1-1-2009

Offshore vs. domestic sourcing in a retail environment : a hybrid decision model utilizing a total cost of ownership and analytic hierarchy process methodology

Iyyad Jariri

Offshore vs. Domestic Sourcing in a Retail Environment: A Hybrid Decision Model Utilizing a Total Cost of Ownership and Analytic Hierarchy Process Methodology

by

Iyyad Jariri

B.Eng, Industrial Engineering

Ryerson University, Canada, 2004

A project report
presented to Ryerson University

In partial fulfillment of the
requirements for the degree of
Master of Engineering
in the Program of
Mechanical Engineering

Toronto, Ontario, Canada, 2009

Author's Declaration

I hereby declare that I am the sole author of this project report.

I authorize Ryerson University to lend this project report to other institutions or individuals for the purpose of scholarly research.

_____

Signature

I further authorize Ryerson University to reproduce this project report by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

_____

Signature

Abstract

In today's fast paced society, consumers expect their demand to be satisfied instantaneously; otherwise, they will go to the competition. Selecting a strategic supplier is an imperative undertaking, especially in a retail environment, to the company's success and profitability. Retailers have been steadily increasing their offshore penetration due to the low cost of goods. Global sourcing has become an important part of a retailer's strategy to achieve a competitive advantage. However, even though low cost is an important element of improving sales margins and profitability, additional criteria must be taken into consideration when determining the optimal sourcing strategy. This project addresses the issue of strategic supplier selection in a retail environment focusing on offshore versus domestic sourcing decisions. This is accomplished by developing a hybrid decision model which utilizes a total cost of ownership (TCO) model incorporated into an analytic hierarchy process (AHP) framework. This model is comprehensive and straightforward to apply in comparison to similar models within the literature. The model is applied to ABC Company, a major Canadian retailer. The analysis carried out in this project indicates that, for ABC Company, a domestic supplier is favorable.

Acknowledgements

I would like to express my sincere and utmost gratitude to my faculty advisor, Dr. Mohamad Jaber, for his enduring support, leadership, and encouragement throughout my graduate studies. Dr. Jaber's guidance has been a key contributor to the invaluable learning and experience that I have acquired during my graduate studies, and his time and direction have been immensely appreciated. I would also like to thank the employees of ABC Company for their cooperation and support. Their expertise and knowledge proved to be invaluable throughout the development and application of the proposed model.

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Introduction

Over the last two decades more and more companies in North America and Europe have been increasing the percentage of their business that is being sourced from an offshore supplier (Jin, 2005). This is due to the low-cost pricing they receive from these suppliers which are usually located in East Asia, as well as South East Asia. This is evident from the widening gap between Canadian imports and exports from other countries. Statistics Canada defines "other countries" as countries not included in the European Economic Community or the Organization for Economic Co-operation and Development (OECD); therefore, East Asia and South East Asia would be among the "other countries" considered in this study. From 2002 to 2007, the balance between imports and exports from other countries has increased by approximately 120% from $12.3 billion to $27 billion (Statistics Canada, 2009). This can be attributed to the 94% increase in imports over the same timeframe.

The majority of North American, as well as European retailers, have been steadily increasing their offshore vendor base year over year. Global sourcing has become an important part of a retailer's strategy to achieve competitive advantage (Jin, 2004; Quintens et al., 2006). However, even though low cost is an important element of improving sales margins and profitability, it is not the only criteria that should be taken into consideration when determining the optimal sourcing strategy (Lowson, 2001a, 2001b, 2001c). Sislian and Satir (2000) proposed a strategic sourcing framework which considered a variety of factors other than the low cost of goods. These factors were divided into primary factors, such as competitive advantage and demand flexibility, as well as secondary factors, such as process capability, process maturity, and strategic risk. Furthermore, Lowson (2001a, 2001b, 2001c) compares offshore versus domestic sourcing based on a variety of strategic objectives, such as flexibility, responsiveness, design, quality, innovation and cost. Moreover, he discusses the hidden costs of offshore sourcing, as well as sourcing strategies based on the strategic objectives of the firm. He presented three strategies which include a low cost offshore strategy, a flexible and responsive domestic strategy and a combined strategy.

As mentioned above, there are many hidden costs or costs that are just not taken into consideration when sourcing an item, especially items that are sourced from an offshore supplier. There have been numerous studies and models developed to determine the total cost of ownership (TCO) when sourcing an item. In addition to the net price, these models take numerous cost components, such as storage, transportation and ordering cost, into consideration. They also attempt to quantify various risks that can occur when sourcing an item,

such as country risks, currency, high inventory, insufficient quality, opportunity costs and penalties, among others (Bremen et al., 2007). The main incentives for TCO are achieving cost transparency, as well as supplier performance measurement, including the application within processes such as supplier selection and evaluation (Ellram, 1995; Bremen et al. 2007; Bhutta and Huq, 2002).

In addition to costs, the supplier selection process is based on multiple criteria, both quantitative and qualitative, and the decision is often not an easy one (Ghodsypour and O'Brien, 1998). The decision maker (DM) must take a range of criteria into account when making decisions. In most cases, these criteria are not equally weighted; some are more important than others depending on the organization's objectives. It is important to determine to what degree each criterion influences the decision making process (Yahya & Kingsman, 1999). Competing suppliers usually have different strengths and weaknesses which require careful evaluation. This usually results in having to make trade-offs between the various supplier selection criteria (Tahriri et al., 2008). The supplier selection problem is a multiple criteria decision making (MCDM) problem that has been studied extensively in the literature. There are numerous MCDM techniques that support the decision makers (DM) in determining the degree of importance for each criterion in order to evaluate a set of suppliers.

This project will attempt to address the issue of strategic supplier selection in a retail environment focusing on offshore versus domestic sourcing decisions. This will be accomplished by developing a hybrid decision model which utilizes a TCO model incorporated into an analytic hierarchy process (AHP) framework. An overview of both methods will provide an understanding of these techniques including the associated benefits, barriers and pitfalls. Furthermore, background information with regards to offshore versus domestic sourcing will also be presented which will provide significance in terms of understanding the differences between both processes. The hybrid model will be developed for ABC Company. It will be applied to a product within the company which can be sourced offshore or domestically to assess the model's effectiveness. Therefore, an evaluation of the current supplier selection process within ABC Company will be carried out to identify gaps in order to develop a comprehensive model which takes into consideration all the necessary costs and criteria required to select a strategic supplier. The project will conclude with an overview of the results and future considerations which can be studied further and implemented.

2.0 Offshore versus Domestic

ABC Company is one of the largest retailers in North America providing a wide assortment of products. Through various operating banners, ABC Company is committed to providing its customers with a one-stop destination in meeting their everyday household needs. As a retailer, ABC's sourcing strategy is directly proportional to the company's bottom line. They do not manufacture items but rather source them from suppliers and distribute them to their retail stores via a distribution network. Therefore, they need to ensure that their products are sourced from suppliers that maximize their profitability. However, selecting the best supplier is always a difficult undertaking; competing suppliers usually have different strengths and weaknesses which require careful evaluation and trade-offs (Tahriri et al., 2008).

There are many factors that must be taken into consideration when developing an optimal sourcing strategy. These factors are primarily related to ensuring you get the best price for a quality product that is delivered at the right time and place to satisfy consumer demand. Generally, retailers can source items from an offshore supplier, domestic supplier or a combination of both (Lowson, 2001a, 2001b, 2001c). Nonetheless, similar to the majority of retailers in North America, ABC Company has been increasing the percentage of offshore sourcing in comparison to domestic. This is due to the low cost of goods offered by offshore suppliers which are usually located in East Asia or South East Asia. However, is this direction providing an optimal sourcing strategy that truly maximizes the profitability of the organization? The following sections will provide background to the supply chain process, associated costs and impacts of sourcing offshore versus domestic.

2.1 Domestic versus Offshore Supply Chain

There are many differences between sourcing from an offshore versus a domestic supplier. Domestic suppliers have a shorter lead time than their offshore counterparts. The domestic lead time can range from 15 – 21 days depending on where the product is located and where it has to be delivered. Figure 1 illustrates the typical domestic supply chain process for ABC Company. This process also involves fewer stakeholders than offshore sourcing which usually results in fewer risks. The process starts with retail stores placing orders for a particular item(s) which are transmitted to head office. Then, buyers within the purchasing department at the head office place an order(s) with the supplier to accommodate this demand. The supplier manufactures the item(s) and processes the order. After this, the order is shipped to one of ABC Company's

distribution centres (DC). The inventory is received at the DC, stored, and then picked to satisfy the store order. Finally, the orders are shipped to the retail stores in order to satisfy consumer demand.

