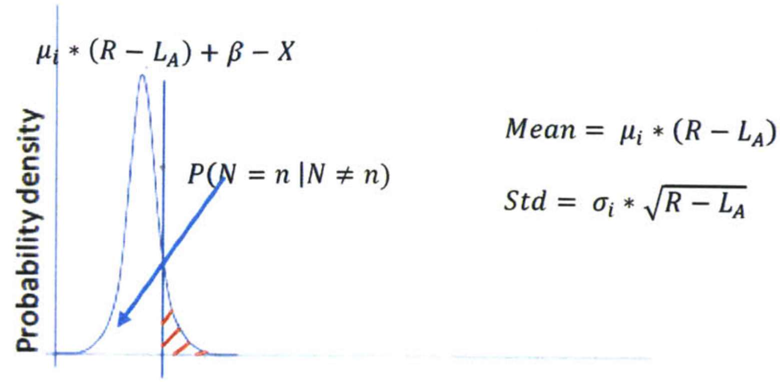


**Figure 7.4: Probability density function for single day demand (Do, 2009)**

As a result $P(N = n \mid AS)$ can be determined and is shown below.

$$P(N = n \mid AS) = \frac{P(N \neq n-1) * P(N = n \mid N \neq n-1)}{P(AS)} = \frac{\int_{x=0}^{\mu_i*(R-L_A)} \left\{ PDF(X)_{n-1} * \int_{k=\mu*(R-L_A)-x}^{\infty} PDF(k)_1 \right\} dk dx}{P(AS)}$$

As previously discussed, the average number of units shipped per air cycle depends on the probability that the air threshold is crossed N days into the period and the air shipment order amount if the threshold is crossed N days into the period. With both components determined the average number of units shipper per cycle, $S_A$, is written as below.

$$S_A = \sum_{n=1}^{R-L_A} \left[ \mu_i * (R - L_A - n) + z\sigma_i \sqrt{R - L_A - n} \right] * P(N = n \mid AS)$$

### *7.3.2.3 Numerical Techniques*

The program Microsoft Excel was used to execute the optimization model. As a result, numerical approximations were required to determine $P(N = n \mid AS)$. In order to determine $P(N = n \mid AS)$, the probability density function of the accumulated demand (figure 7.3) is altered to a probability histogram with a discrete random variable j. The random variable j represents one-half standard deviation of the distribution with $-12 \leq j \leq 12$ . Figure 7.5 shows the distribution in discrete form and figure 7.6 shows the area for each j, A(j), which is used in the calculation of $P(N = n \mid AS)$ .