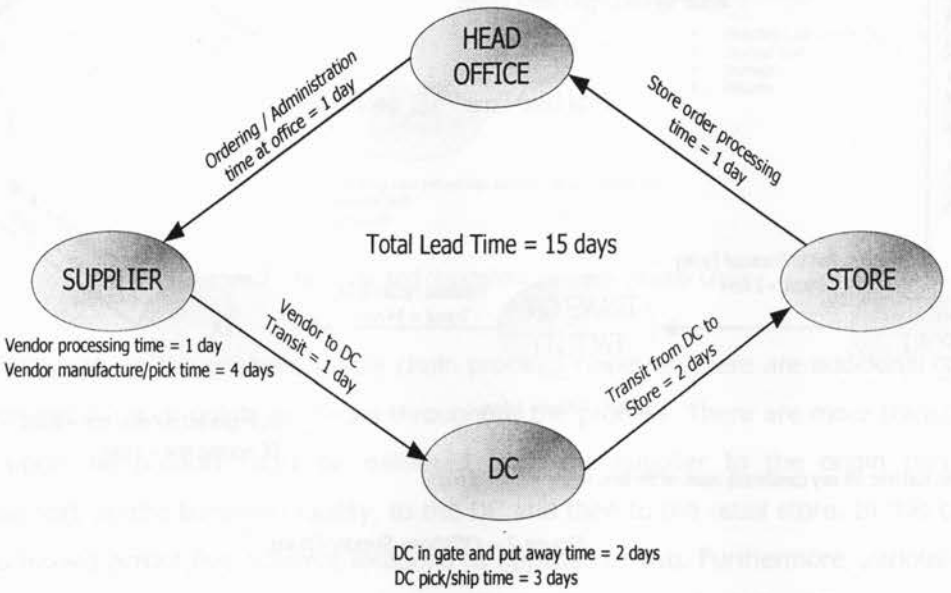


Figure 1 – Domestic Supply Chain

On the other hand, offshore lead times can range from 120 – 200 days depending on where the product is located and where it has to be delivered. Figure 2 illustrates the typical offshore supply chain process for ABC Company. It should be noted that the offshore process has almost twice the amount of stakeholders in comparison with the domestic process. The increase in touch-points also increases risks due to uncertain events at each stage of the process. The offshore process starts similar to the domestic process, with retail stores placing orders and buyers at head office placing purchase order(s) with the supplier to accommodate the store orders. However, the purchase order must be received by the supplier well in advance of the projected requirement due to the long transit lead times. The supplier manufactures the item(s) and processes the order. After this, the order is shipped to the port of origin where it is either consolidated prior to loading on the vessel or directly loaded in the cases where the vendor shipped a full container. The vessel sails from the origin port to the destination port which in most cases is the port of Vancouver. Once the container hits the destination port, it must be customs cleared and sent to the transload facility for destuffing. Orders are then reloaded on trailers and sent to one of ABC Company's DCs. Once the product arrives at the DC, it flows similar to the domestic process.

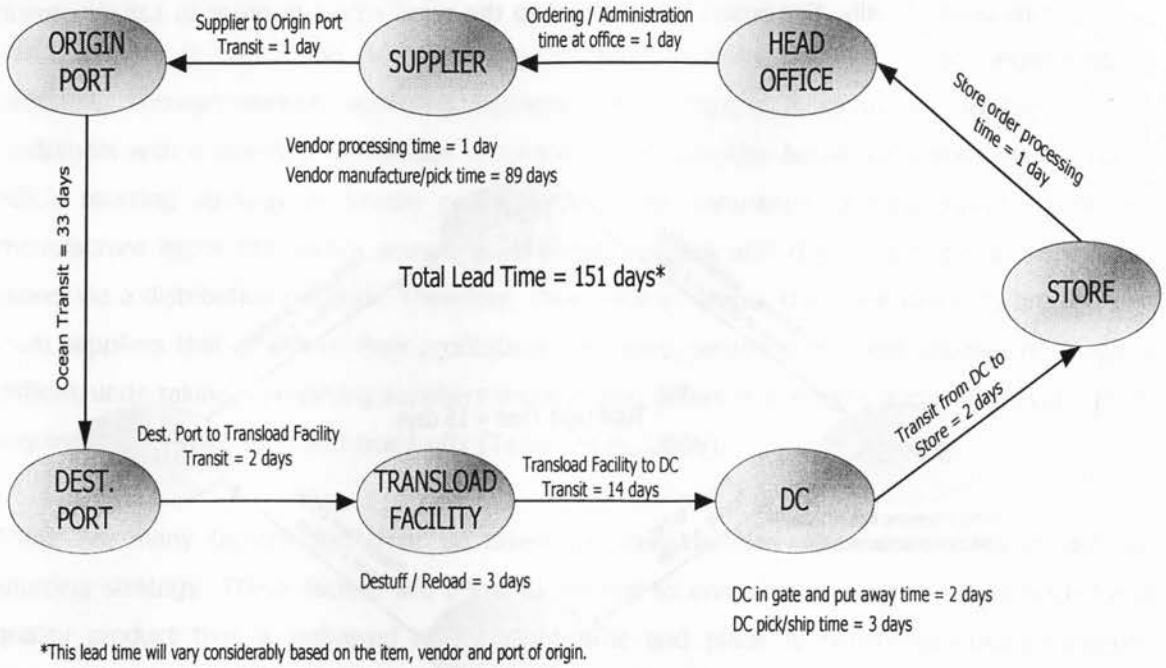


Figure 2 – Offshore Supply Chain

2.2 Domestic versus Offshore Costs

The costs associated with domestic versus offshore sourcing vary significantly. As mentioned above, the offshore supply chain process is much more involved than the domestic process; in turn, there would be additional costs incurred that would not apply to a domestic item. Figure 3 below illustrates the costs applied at the various stages within the domestic supply chain process. Initially, administrative ordering costs from the retail store to the head office and from the head office to the supplier are incurred. Once the supplier receives the purchase order, they will manufacture the product. At this point, they will incur a variety of costs including raw material costs, direct overhead costs (e.g., lighting, maintenance), indirect overhead costs (e.g., office expenses), and labour costs, among others. However, all of these costs are incorporated into the item price provided by the supplier to ABC Company. After the goods have been produced, transportation costs (freight costs) are applied when moving the product from the supplier to the DC, as well as from the DC to the Store. Furthermore, a variety of costs are applied at the DC and retail store such as handling costs (i.e., receiving, storing, picking, shipping, restocking), storage costs, costs for damages and returns.

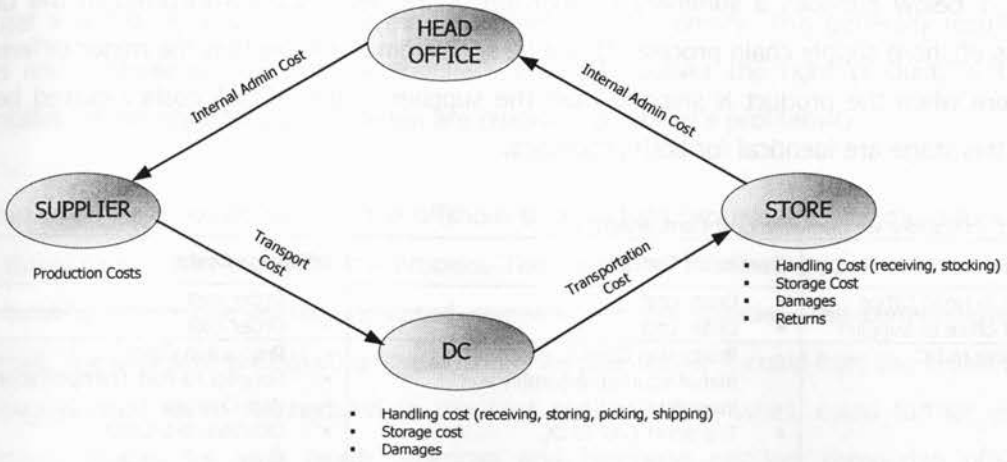
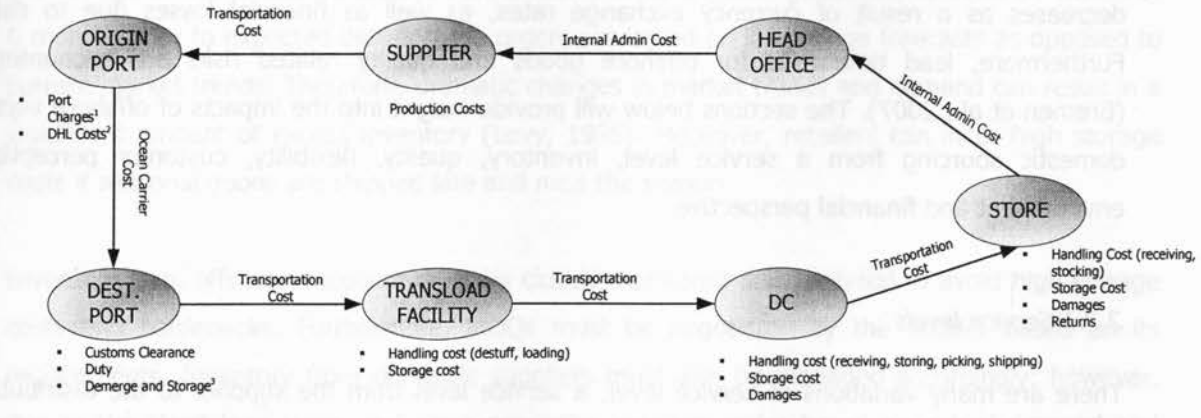


Figure 3 – Costs applied throughout Domestic Supply Chain

Similar costs apply to the offshore supply chain process; however, there are additional costs due to the increase in touch-points or stages throughout the process. There are more transportation charges since the product must be delivered from the supplier to the origin port to the destination port, to the transload facility, to the DC and then to the retail store. In this case, the product is moved across five different locations as opposed to two. Furthermore, various charges are applied at the ports such as port charges, offshore third party logistics (3PL) costs, customs clearance, duty, demerge and storage. Also, the transload facility incurs handling costs from destuffing containers and reloading the product onto trailers, as well as storage costs. Once the product arrives at the distribution centre, it would incur the same costs as the domestic item. Figure 4 below illustrates the various costs associated with a typical offshore supply chain at ABC Company.



1 These costs vary depending on the Port of Origin
2 These costs vary depending on the type of load
3 Applied when containers are not emptied/moved in a timely manner

Figure 4 – Costs applied throughout Offshore Supply Chain

Table 1 below provides a summary comparison of the various costs incurred in the domestic versus offshore supply chain process. It can be seen from this table that the major differences in cost are when the product is shipped from the supplier to the DC. All costs incurred before or after this stage are identical for both processes.