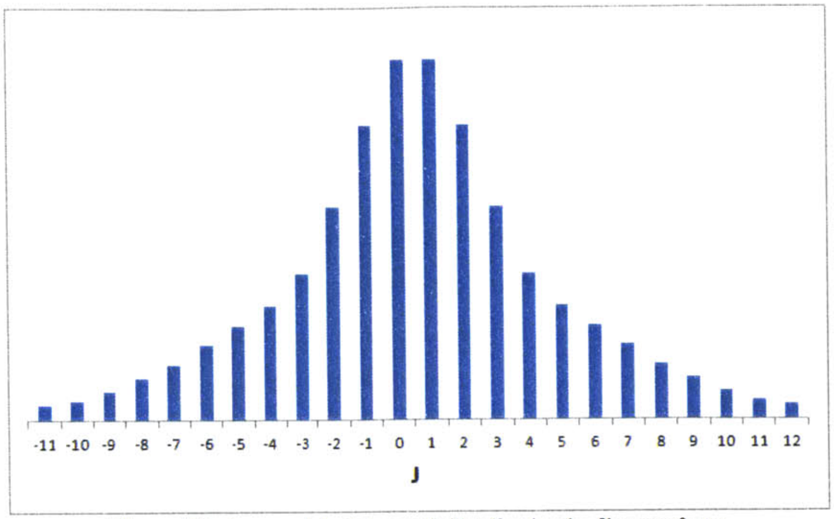


**Figure 7.5: Accumulated demand distribution in discrete form**

| J | Bar | A(j) | A(j) |
|---|---|---|---|
| -12 | | ϕ(-12) | 9.86588E-10 |
| -11 | 1 | ϕ(-12)-ϕ(-11) | 1.8003E-08 |
| -10 | 2 | ϕ(-11)-ϕ(-10) | 2.67662E-07 |
| -9 | 3 | ϕ(-10)-ϕ(-9) | 3.11102E-06 |
| -8 | 4 | ϕ(-9)-ϕ(-8) | 2.82736E-05 |
| -7 | 5 | ϕ(-8)-ϕ(-7) | 0.000201 |
| -6 | 6 | ϕ(-7)-ϕ(-6) | 0.001117 |
| -5 | 7 | ϕ(-6)-ϕ(-5) | 0.004860 |
| -4 | 8 | ϕ(-5)-ϕ(-4) | 0.016540 |
| -3 | 9 | ϕ(-4)-ϕ(-3) | 0.044057 |
| -2 | 10 | ϕ(-3)-ϕ(-2) | 0.091848 |
| -1 | 11 | ϕ(-2)-ϕ(-1) | 0.149882 |
| 0 | 12 | ϕ(-1)-ϕ(0) | 0.191462 |
| 1 | 13 | ϕ(0)-ϕ(1) | 0.191462 |
| 2 | 14 | ϕ(2)-ϕ(1) | 0.149882 |
| 3 | 15 | ϕ(3)-ϕ(2) | 0.091848 |
| 4 | 16 | ϕ(4)-ϕ(3) | 0.044057 |
| 5 | 17 | ϕ(5)-ϕ(4) | 0.016540 |
| 6 | 18 | ϕ(6)-ϕ(5) | 0.004860 |
| 7 | 19 | ϕ(7)-ϕ(6) | 0.001117 |
| 8 | 20 | ϕ(8)-ϕ(7) | 0.000201 |
| 9 | 21 | ϕ(9)-ϕ(8) | 2.82736E-05 |
| 10 | 22 | ϕ(10)-ϕ(9) | 3.11102E-06 |
| 11 | 23 | ϕ(11)-ϕ(10) | 2.67662E-07 |
| 12 | 24 | ϕ(12)-ϕ(11) | 1.8003E-08 |

**Figure 7.6: Discrete Areas for Accumulated Demand Distribution**

Under the discrete distribution method, $P(N = n\,|T)$ is transformed as shown below.

$$P(N = n\,|AS) = \frac{\sum_{j=-12}^{upper\ level\ sigma} A(j) * (1 - \Phi(\frac{\mu * (R - L_A) + \beta - \mu * (n-1) - j * (\frac{\sigma}{2}) * \sqrt{n-1} - \mu}{\sigma}))}{P(AS)}$$

An example helps to illustrate the equation above by finding $P(N = n\ |AS)$ on the third day or $P(N = 3\ |AS)$. Assume daily demand has a mean of 500 and standard deviation of 100. The inventory policy has a review period of 13 days and added safety stock (β) of 25 units. The air shipping time, $L_A$, is 10 days. Under these assumptions the air shipping threshold is 1525 units. If the accumulated demand over the previous two days is equal to the mean accumulated demand (j=0), then the accumulated demand is equal to 1,000 units. Therefore, the demand needed to break the threshold on the third day is 525 units. Given a mean daily demand of 500 and standard deviation of 100, the probability that demand is greater than 525 units on the third day is 40%. This probability must be found and summed over all j's to determine $P(N = 3\ |AS)$ by dividing by $P(AS)$.