Table 1 – Offshore vs. Domestic Cost Comparison

Stage	**Domestic Costs**	**Offshore Costs**
Store to Head Office	▪ Order cost	▪ Order cost
Head office to Supplier	▪ Order cost	▪ Order cost
Supplier to DC	▪ Production Costs (i.e. setup, manufacturing, assembly and inspection) ▪ Transport Cost to DC	▪ Production Costs ▪ Supplier to Port Transportation Cost ▪ Port Charges ▪ Offshore 3PL Costs ▪ Duty ▪ Ocean Carrier Costs ▪ Customs Clearance Charges ▪ Handling costs at Transload Facility ▪ Storage costs at Transload Facility ▪ Transportation costs from Transload facility to DC
DC to Store	▪ Handling costs (receiving, storing, picking, and shipping) ▪ Storage costs ▪ Damages ▪ Transportation cost to store	▪ Handling costs (receiving, storing, picking, and shipping) ▪ Storage costs ▪ Damages ▪ Transportation cost to store
At Store	▪ Handling costs (receiving, stocking) ▪ Storage Cost ▪ Damages ▪ Returns	▪ Handling costs (receiving, stocking) ▪ Storage Cost ▪ Damages ▪ Returns

2.3 Impacts of Sourcing Offshore vs. Domestic

Many risks emerge when considering offshore sourcing strategies that do not have to be taken into consideration when sourcing domestically. These risks include profit losses due to margin decreases as a result of currency exchange rates, as well as financial losses due to risks. Furthermore, lead time risks for offshore goods and quality related risks are encountered (Bremen et al., 2007). The sections below will provide insight into the impacts of offshore versus domestic sourcing from a service level, inventory, quality, flexibility, customer perception, environment and financial perspective.

2.3.1 Service levels

There are many variations of service level; a service level from the supplier to the distribution centre, the distribution centre to the retail store and the retail store to the consumer. However, the service level from the supplier to the distribution centre is the most important because when the product is not received into the DC on time it will create a ripple effect whereby the DC will

not get it to the store on time and the retail shelf remains empty. This generally results in lost sales and customers. Therefore, a supplier's ability to deliver the right product, in the right quantities, at the right time and location are crucial to a retailer's profitability.

As shown in the previous section, the offshore supply chain process involves more touch points and stakeholders than the domestic process. This increases the likelihood of delays, as well as the bullwhip effect due to the increased complexity in coordination and communication. For example, if a shipment is delayed at the offshore supplier facility it could miss the vessel sail date and would need to be rescheduled to the next available date which could further delay the shipment. Studies for both North American and European retailers comparing offshore to domestic supplier service levels have shown that service levels for offshore suppliers tend to be less than domestic suppliers (Lowson, 2001a, 2001b, 2001c). Therefore, although offshore goods are sourced at a lower cost, the percentage of lost sales for these items is much greater than domestic items.

2.3.2 Inventory

Inventory carrying or storage costs are an important consideration when deciding whether to source from an offshore or domestic vendor. This is due to the large minimum order quantities (MOQ) that offshore suppliers impose on their customers. Therefore, retailers need to ensure that they have enough space in their distribution network to avoid capacity constraints and bottlenecks. They must also consider the storage costs associated with carrying these large quantities. In many cases, inventory sourced from offshore suppliers contributes to a large percentage of the excess inventory. Furthermore, since offshore goods are sourced 26 weeks or 6 months prior to expected delivery, the orders are based on long range forecasts as opposed to current market trends. Therefore, dramatic changes in market trends and demand can result in a significant amount of excess inventory (Levy, 1995). Moreover, retailers can incur high storage costs if seasonal goods are shipped late and miss the season.

Inventory from offshore suppliers must be closely monitored and analyzed to avoid high storage costs and bottlenecks. Furthermore, MOQs must be negotiated by the retailer based on its requirements. Inventory from domestic suppliers must also be managed accordingly; however, due to the short lead times and close proximity, retailers order based on actual demand and current market trends. Therefore, the risks associated with inventory from domestic suppliers tend to be less than the risks associated with offshore sourcing.

2.3.3 Quality

Quality has been identified as one of the top supplier selection criteria for both offshore and domestic suppliers (Jin, 2005; Lowson, 2001a, 2001b). Improvements in manufacturing and inspection technologies, as well as the adoption of lean practices such as total quality management (TQM) and just-in-time (JIT), have contributed to quality improvements. However, defective items are still produced and must be managed by the retailer. This tends to be a simple undertaking with domestic suppliers where the goods can easily be returned to the supplier. Meanwhile, the same practice cannot be applied to many offshore suppliers due to the complexity of the reverse logistics. Therefore, most companies would appropriately dispose of the items because the cost of the item would be less than the cost to transport it back to East Asia or South East Asia. This results in loses, especially if the item must be disposed using specialized techniques such as hazardous materials disposal.

There are retailers that manage defects from offshore suppliers by introducing a defective allowance. This allowance is a discount on the cost of goods to account for potential defectives. However, this depends on the supplier's willingness to accept this allowance. Also, some offshore suppliers have local distributors where the goods can be returned. In any case, it is extremely important for offshore suppliers to ensure quality standards are met prior to shipping to the retailer (Jin, 2005).

2.3.4 Business flexibility and responsiveness

In today's fast paced society, consumers' expectations have increased; they expect their demand to be satisfied immediately otherwise they will likely go to the competition. Therefore, it is extremely important for retailers to ensure that goods are available for consumers when they need them. In turn, a retailer must be flexible and responsive to uncertain consumer demand and unpredictable market trends (Jin, 2004; Lowson, 2001a, 2001c). This has resulted in many companies adopting a just-in-time (JIT) approach to improve both agility and flexibility. Furthermore, lean retailing has also been adopted as a result of consumer demand for product variety, as well as increased rates of product introduction (Jin, 2004). Lean retailing, as well as the JIT approach, both require collaborative working relationships with suppliers and place a tremendous amount of responsibility on purchasing managers. Furthermore, sourcing directly from offshore suppliers requires greater purchasing knowledge, accurate forecasts and is riskier than other alternatives that use locally based wholesalers and representatives (Katobe and Murray, 2004).

Furthermore, these concepts are difficult to implement with offshore suppliers due to long lead times and high MOQs. The ability to quickly cancel orders that are no longer needed, avoid markdowns, operate with small stock rooms and incur lower inventory holding costs is a complex undertaking when sourcing offshore. For example, once a vessel has shipped from an offshore vendor's port of origin, there is no way that the order can be canceled. There can be over a month before the product is expected to arrive depending on the lead time. On the other hand, due to the close proximity of domestic suppliers, orders can be canceled within days of expected arrival. This allows the company to circumvent an excess inventory position, in turn avoiding markdowns and increased holding costs.

Moreover, inadequate planning, poor communication between departments, and weak performance measurements are typically problems related to existing buying practices (Degraeve et al., 2005). Conflicts of interest also exist among the various stakeholder groups such as merchandising and distribution due to differing objectives. Excessive product changes for the sake of satisfying customer requirements will increase the cost of production and eat into the distribution lead time which would result in product arriving late (Katobe and Murray, 2004). Offshore sourcing requires a close coordination among the supplier and the retailer, as well as all departments within the retail organization such as merchandising, sourcing, replenishment, and distribution, among others, across national boundaries.

2.3.5 Customer perception

Generally, Canadians prefer products made in Canada over imports (Wall and Heslop, 1986). Wall and Heslop (1986) conducted a survey of 635 Canadian men and women revealed that overall attitudes toward Canadian-made products were positive. However, certain imports were preferred over Canadian-made products. For example, Japanese-made automobiles and electronics rated higher, while European wines were rated ahead of Canadian wines. Nowadays, it's fairly rare to find products made in Canada. The majority of manufacturing is now taking place in East Asia and South East Asia due to lower production costs.

Customer perceptions are very important to retailers. The majority, if not all, of retailers have implemented Corporate Social Responsibility (CSR) programs when working with offshore supplier to ensure they are socially responsible. CSR programs consist of audits to inspect the factories in order to ensure suppliers adhere to environmental and legislative policies and guidelines, as well as customer requirements. According to the Bureau of Statistics of the International Labour Organization, in 1995 the number of children employed full-time and

working over 10 hours per day amounted to least 120 million children globally. Their ages ranging between five and fourteen years old and working under unsafe and unhealthy conditions. (Basu, 1999). It is imperative for retailers to ensure that their suppliers are not partaking in such practices. Consumers will generally boycott a retailer dealing with an irresponsible supplier. These audits are not free of charge; the cost of CSR programs is paid by the supplier and ultimately built into the cost of goods.

2.3.6 Environment

In recent years, there has been significant attention given to the environment and sustainability. More and more companies are striving to "Go Green". They have been investing in energy efficient solutions to reduce their carbon footprint; however, sourcing strategies are often missed as part of these initiatives. Over the last 20 years retailers have been increasing their offshore penetration. The low cost of goods from offshore suppliers has been very attractive for retailers; nevertheless this ultimately leads to an increase in energy consumption and green house gas emissions due to the transportation requirements. Energy use for freight transportation has grown by 59.9% from 1990 – 2006; meanwhile passenger energy use showed growth of only 15.7% during the same timeframe. Furthermore, the amount of CO_2 emissions for freight transportation has increased by 59.2% from 1990 – 2006; however, CO_2 emissions resulting from passenger transportation showed moderate growth of 13.6% over the same duration. Freight and passenger figures for energy use and emissions from 1990 – 2006 are shown in Table 2.

Table 2 – Transportation Energy Use and Emissions from 1990 – 2006

	Energy Use (PJ)			Emissions ($MtCO_2e$)		
	1990	**2006**	**Total Growth 1990–2006**	**1990**	**2006**	**Total Growth 1990–2006**
Passenger Transportation	1,187.6	1,373.7	15.7%	84.6	96.1	13.6%
Freight Transportation	636.9	1,018.5	**59.9%**	46.4	73.8	**59.2%**
TOTAL	1,824.5	2,392.3	31.1%	130.9	169.9	29.7%

Source: Natural Resources Canada (2008)

When an item is sourced domestically, the impact to the environment is significantly less than sourcing offshore products. Offshore products are transported via trucks from the manufacturing facility to the origin port. Once they arrive at the port, heavy duty machinery loads the containers onto the vessel. The vessel transports the containers to the destination port. The containers are then offloaded using heavy duty machinery once again and sent to the distribution centre either by truck or by rail. On the other hand, domestic products are simply shipped from the supplier

straight to the distribution centre. Therefore, delivering goods from offshore suppliers requires numerous transportation modes such as trucks, rail, marine and occasionally air freight. As a result, the energy requirements for transporting offshore goods would be much greater than the requirements for transporting domestic goods. Hence, the CO_2 emissions resulting from offshore freight transportation would be far greater than domestic. Table 3 illustrates energy use and emissions from 1990 – 2006 for the different freight transportation modes. Although there have been minor decreases in rail and marine transportation, the light and heavy truck figures have increased dramatically from both an energy use CO_2 emissions standpoint.