#### *7.3.2.4 Objective Function Calculations*

TLC = Total Landed Cost

$I_R$ = Inventory Holding Interest Rate

$S_A$ = Average Amount of Air Shipping per Cycle

**Safety Stock:**

The savings from the reduction in safety stock is determined by subtracting the inventory holding cost under dual mode from the inventory holding cost under ocean only mode. If the safety stock savings is positive, the inventory carrying cost under dual mode sourcing has reduced supply chain costs.

Safety Stock Savings = Safety stock holding costs under ocean only
– Safety stock holding costs under dual mode

$$SS\ Savings = TLC * I_R * (z\sigma_i\sqrt{R + L_O} - z\sigma_i\sqrt{L_A} - \beta)$$

**Cycle Stock:**

The savings from the reduction in cycle stock is determined by subtracting the inventory holding cost under dual mode from the inventory holding cost under ocean only mode. If the cycle stock savings is positive, the inventory carrying cost under dual mode sourcing has reduced supply chain costs. Savings will occur if the review period of dual mode is less than the review period of ocean only mode.

Cycle Stock Savings = Cycle stock holding costs under ocean only
– Cycle stock holding costs under dual mode

The cycle stock inventory level under dual mode sourcing is the combination of the ocean cycle and air cycle stock. The ocean cycle stock is the total cycle stock minus the air freight cycle stock ($\frac{\mu_i}{2} * R_{Dual\,Mode} - S_A$). The air cycle stock is the average amount of air shipment per cycle ($S_A$). Therefore, the cycle stock under dual mode is $\frac{\mu_i}{2} * R_{Dual\,Mode}$ . The cycle stock for ocean only is $\frac{\mu_i}{2} * R_{Ocean}$ .

$$CS\ Savings = TLC * I_R * \frac{\mu_i}{2} * (R_{Ocean} - R_{Dual\,Mode})$$

**Pipeline Stock:**

The reduction in pipeline stock is due to the fact that shorter lead times from air freight reduces inventory holding cost. The cost savings is determined by subtracting the pipeline holding costs under dual mode from the pipeline holding costs under ocean only mode.

Pipeline Stock Savings = Pipeline holding costs under ocean only
– Pipeline holding costs under dual mode

Ignoring second order effects such as unfilled demand, the pipeline inventory savings is shown below.

$$PS\ Holding\ Cost_{Ocean} = \mu_i * L_O$$

$$PS\ Holding\ Cost_{Dual\,Mode} = S_A * L_A + (\mu_i - S_A) * L_O$$

$$PS\ Holding\ Cost\ Savings = S_A * (L_O - L_A)$$

**Warehouse Space:**

The reduction in safety stock requires less warehouse space to hold inventory. If a dual mode sourcing inventory policy is utilized for a significant number of parts, it would drastically alter the warehousing requirements for inventory reducing costs in the short and long term. The optimization model incorporates the benefit of reduced warehouse space into the model.

The savings from the reduction in warehouse space is determined by subtracting the warehouse cost of safety stock inventory under dual mode from the warehouse cost of safety stock cost under ocean only mode. The safety stock levels under each mode are described in the safety stock section of this chapter. The cost of inventory in the warehouse is not a component of the inventory holding interest rate used in other calculations in the model. A cost of storage is calculated as USD per $M^3$and is determined based on labor, maintenance, transportation from the plant to the warehouse and back, and price per $M^2$ to occupy the space. The volume occupied by the safety stock is determined by average safety levels and the packaging dimensions for the part.

**Additional Air Freight:**

The cost of air freight is composed of two components: 1. Fixed cost of air freight which varies by location 2. Variable air freight charge that is dependent on weight. The chargeable weight ($W_C$) for the air freight is the greater of the weight of the package (W) and dimensional weight ($W_D$) of the package. The dimensional weight of the packaging is the product of a density factor (kg/m$^3$) and the volume of the packaging. For air freight the density factor is 166 kg/m$^3$. For very large, light packages, the chargeable weight is the dimensional weight. For very small, heavy packages, the chargeable weight is the weight of the package. The formula for the cost of air freight is shown below. The air charge units are in $\$/W_C$.

$$Air\ Freight\ Cost = [P(AS) * S_A * \#\ Cycles * W_C * Air\ Charge] + (Min\ Charge * \#\ Cycles)$$

**Ocean Freight:**

If air freight is utilized under the dual mode sourcing model, there are costs savings for ocean freight as less inventory is shipped by ocean. The cost savings is the differential between the cost of shipping under ocean only mode and dual mode.