Table 3 – Freight Transportation Mode Energy Use and Emissions from 1990 – 2006

	Energy Use (PJ)			Emissions ($MtCO_2e$)		
	1990	**2006**	**Total Growth 1990–2006**	**1990**	**2006**	**Total Growth 1990–2006**
Light Trucks	96.0	172.7	**79.9%**	6.7	12.1	**80.3%**
Medium Trucks	134.0	154.9	15.6%	9.4	11.0	16.6%
Heavy Trucks	209.5	505.5	**141.2%**	14.9	36.4	**143.7%**
Air	6.5	7.1	9.5%	0.5	0.5	6.5%
Rail	84.4	78.9	-6.6%	6.7	6.3	-5.6%
Marine	106.5	99.5	-6.6%	8.2	7.6	-7.2%
TOTAL	636.9	1018.5	59.9%	46.4	73.8	59.2%

Source: Natural Resources Canada (2008)

2.3.7 Financial Impacts

Cash-to-cash cycle time is considered to be an important indicator of a company's financial health. The faster the cycle time, the healthier the company. Sourcing products from an offshore versus domestic supplier impacts the company's cash-to-cash cycle time and liquidity. Payment terms are generally 30 – 45 days which means that the vendor is paid 30 – 45 days after receiving the goods. Due to the long lead times for offshore vendors, this means that the vendor is paid prior to even receiving the goods into the distribution centre. Therefore, the company's cash is invested in the inventory which may or may not sell. This means the cash-to-cash cycle time, as well as the company's liquidity are negatively impacted. For example, if seasonal items are delivered late and miss the season, these items will need to be sold at a reduced price whereby the company's return on investment would be significantly reduced. In some cases the company would even take a loss to clear the inventory out of the distribution network to avoid additional carrying costs.

On the other hand, domestic suppliers are usually paid after the goods have sold at store level due to the short lead times. For example, the full product flow cycle for a particular domestic

item could be less than 30 days which includes receiving the order and selling at the retail store. Therefore, the retailer would have sold all the goods, made profit and then paid the vendor. This improves the company's cash flow and liquidity because they are able to easily convert the inventory into cash with minimal inventory investment.

Furthermore, global economic risks must be taken into consideration when souring from an offshore supplier. Since the 1997 Asian financial crisis took place and the spreading of severe acute respiratory syndrome (SARS) from China in 2003, the world economy has continued to stagnate with many uncertainties (Kotabe and Murray, 2004). Moreover, companies with increased diversification in global suppliers will encounter difficulty managing currency fluctuations. Therefore, the expected profit margins will vary based on these fluctuations. Meanwhile, companies that mainly deal with domestic suppliers are not affected easily by fluctuating exchange rates.

In addition, there are many hidden and unexpected costs associated with offshore sourcing (Levy, 1995). These costs are often difficult to quantify and are not taken into consideration when sourcing from an offshore supplier. Hidden costs are often a result of the risks that can be encountered such as irrevocable letters of credit charges, delays at the port of entry, last minute use of air freight, and early commitment of orders prior to sales visibility (Lowson, 2003). Furthermore, noncompliance to customs clearance requirements can result in fines, storage charges from not moving the container out of the port or rail yard in a timely manner, as well as demerge charges if the container is not returned to the shipping company in time. Therefore, the low cost offshore goods might not be as attractive to retailers if they took into account the hidden costs, as these costs could drastically erode profit margins.

3.0 Objective

As previously mentioned, ABC Company, much like other retailers in the industry, has been increasing the proportion of products sourced from an offshore supplier. However, this has many implications to the business which are usually not taken into consideration. The objective of this project will be to develop a hybrid TCO and AHP model to ensure strategic suppliers are selected, as opposed to low cost suppliers, with a focus on offshore versus domestic sourcing. This will ultimately lead to a structured process resulting in improved profitability. This is due to the holistic nature of the model as opposed to making decisions based on an incomplete, inaccurate and unstructured methodology.

4.0 Current Sourcing Process

The sourcing department within ABC Company has a large vendor base which provides a variety of products to the company. Currently, the majority of these vendors are offshore and many of the domestic vendors are actually importers. To determine which supplier to choose for a particular item, the sourcing department sends the vendor a quote sheet, shown in Appendix A, which contains all the vendor information such as vendor name, contact name and email, FOB port, FOB country. This sheet also contains product information such as the item number, dimensions, weight, minimum order quantity (MOQ), and the estimated quantity per container depending on the container size (i.e., 20 foot, 40 foot, 40 foot high cube). Furthermore, the cost information that is taken into consideration includes FOB cost, duty, inland freight per 40 foot container, ocean freight, commission, and royalties which provide the estimated landed cost for the item.

The main deciding factors on whether to source from a domestic or offshore supplier include the estimated landed cost and MOQ. If the MOQ is too high, based on projected demand, the item is sourced from a domestic supplier which is usually a distributor for items manufactured offshore. This occurs in cases where MOQs are very high and could result in a substantial amount of excess inventory; however, since the domestic importers supply the product to multiple retailers, they are able to order the full MOQ and distribute to these retailers accordingly without incurring outrageous storage costs. More importantly, the estimated landed cost of the item is weighted higher when it comes to making the final sourcing decision. The supplier with the lowest landed cost is generally chosen subject to having a reasonable MOQ. Table 4 describes the various cost components which are taken into consideration when calculating the landed cost. The supplier with the lowest landed cost is generally chosen subject to a reasonable MOQ. Figure 5 illustrates this process.

Table 4 – Current Sourcing Cost Elements

Cost	Description
FOB Cost (USD)	Cost per unit delivered to the port at origin
Duty	Percentage of the unit cost applied to items where a free trade agreement does not exist with that Country. This percentage will vary based on the item
Inland Freight per 40' CY	Freight cost from destination port to DC
Ocean Freight per 40' CY	Freight cost from origin port to destination port
Commission	Paid to offshore agent; typically 5%
Est. Landed Cost (USD)	Estimated total cost per unit taking into consideration production, duty, freight, commission and royalties.

* CY – Consolidated Yard load which is consolidated by the supplier as opposed to offshore 3PL

Once a supplier has been selected, Purchasers within the Supply Chain Replenishment team create purchase orders to satisfy consumer demand. The Purchasers are held accountable for ensuring that the merchandise is always in-stock with optimal inventory (i.e., avoid storing

excess inventory which increases carrying costs). Purchasers are usually dealing with the suppliers on an on-going basis to coordinate orders and deliveries to ensure that product is delivered in the right quantities, at the right time and place. Therefore, constant interaction with suppliers provides first-hand visibility to service performance, order changes, and flexibility in terms of negotiating lead time. However, the Sourcing department does not consult with the purchasers when making the decision to partner with a particular supplier.

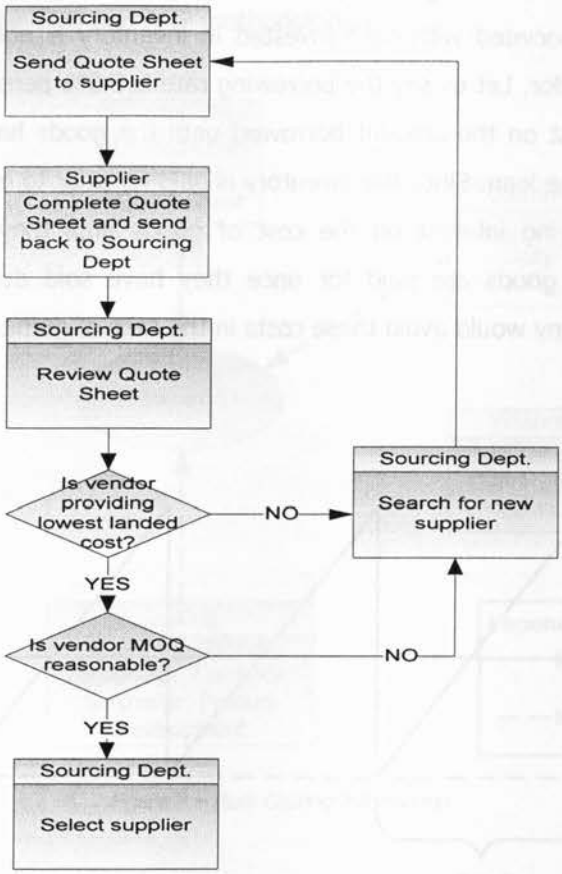


Figure 5 – Current Sourcing Process

Furthermore, accurate costing for an item is not taken into consideration until the vendor has been selected and the item listed within the system. This is completed by the costing group who enter the various cost components associated with the item. Cost components will vary depending on the type of item and whether it's sourced offshore or domestically. The percent cost increase for offshore items is greater than domestic items. This is due to the numerous cost components added to offshore items. Offshore cost components include duty, offshore

brokerage, repiling charges, among others. To improve the supplier selection process, the various cost components should be taken into consideration up front, especially for offshore items.

In addition, the carrying costs associated with ordering high MOQs from offshore suppliers is not taken into consideration. Although the MOQs might be reasonable, they are larger than domestic MOQs due to the long lead times. Generally, ABC Company's safety stock policy for offshore items is 4 weeks of stock which is four times the amount of safety stock for domestic suppliers where the average is 1 week. Therefore, the average inventory level for offshore items is 4 weeks of stock plus the average MOQ. This behaviour is shown in Figure 6. Moreover, the opportunity costs associated with cash invested in inventory is not considered when sourcing from an offshore vendor. Let us say the borrowing rate is 5.9% percent; therefore, the company will be paying interest on the amount borrowed until the goods have sold, at which point the company will repay the loan. Since the inventory is paid for prior to even receiving the goods, the company will be paying interest on the cost of goods until they have sold. However, with domestic items, the goods are paid for once they have sold due to the short lead times. Therefore, the company would avoid these costs in the case of domestic sourcing.

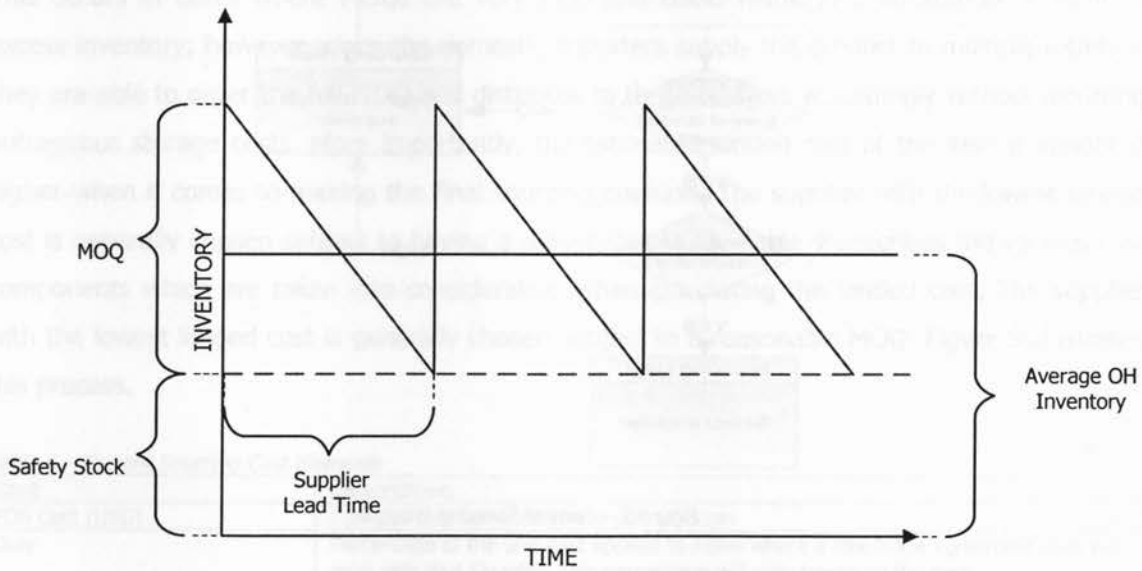


Figure 6 – ABC Company Average Inventory Graph

Thus, there are numerous costs and criteria that must be taken into consideration in order to select the best supplier that will contribute to the company's competitive advantage. Currently, costs are being compiled autonomously and informally within ABC Company. This is illustrated in Figure 7. The Sourcing team is applying some of the costs associated with an item through initial negotiations with the vendor. Once the sourcing decision has been made, the Costing team then includes additional cost components when the item is being listed in the system. In addition, key

obtaining costs could be a difficult undertaking, especially if the company is not tracking costs at the micro level. Furthermore, quantifying certain risks is also difficult without the appropriate data. For the purposes of this project, the TCO model will be developed based on the dollar based approach due to ease of applicability and understanding.

5.2 AHP and Supplier Selection

There have been many studies addressing the supplier selection problem throughout the literature. These studies touch on various qualitative and quantitative criteria to effectively select, evaluate, and measure suppliers. They also utilize different MCDM techniques to facilitate the decision making process. The sections below will touch on a few of these studies by assessing the supplier selection criteria, as well as the various techniques that have been used to address this problem.

5.2.1 Supplier Selection Criteria

Identifying the criteria and sub-criteria required to assess a supplier is one of the most important steps when applying any MCDM technique. It is imperative to ensure that the various criteria will support company objectives in order to select a strategic supplier. Supplier selection criteria have been studied since the late 1960's (Weber et al., 1991). Weber et al. (1991) conducted a review of 74 articles within the literature since the Dickson (1966) study in order to provide a comprehensive view of the criteria that researchers and purchasing practitioners feel are important in the supplier selection decision. The criteria discussed throughout these 74 articles are shown in Table 5.

Table 5 – Criteria Findings in Weber et al. (1991) Study

Supplier Selection Criteria		
▪ Net price	▪ Delivery	▪ Quality
▪ Production facilities and capacity	▪ Geographic location	▪ Technical capability
▪ Management and organization	▪ Reputation and position in industry	▪ Financial position
▪ Performance history	▪ Repair service	▪ Attitude
▪ Packaging ability	▪ Operational controls	▪ Training aids
▪ Bidding procedural compliance	▪ Labor relations record	▪ Communication system
▪ Reciprocal arrangements	▪ Impression	▪ Desire for business
▪ Amount of past business	▪ Warranties and claims	

Later studies have also disaggregated some of these criteria into sub-criteria. Choi and Hartley (1996) disaggregated quality, time, flexibility and relationship into various sub-criteria. Barbarosoglu and Yazgac (1997) also touch on numerous criteria, sub-criteria, sub-sub criteria and even sub-sub-sub criteria by disaggregating the performance assessment, business structure and manufacturing capability assessment, and quality system assessment criteria. Moreover, Sarkis and Talluri (2002) compiled strategic criteria and sub-criteria based on the Choi and Hartley (1996) and Barbarosoglu and Yazgac (1997) studies, as well as the Ellram (1990) study which discusses culture as an important supplier selection criterion. Kannan and Tan (2002) have also compiled the various criteria mentioned in the literature; however, they divided these criteria into two groups; selection criteria and assessment criteria.

5.2.2 Multiple-Criteria Decision Making Techniques

There have been several MCDM techniques studied and applied to the supplier selection problem. These range from simple weighting techniques to complex simulation and programming techniques. Hybrid techniques, where two or more methods are applied concurrently, have also been studied.

A simulation optimization methodology for the supplier selection problem was proposed by Ding et al. (2005). This methodology was composed on a genetic algorithm (GA) optimizer for supplier selection decision, a discrete event simulator for operational performance evaluation, and a supply chain modeling framework. Hong et al. (2005) presented a mathematical programming model that considers the change in suppliers' supply capabilities and customer needs over a period of time which not only maximizes revenue but also satisfies customer needs. PROMETHEE and Geometrical Analysis for Interactive Assistance GAIA) techniques were applied to the supplier selection problem by Dulmin and Mininno (2003) to rank alternatives and to analyze the relations between criteria.

Ng (2008) presented a linear optimization model for the supplier selection problem which retains the advantages of data envelopment analysis (DEA) non-parametric approach. Additionally, the proposed model reduces the subjective element, in comparison with the analytic hierarchy process (AHP) and multi-objective optimization (MOP) models, from the decision maker's role. There have also been numerous fuzzy approaches to the supplier selection problem. Chen et al. (2006) presented a fuzzy decision making approach by extending the technique for order performance by similarity to ideal solution (TOPSIS) to solve supplier selection problems in a fuzzy environment. Furthermore, Amid et al. (2006) developed a fuzzy multiobjective linear

model to overcome the vagueness of the goals, constraints, and parameters in the supplier selection problem.

Perhaps one of the most popular methods that has been used to address this problem is the AHP method. AHP was developed by Saaty (1980) and has aroused considerable interest in practitioners and researchers in recent years (Muralidharan et al., 2002). It is a simple and straightforward method that has been applied to the supplier selection problem by various researchers (Muralidharan et al., 2002; Barbarosoglu and Yazgac, 1997; Nydick and Hill, 1992; Cheung et al., 2001; Tahriri et al., 2008; Chan, 2003; Liu and Hai, 2005). The Analytic Network Process (ANP), which is a generalization of the AHP, can be used to treat more sophisticated decision problems than the AHP. This method has also been applied to the supplier selection problem by a number of researchers and practioners (Saaty, 1996; Sarkis and Talluri, 2002; Bayazit, 2006; Gencer and Gurpinar, 2007).

Xia and Wu (2007) presented an integrated approach of the AHP that included rough set theory and multi-objective mixed integer programming to simultaneously determine the number of suppliers to employ and the order quantity allocated to these suppliers. This model was designed with multiple sourcing, products, and criteria, taking into account the supplier's capacity constraints. Similarly, an integrated AHP and linear programming model was used to develop a decision support system for supplier selection by Ghodsypour and O'Brien (1998). Shyur and Shih (2006) proposed a hybrid MCDM model utilizing ANP, TOPSIS and the nominal group technique (NGT) for strategic supplier selection.

For the purpose of this project, a hybrid approach utilizing TCO incorporated into an AHP framework will be used for its precise assessment of values through hierarchical structuring and pair-wise comparison. Bhutta and Huq (2002) conducted a comparison study between TCO and AHP for supplier selection but did not consider the possibilities from merging both techniques. Furthermore, an approach similar to the one developed in this project has been developed by Ramanathan (2007). However, a more sophisticated methodology utilizing data envelope analysis (DEA) was used to combine the results of TCO and AHP. The method proposed in this project will incorporate the TCO model as a criterion within the AHP hierarchical structure which will prove to be a simpler methodology in comparison to the DEA approach. AHP has found widespread application in MCDM problems including the supplier selection problem. This method has the ability to structure complex, multi-participant, multi-criteria problems hierarchically to reduce the number of pairwise comparisons at each level (Yahya and Kingsman, 1999). This method can also be easily understood and applied to real world problems in a timely manner.

6.0 Total Cost of Ownership

6.1 Overview

TCO is a methodology and philosophy which provides a comprehensive cost assessment by considering the various costs incurred throughout the supply chain and not just the purchase cost. This approach has become increasingly important for organizations in order to better understand and manage their costs (Bhutta and Huq, 2002). Therefore, TCO contributes towards achieving cost transparency within an organization, as well as supplier selection and evaluation (Ellram, 1995; Bremen et al. 2007; Bhutta and Huq, 2002).