Ocean Freight Savings = Ocean freight costs under ocean only
– Ocean freight costs with dual mode

The cost of ocean freight is determined by the number of containers used to ship the material. Packaging information and a utilization factor are used calculate the number of containers required. The cost of shipping

$$Ocean\ Freight\ Savings = Cost\ per\ Container * (\#\ Container_{Ocean} - \#\ Container_{Dual})$$

## 7.4 Results and Analysis

An electrical component used in several vehicle platforms assembled in Brazil was tested to see the cost savings impact of the dual mode sourcing model. Figure 7.7 below shows the part characteristics for the base case tests. The supplier of the part is from the Asia-Pacific region which requires an ocean lead time of 49 days. It is important to note that the air lead time to fly parts into Brazil is significantly longer than most countries partly due to congestion at the ports. An estimate of the best case scenario for air freight lead time is 10 days. The air freight lead time into the United States is closer to 1-3 days. The different assumptions and conditions for the Brazil and the Unites States and how each impacts the dual mode sourcing results is discussed later in this section.

| | |
|---|---|
| Annual Volume | 101,380 |
| Daily Demand | 390 |
| Std of Daily Demand | 352 |
| Ocean Lead Time | 49 Days |
| Air Lead Time | 10 Days |
| Total Landed Cost | $10.00 |

**Figure 7.7: Part Characteristics for Base Testing**

Using the assumptions in figure 7.7, the dual mode sourcing model produced a cost savings of $60,289 using no additional safety stock above the minimum for air freight ($z\sigma_i\sqrt{L_A}$) and a review period of 21 days. The savings represents a cost reduction of $0.59 per part which is not an insignificant result. Automotive companies work very hard to find savings of just a few cents in the manufacturing costs to improve their bottom line.

Cost savings under the dual mode sourcing model is not always guaranteed. There are part characteristics which have a big impact on the cost savings under the dual mode sourcing model. The standard deviation of daily demand, the ocean freight lead time, the total landed cost of the part, and packaging are important components in determining whether dual mode sourcing should be used.

If the standard deviation of demand from the example above is lowered from 352 to 156 units, the cost savings decreases from $60,289 to $28,546. If the standard deviation of demand is increased from 352 to 503 units, the cost savings increases to $85,381. Overall, parts with high standard deviation of daily demand are well suited for dual mode sourcing.

| | Input | | Cost Savings | |
|---|---|---|---|---|
| Input | Before | After | Before | After |
| Std of Daily Demand | 352 | 156 | $60,288 | $28,546 |
| | 352 | 503 | $60,288 | $85,381 |
| Ocean Freight Lead Time | 49 | 40 | $60,288 | $39,225 |
| | 49 | 60 | $60,288 | $83,109 |
| Total Landed Cost | $10.00 | $5.00 | $60,288 | $8,262 |
| | $10.00 | $15.00 | $60,288 | $112,314 |

**Figure 7.8: Cost Saving Changes Under Changing Inputs**

Figure 7.8 above shows the impact of varying inputs on the cost savings for dual mode sourcing. From the figure, it is clear that the total landed cost of the part is sensitive to the standard deviation of daily demand, ocean freight lead time, and total landed cost of the part. Parts with a high standard deviation of demand, long ocean lead times, and high total landed cost are best suited for dual mode sourcing. This result is consistent with the cash flow model, described in chapter 4, which showed high value parts with longer ocean lead times drastically impact the supplier decision process. These types of parts, which usually represent a large percentage of the annual purchase value of the vehicle, have the biggest impact on the overall supplier decision and should be closely examined during the sourcing process.