6.2 TCO Barriers and Requirements for Successful Adoption

Total cost of ownership is a straightforward method which consists of identifying all costs related to acquiring an item. These can be determined by following the end-to-end process from creating a purchase order to receiving product into the distribution centre. However, there are complexities associated with TCO which may limit its adoption. One of the major barriers to adopting TCO is the lack of readily available accounting and costing data in many organizations. Also, there's no standard approach to TCO analysis as shown in the literature review. There are many models and methods to implement TCO. Furthermore, it requires a cultural change from focusing on the price of an item to adopting a total cost understanding (Ellram, 1995; Bremen et al. 2007). This education and shift in thinking must be implemented corporate wide, as well as externally. Suppliers must give their customers visibility to the various costs associated with the cost of goods. Moreover, lack of understanding of TCO can be very costly to the firm. Poor decisions will likely result, hurting the firm's overall competitiveness, profitability, pricing decisions and product mix strategies (Ellram, 1995).

Organizations interested in adopting a TCO approach need to overcome the various barriers that can be encountered. This might be more difficult for certain organizations more than others. If a company has solid accounting and costing data readily available, it would be much easier to adopt TCO versus organizations that do not have these key elements. Wouters et al. (2005) hypothesized a structural model for successful TCO adoption which included customer market pressure, top management support, purchasing orientation, functional management commitment, value analysis experience, information adequacy, past TCO initiative success and TCO based review and reward. The study stresses the importance of these factors and the relationships between them for successful TCO adoption. The authors suggest that top management will only support the introduction and adoption of TCO models for sourcing decisions when purchasing has

become a strategic and truly cross-functional process in response to customer market conditions. Furthermore, the study demonstrates the importance of value analysis experience for TCO adoption. Value analysis experience leads to the improvement of TCO information and success of TCO initiatives for sourcing decisions.

6.3 Benefits of TCO

The implementation of a total cost of ownership process provides many benefits to both the supplier and the retailer. TCO provides a consistent supplier evaluation tool, improving the value of supplier performance comparisons among suppliers and over time (Bremen et al., 2007; Ellram, 1995, Degraeve et al., 2005). It also helps clarify and define supplier performance expectations both in the firm and for the supplier. Moreover, it provides a focus and sets priorities regarding the areas in which supplier performance would be most beneficial (supports continuous improvement), creating major opportunities for cost savings. By utilizing TCO, purchasers improve their understanding of supplier performance issues and cost structure. Furthermore, it provides excellent data for negotiations (Ellram, 1995; Degraeve et al., 2005) and helps to justify higher initial prices based on better quality and lower total costs in the long run.

TCO analysis provides valuable data for improving supplier performance, focusing on and negotiating the cost and performance issues that are of most value to the company, and monitoring supplier performance over time (Ellram, 1995). It also supports the strategic role of purchasing by stimulating interdepartmental interaction (Degraeve et al., 2005). One of the major benefits of TCO is the achievement of cost transparency which makes it possible to choose low cost supplier as opposed to low price suppliers (Bremen et al., 2007).

7.0 The Analytic Hierarchy Process

7.1 Overview

The AHP method was developed by Saaty (1980) and can be defined as a theory of measurement through pairwise comparisons that relies on the judgments of experts to derive priority scales (Saaty, 2008). It is a robust technique that allows decision makers to determine preference of criteria for selection and evaluation purposes, as well as quantify those preferences (Sarkis and Talluri, 2002). The AHP also allows financial and nonfinancial quantitative and qualitative measures to be considered and trade-offs among them to be addressed (Rangone, 1996). This method has the ability to restructure complex problems in the form of a simple hierarchy by creating levels to reduce the number of pairwise comparisons. The levels of hierarchy describe an MCDM problem from the lowest level which is the set of alternatives, through the intermediate level which consist of criteria and sub-criteria, to the highest level of achieving the overall goal of the decision problem (Liu and Hai, 2005). The AHP is ideally suited for the supplier selection problem because it offers a methodology to rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each alternative (Nydick and Hill, 1992).

7.2 Methodology

The AHP methodology includes the following steps:

Step 1 – Define and understand the problem

Step 2 - Develop a hierarchical structure for the decision problem in terms of overall objective, criteria, sub-criteria and decision alternatives (see Figure 8).

Step 3 – Identify an appropriate scale to prioritize pairwise comparisons of criteria and sub-criteria to identify the intensity of the preferred criteria or sub-criteria.

Step 4 – Create a questionnaire or survey to be sent to the stakeholders where they would identify criteria and sub-criteria preferences based on pairwise comparisons, as well as the degree of preference utilizing the scale identified in step 3.

Step 5 - Determine the local priorities of criteria and sub-criteria based on stakeholder preferences and the degree of importance

Step 6 – Obtain the global priorities by multiplying the criteria local priority weights by the sub-criteria local priority weights

Step 7 – Conduct pairwise comparisons of the various alternatives with respect to the sub-criteria to determine the local priorities of the alternatives

Step 8 - Calculate the overall ratings of the decision alternatives, weighting the suitability ratings with the relative priorities of criteria and sub-criteria.

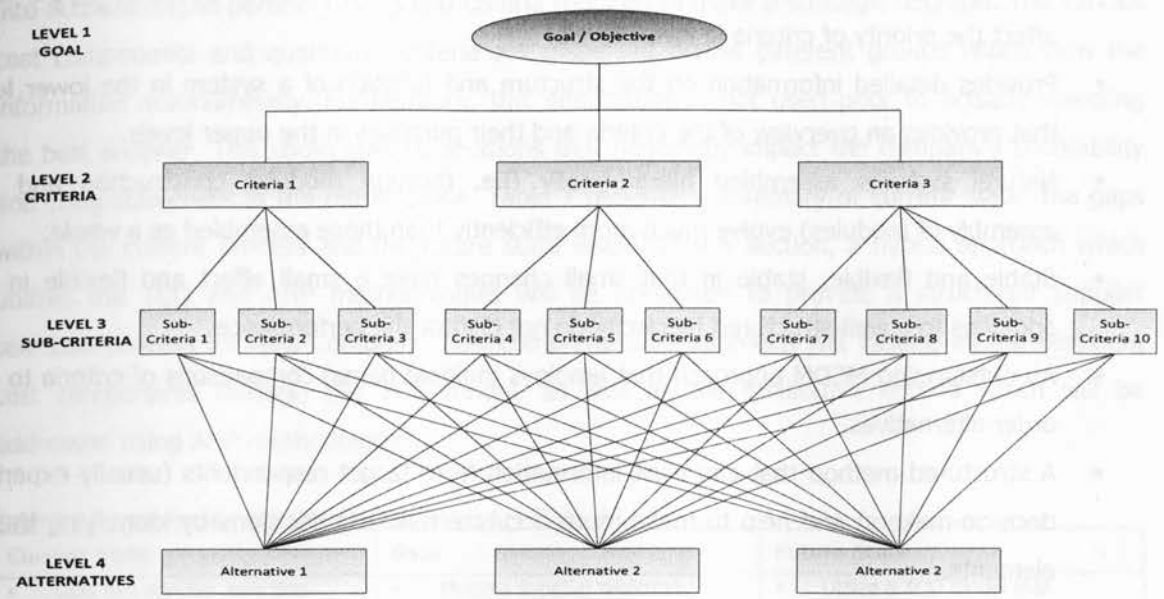


Figure 8 - The hierarchical structure of a decision problem

To make comparisons, a scale of numbers is needed that indicates how much more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared (Saaty, 2008). Table 6 below illustrates the fundamental scale for pairwise comparisons.

Table 6 – Fundamental scale for pairwise comparisons

Intensity of Importance	Definition	Explanation
1	Equally preferred	Two elements contribute equally to the objective
3	Moderately preferred	Experience and judgment slightly favor one element over another
5	Strongly preferred	Experience and judgment strongly favor one element over another
7	Very Strongly preferred	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extremely preferred	The evidence favoring one element over another is of the highest possible order of affirmation
2, 4, 6, and 8	Intermediate values between two adjacent judgments	

7.3 Benefits of AHP

Chan (2003) has identified the following advantages to the AHP method:

- Hierarchical representation of a system that describes how changes in priority at upper levels affect the priority of criteria in lower levels.
- Provides detailed information on the structure and function of a system in the lower levels that provides an overview of the criteria and their purposes in the upper levels.
- Natural systems assembled hierarchically (i.e. through modular construction and final assembly of modules) evolve much more efficiently than those assembled as a whole.
- Stable and flexible, stable in that small changes have a small effect and flexible in that additions to a well-structured hierarchy do not disrupt the performance.
- An outstanding MCDM approach that employs multiple paired comparisons of criteria to rank order alternatives.
- A structured method that can elicit information from target respondents (usually experts or decision-makers) and help to make more accurate business decisions by identifying the key elements.
- Selection criteria in the hierarchy can best represent the desired supplier's performance.

7.4 Pitfalls of AHP

Chan (2003) has also identified the following disadvantages to the AHP method:

- Potentially time consuming due to required consensus among team members.
- No single hierarchy for most supplier selection problems.
- Heavily based on the principle that experience, knowledge, and judgment of decision-makers are at least as valuable as the data they use. Human judgment, however, is always subjective and has bias towards individual thought processes.
- Ineffective at taking into account risk and uncertainty assessing potential supplier performance because it presumes that the relative importance of criteria affecting supplier's performance is known with certainty.
- The characteristic property of AHP that it is fully compensatory might not always be realistic. In addition, it might be costly to obtain the necessary information since the assumption of comparability is not always valid due to lack of information or unwillingness to compare two alternatives with respect to some criterion.

8.0 Future State Model

The current supplier selection process within ABC Company is not structured and does not take into account all the pertinent costs and criteria required to make a strategic decision. The various cost components and qualitative criteria are dispersed across different groups which view the information autonomously. Furthermore, this information is not used prior to actually selecting the best supplier. This could lead to decisions that negatively impact the company's profitability and competitiveness in the marketplace. Table 7 provides a summary of current state, the gaps within the current process and the future state vision. In this section, a hybrid approach which utilizes the TCO and AHP methodologies will be presented to provide a structured supplier selection process for ABC Company. This comprehensive approach will include all the pertinent cost components through the TCO model, as well as the qualitative criteria which will be addressed using AHP methodology.

Table 7 – Current Supplier Selection Findings and Future State Vision

Current State	Gaps	Future State
▪ Only two supplier selection criteria taken into consideration (i.e. MOQ, Landed Cost) ▪ Landed cost heavily weighted ▪ Cost components are decentralized ▪ Certain cost components are not incorporated into the item cost (e.g. DC and Opportunity Costs) ▪ Costing team adds cost components to item when it's being listed in system (i.e. after it has been sourced)	▪ Multiple supplier selection criteria must be taken into consideration when selecting the best supplier ▪ Determine criteria weights using formal methodology ▪ Centralize cost components into one document when costing an item ▪ Capture all pertinent cost components ▪ All costs should be taken into consideration prior to sourcing the item	▪ Utilize a TCO model that incorporates all the pertinent cost components associated with an item prior to selecting the vendor partner ▪ Incorporate the TCO model into an AHP framework to assess quantitative and qualitative criteria other than costs

8.1 TCO Model Development

To develop the TCO model, an investigation was carried out to understand all the various cost components associated with offshore and domestic items. This was accomplished by meeting with various stakeholders within ABC Company. These stakeholders include Sourcing, Finance, offshore 3PL, Costing, Customs, Transportation and Supply Chain. As previously mentioned, these costs are currently applied to the item at different points within the Supply Chain process. Furthermore, the company is being charged certain costs such as the offshore 3PL administrative and freight charges which are incurred outside of the item costing process.

The objective of the TCO model was to ensure that all the costs were understood and captured up front, prior to making the supplier selection decision. The first step was to incorporate the cost matrix used by the Costing team into the quote sheet to capture the various cost

components added to the item once it has been listed in the system. This includes the various freight rates based on the where the item is shipping from and the type of load. Furthermore, since the duty can range anywhere from 2 to 20%, an average duty of 10% has been applied. DC costs and opportunity costs were also considered since they would drastically vary between offshore and domestic items due to the large MOQs and long lead times for offshore.

The model was developed in an Excel spreadsheet, shown in Figure 9, which incorporates costing information from various tabs to calculate administrative and freight costs, as well as exchange rates. The user would need to select the critical information in order to accurately calculate the various cost components. They would first start by selecting the city or origin port from where the product is shipping and the destination DC since this is a key piece of information that would dictate the freight cost. Moreover, the item cube or volume, typical shipment container size and shipment type will affect the 3PL administrative cost, as well as the freight costs for offshore shipments. The 3PL administrative cost is based on the negotiated rate per cubic meter (cbm). This cost is associated with the administrative work required by the 3PL to manage an offshore purchase order. An item can be shipped in a 20, 40, or 40 high cube container. Furthermore, the flow of these containers and the freight costs applied will vary depending on whether the shipment is a CFS/CFS, CFS/CY or CY/CY where CFS stands container freight station and CY is container yard. Domestic item freight costs depend on the terms of sale whether it's backhaul or prepaid. If the item is prepaid then the unit cost will incorporate freight; however, if the item is backhaul then the backhaul rate will be calculated based on average rate from the particular city to the DC.

Other costs that have been applied to the model include offshore brokerage, currency fluctuation surcharge, product development, commission, repiling charges and duty. These are the costs that the Costing group applies to the item when listing it in the system. The offshore brokerage cost is a customs charge of $0.0008 per dollar of unit cost. Since the exchange rate for an offshore item can fluctuate within the lead time, a currency fluctuation surcharge is applied to reflect the fluctuations. Also, a product development charge can apply for both offshore and domestic items. This charge is applied to items that are private label and have been developed by a design house that has partnered with ABC Company for this purpose. A commission of 5% is applied to items that have been sourced through an offshore agent. As previously mentioned, an average duty of 10% is applied to all offshore items. Moreover, a repiling charge is applied to floor loaded items. Repiling charges will vary depending on the destination DC, container size and item cube.

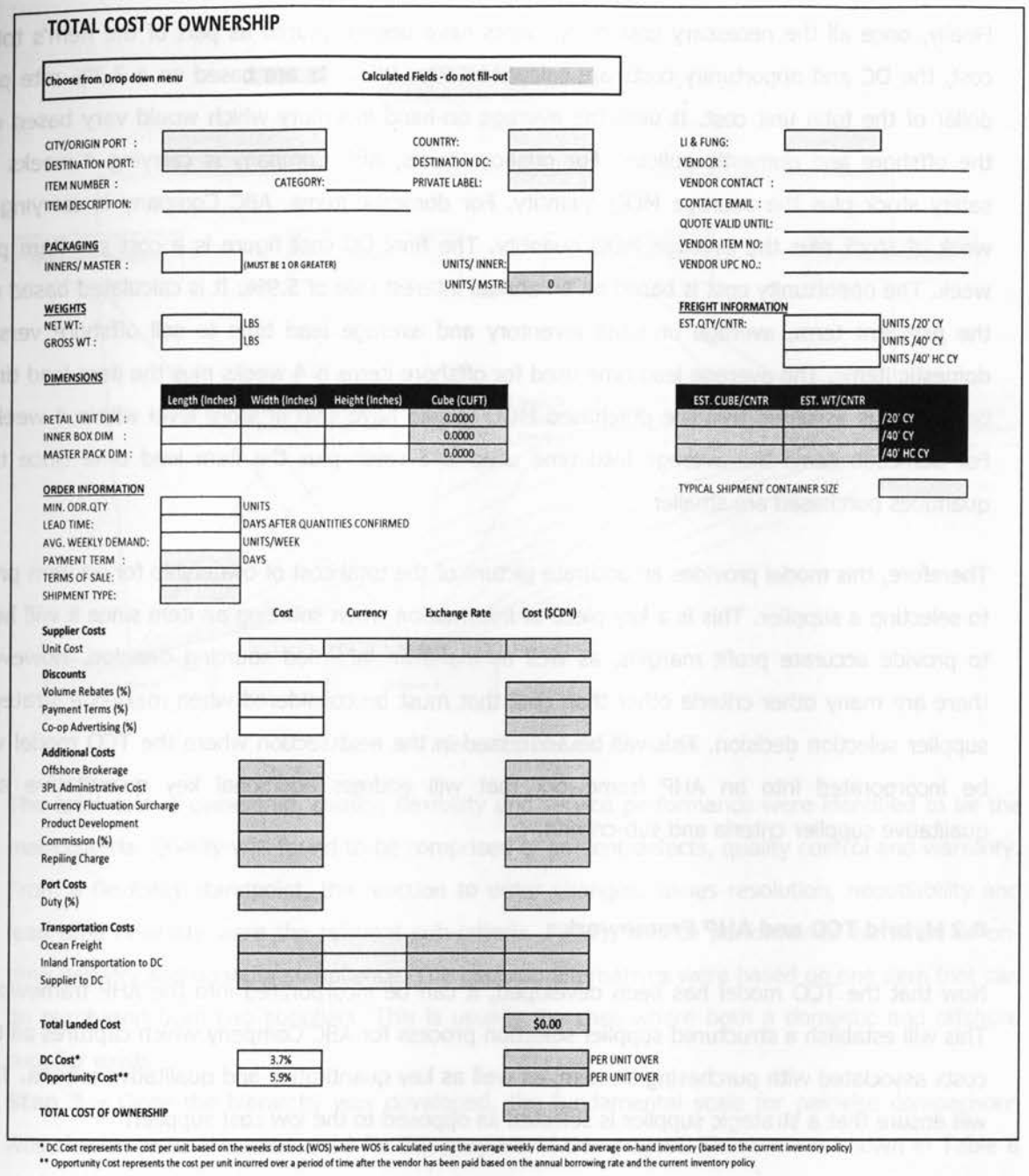


Figure 9 – TCO Model

In addition, the user will also be able to apply various types of discounts that could be offered by a supplier. These discounts include volume rebates, payment terms and co-op advertising. Volume rebates are offered by supplier when the company purchasers over a certain amount of product. Payment term discounts are offered when the company accepts reduced payment terms by the supplier, i.e., going from 60 to 30 days. Discounts associated with co-operative advertising between the company and the supplier can also be applied by using the co-op advertising field.

Finally, once all the necessary cost components have been captured as part of the item's total cost, the DC and opportunity costs are calculated. The DC costs are based on a 3.7% rate per dollar of the total unit cost. It uses the average on-hand inventory which would vary based on the offshore and domestic policies. For offshore items, ABC Company is carrying 4 weeks of safety stock plus the average MOQ quantity. For domestic items, ABC Company is carrying 1 week of stock plus the average MOQ quantity. The final DC cost figure is a cost per item per week. The opportunity cost is based on an annual interest rate of 5.9%. It is calculated based on the payment term, average on-hand inventory and average lead time to sell offshore versus domestic items. The average lead time used for offshore items is 4 weeks plus the item lead time because it is assumed that the purchased MOQ should have sold at store level within 4 weeks. For domestic items the average lead time used is 1 week plus the item lead time since the quantities purchased are smaller.

Therefore, this model provides an accurate picture of the total cost of ownership for an item prior to selecting a supplier. This is a key piece of information when sourcing an item since it will help to provide accurate profit margins, as well as make an informed sourcing decision. However, there are many other criteria other than cost that must be considered when making a strategic supplier selection decision. This will be addressed in the next section where the TCO model will be incorporated into an AHP framework that will address additional key quantitative and qualitative supplier criteria and sub-criteria.

8.2 Hybrid TCO and AHP Framework

Now that the TCO model has been developed, it can be incorporated into the AHP framework. This will establish a structured supplier selection process for ABC Company which captures all the costs associated with purchasing an item, as well as key quantitative and qualitative criteria. This will ensure that a strategic supplier is selected as opposed to the low cost supplier.

8.2.1 Methodology

Step 1 – A need was identified to structure the supplier selection decision process to ensure that suppliers are selected strategically based on all the pertinent criteria and sub-criteria.