Packaging is also an important component to the cost savings from dual mode sourcing. The base case example in figure 7.7 uses the packaging information from figure 7.9 below. The packaging for the component was 400X300X150 and contained 25 parts per pack. If the component were bigger (equal in weight) and required larger packing (1,100X850X250mm) to fit 25 parts, dual mode sourcing is more expensive than ocean only shipments with a review period of 21 days and β=0. Increasing β to 187 units and lengthening the review period to 24 days produces a cost savings of $7,233 under dual mode sourcing.

| Input | Before | After | Before | After |
|---|---|---|---|---|
| Length (mm) | 400 | 1,100 | $60,288 | ($22,333) |
| Width (mm) | 300 | 850 | | |
| Depth (mm) | 150 | 250 | | |
| Parts per Pack | 25 | 25 | | |

**Figure 7.9: Packaging Information**

There are some parts which are too large or too heavy for dual mode sourcing. There were no realistic combinations of safety stock and review period which produced cost savings under dual mode sourcing for a large stamping part on the body of the vehicle. Large and heavy parts (frames, axles, suspensions) are usually in every vehicle so they have a low standard deviation of demand making it less likely to realize cost savings from dual mode sourcing.

Vehicle platforms with high variation are well suited for the dual mode sourcing model. GM has recently launched the Chevy Sonic in a sedan and hatchback version assembled at the same facility. Providing two different versions of the vehicle should create a high variation in demand for parts that are specific to only of the two versions. The parts in the "LTZ" package of all GM vehicles are also well suited for dual mode sourcing. The "LTZ" package is the high-end package of all GM vehicles and is typically the vehicle package with the lowest demand. Parts in this package are usually high value and low demand which are strong candidates for dual mode sourcing.

The two biggest differences which impact the cost savings are the air freight lead time and the service level. The estimated best case scenario for air freight lead time from the Asia-Pacific to Brazil is 10 days while the air freight lead time to the United States is reliably 2 days. The shorter air freight lead time has a drastic impact on the dual mode sourcing model. If the air freight lead time is reduced to 2 days under the base case scenario with $\beta$=0 and a review period of 21 days, the cost savings more than doubles to $124,760. The optimal solution under the lower air freight lead time is $\beta$=277 units and a review period of 24 days which produces cost savings of $155,353. The results show that the longer air freight lead time into Brazil lowers the cost saving opportunities under dual mode sourcing.

The second unique factor to Brazil is the very high service level. Because of port congestion and the uncertainty of strikes at the port, GM and other manufacturers keep large amounts of safety stock which produces (unintentionally) high service levels. Unlike the higher air freight lead times, a higher service level requirement increases the cost savings from dual mode sourcing. If the service level is lowered to 95% under the base case with all other factors remaining constant, the cost savings under dual mode sourcing is reduced to $28,757.

Although Brazil faces different issues than the Unites States which impact inventory policy, it is clear that dual mode sourcing optimization is a viable inventory policy that can produce significant cost savings. High value parts with a high standard deviation of demand are best suited for dual mode sourcing and should be targeted first. Suppliers with long ocean freight lead times and parts in smaller and densely packed packages should also be targeted for dual mode sourcing.

## 7.5 Conclusion

This chapter described in-depth a dual mode sourcing optimization model which reduces total logistics cost for sourcing parts by both ocean and air freight. The model varies two decision variables, the review period and overall safety stock; to produce the overall cost savings. Testing showed that parts with a high total landed cost and standard deviation of demand that are sourced from suppliers with long ocean lead times to regions with high service level achieve the highest cost saving through dual mode sourcing. Brazil and the United States showed differing results for the dual mode sourcing model because of differences in service levels and air freight lead times. GM could best utilize the dual mode sourcing model for platforms with multiple versions and for parts in the "LTZ" package across all GM platforms.

# 8 Conclusion

The air freight risk model, cash flow model, and foreign exchange sensitivity analysis provide a comprehensive approach to choose between two or more suppliers and understand the risks involved in the decision. The air freight risk model delivers an expect cost of air freight per part in order to quantify the risk of choosing an international supplier. The proposed model uses historical data to determine an expected percentage of annual volume which is converted to an expected cost per part based on shipping and packaging information. This method produces stable results that quantify the risk of air freight within bounds that properly account for the risk of air freight.

Air freight risk is a key component of the supplier decision because air freight costs tend to be volatile. Properly accounting for the risk is vital and can drastically alter the supplier decision. Other models are proposed which take a broader approach to accounting for the risk. Instead of determining a single expected cost of air freight per part, the additional models determine the probability that air freight costs will alter the supplier choice.

The cash flow model calculates the net present value (NPV) of the cash flows for each supplier over the life of the product. Traditional finance models use accounting costs to compare suppliers but do not accurately account for the cash impact of the supplier choice. The cash flow model is a superior method for better understanding the financial impact of a supplier decision. For foreign suppliers, longer lead times cause payment term disadvantages and require more cash outflow at the start of the program. Separate inventory policies create timing differences of cash flows which impact net working capital. The focus on cash flow versus accounting cost can have a dramatic impact on the supplier decision, especially for high volume, high cost parts. Overall, the traditional accounting method provides an artificial advantage for foreign suppliers making them look for attractive from a financial standpoint.

The foreign exchange sensitivity techniques help decision makers understand how foreign exchange volatility and forecast assumptions impact the decision making process. This method prevents decision makers from choosing a particular supplier because the forecasted foreign exchange rate creates biases in the decision. The historical volatility of a currency provides a useful benchmark for the bounds of the sensitivity analysis to test how assumed forecast rates can alter the supplier decision. Using the three frameworks described above allows decision makers to determine the best supplier when considering financial costs and associated risks. The frameworks do not intend to measure or validate other important aspects of the supplier choice such as the supplier's quality, technical capabilities, capacity, or finance health. These are all important considerations when evaluating the supplier choice.

The three frameworks can be applied to a supplier choice for industries besides auto manufacturers. Companies such as Caterpillar which operate globally and build complex machines face many of the same issues as automotive manufacturers for supplier decisions. Caterpillar could very easily adopt the three frameworks when evaluating suppliers and considering altering the global versus local sourcing strategy.

The dual mode sourcing optimization model is a useful tool to reduce overall logistics costs through the combined use of air and ocean freight. The strategic use of air fright allows for a reduction in overall inventory while maintaining service levels. Results showed significant cost savings for parts but the savings can vary based on the part and region of implementation. The dual mode sourcing model is ideal for parts with long ocean lead times, regions with high service levels, and parts with a high variability of demand.

Although suppliers in the Asia-Pacific region have a competitive advantage over suppliers in the Unites States, Europe, and South America on the cost per part basis, rising logistics costs are reducing the price advantage from a total landed cost perspective. High service levels require high inventory levels and the use of air freight is a significant risk. The dual mode sourcing policy can reduce inventory levels and overall logistic costs dramatically despite the use of air freight. Adopting the policy makes foreign suppliers more competitive from a total landed cost perspective improving the case for a global sourcing strategy. The dual mode sourcing model can be applied to any industry or supply chain. Automotive manufacturers, pharmaceutical companies, clothing retailers, and many other industries could utilize the sourcing policy to reduce overall logistics costs.

Overall, the models and strategies discussed here provide a more comprehensive set of parameters to make an educated supplier decisions. The air freight risk model assigns a cost to a major risk factor of foreign suppliers. The cash flow model shows how the supplier choice impacts a company's cash position. The foreign exchange sensitivity techniques provide a framework to understand the impact of foreign exchange volatility and forecast assumptions on the supplier decision. The dual mode sourcing policy model provides a way to reduce overall logistic costs and improve the competitiveness of foreign suppliers.

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