Step 2 - A hierarchical structure was developed for the supplier selection problem in terms of overall objective, criteria, sub-criteria and decision alternatives. This hierarchy is shown in Figure 10. The objective was to select the best supplier. The criteria and sub-criteria were determined through literature review, as well as interviews with the stakeholders.

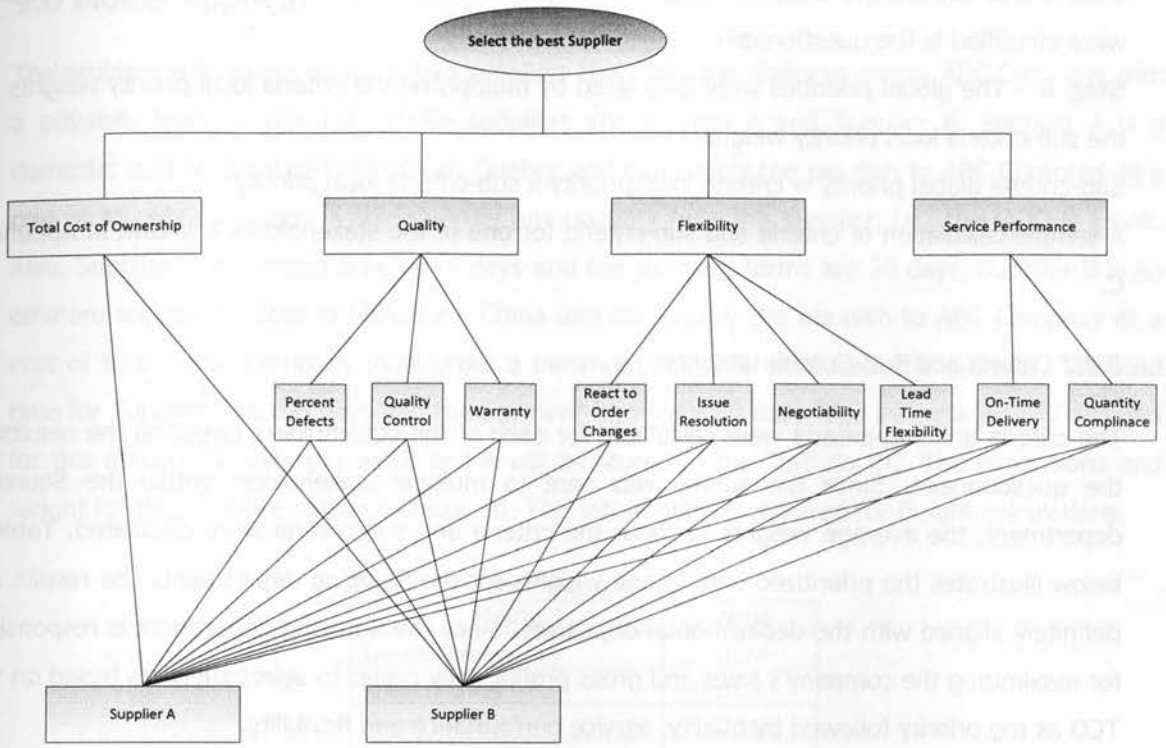


Figure 10 – Hybrid TCO and AHP Framework

The total cost of ownership, quality, flexibility and service performance were identified to be the main criteria. Quality was found to be comprised of percent defects, quality control and warranty. From a flexibility standpoint, the reaction to order changes, issues resolution, negotiability and lead time flexibility were the relevant sub-criteria. Finally, service performance consisted of on-time delivery and quantity compliance. The decision alternatives were based on one item that can be purchased from two suppliers. This is usually the case where both a domestic and offshore supplier exists.

Step 3 – Once the hierarchy was developed, the fundamental scale for pairwise comparisons was chosen to be the scale used for the purpose of this project. This scale is shown in Table 6 and will be used to identify preferences based on pairwise comparisons of criteria and sub-criteria.

Step 4 – A questionnaire containing the various criteria and sub-criteria comparisons was created and sent to the stakeholders from the Sourcing department. This questionnaire is shown in Appendix B. The questionnaire required the stakeholder to conduct pairwise comparisons between option A and option B. The user would select the preferred criteria or sub-criteria as well as the intensity, based on the fundamental scale of pairwise comparison, associated with the preference from a drop down menu within the questionnaire.

Step 5 – A hidden tab within the questionnaire was developed to determine the local priorities of criteria and sub-criteria based on stakeholder preferences and the degree of importance that were identified in the questionnaire.

Step 6 – The global priorities were calculated by multiplying the criteria local priority weights by the sub-criteria local priority weights.

Sub-criteria global priority = criteria local priority x sub-criteria local priority

A sample calculation of criteria and sub-criteria for one of the stakeholders is shown in Appendix C.

8.2.2 Criteria and Sub-Criteria Weights

The criteria and sub-criteria were calculated for each of the stakeholders based on the results of the questionnaire. Since the survey was sent to multiple stakeholders within the Sourcing department, the average weights for both the criteria and sub-criteria were calculated. Table 8 below illustrates the prioritized criteria and weights for the Sourcing department. The results are definitely aligned with the departmental objectives. Since the Sourcing department is responsible for maximizing the company's sales and gross profits, they prefer to select suppliers based on the TCO as top priority followed by quality, service performance and flexibility.

Table 8 –Prioritized Criteria

Rank	Criteria	Local Priorities
1	Total Cost of Ownership	0.410
2	Quality	0.334
3	Service Performance	0.164
4	Flexibility	0.092

The ranked sub-criteria and weights are shown in Table 9. The sub-criteria weights and priorities are inline with the aggregated criteria. The top three sub-criteria were found to be quality control, on-time delivery and percent defects.

Table 9 –Prioritized Sub-Criteria

Rank	Sub-Criteria	Global Priorities
1	Quality Control	0.165
2	On-Time Delivery	0.130
3	Percent Defects	0.093
4	Warranty	0.076
5	Issue Resolution	0.044
6	Quantity Compliance	0.035
7	Negotiability	0.022
8	React to Order Changes	0.018
9	Lead-Time Flexibility	0.008

9.0 Model Application

The problem is to select between two suppliers that have the ability to supply ABC Company with a privately branded pie dish. These suppliers are Supplier A and Supplier B. Supplier A is a domestic supplier located in Montreal, Quebec and can supply the pie dish to ABC Company at a cost of $5. ABC Company is able to order any quantity from this supplier, i.e., the MOQ is 1 unit. Also, Supplier A has a lead time of 14 days and the payment terms are 30 days. Supplier B is an offshore supplier located in Shenzhen, China and can supply the pie dish to ABC Company at a cost of $3.67. ABC Company must order a minimum of 2,000 units from this supplier. The lead time for Supplier B is 100 days and the payment terms are 60 days. The average weekly demand for this item is 20 units per week and it will be stored in the Toronto DC. The dimensions and weight for this item are shown in Table 10. This information is required for freight calculations.

Table 10 –Pie dish Dimensions

Metric	Value
Length (inches)	10.24
Width (inches)	10.24
Height (inches)	2.28
Weight (kgs)	5.9

The first step in utilizing the hybrid model is to determine the TCO for both scenarios. This was accomplished by inputting the information above into the TCO spreadsheet Therefore, the total landed cost for the pie dish from Supplier A was found to be $5.46 and $4.95 from Supplier B. It can be seen that the difference in price has been reduced from $1.33 to $0.51 once all the cost components have been considered. This amounts to a 62% reduction in the perceived profitability difference. Furthermore, the DC costs were found to be $0.21 per unit based on the average weeks of stock (WOS) when the pie dish is supplied by Supplier A and $9.89 per unit per average WOS when the pie dish is supplied, by Supplier B. There is a substantial difference in the DC costs due to the large MOQ that must be ordered from Supplier B. Considering Supplier B's MOQ and the average weekly demand for this item, ABC Company would be holding 54 weeks of stock at any given time based on the safety stock policy plus average inventory. Moreover, there were no opportunity costs incurred when the item was sourced from Supplier A due to the short lead; however, the opportunity costs incurred when the item was sourced from Supplier B amounted to $0.33 per unit incurred over a period of time after the vendor has been paid based on the annual borrowing rate of 5.9% and the current inventory policy. Therefore, the TCO for suppliers A and B are $5.66 and $15.17, respectively. These results are shown in Table 11. Although supplier B is able to supply the product at a lower price, the DC and opportunity costs that will be incurred by sourcing from this supplier will drastically reduce the perceived profit

margins. Historically, this might have been an easy decision for ABC Company whereby Supplier B would have been selected. However, by considering the TCO, Supplier A would be the best choice.

Table 11 – Summary of TCO Results

Costs	Supplier A	Supplier B	Difference
Price	$5.00	$3.67	$1.33
Total Landed Cost	$5.46	$4.95	$0.51
DC Costs	$0.21	$9.89	-$9.68
Opportunity Costs	$0.00	$0.33	-$0.33
Total Cost of Ownership	**$5.66**	**$15.17**	**$9.51**

Furthermore, since cost is not the only criteria associated with selecting a strategic supplier, the AHP method will be applied to consider other key quantitative and qualitative criteria. This requires the user to gather additional information about the supplier with regards to quality, service performance and flexibility.

With regards to quality control, Supplier A utilizes total quality management (TQM) and ISO9000 quality practices and has historically shown a 2% defect rate. Additionally, a 6 month warranty is offered for each pie dish. The on-time delivery and quantity compliance for this supplier are 96% and 98%, respectively. On the other hand, Supplier B conducts random inspections off the production line and has historically shown a 3% defect rate on similar products. Moreover, a 1 year warranty is offered on all pie dishes. The on-time delivery and quantity compliance for Supplier B are 90% and 98%, respectively. The details for both suppliers are shown in Table 12.

Table 12 – Supplier Performance

	Supplier A	Supplier B
Total Cost of Ownership	$5.66	$15.17
Percent Defects	2%	3%
Quality Control	TQM, ISO9000	Sample inspection
Warranty	6 month	1 year
Lead-Time Flexibility	Domestic	Offshore
On-Time Delivery	96%	90%
Quantity Compliance	98%	98%

To effectively select the best supplier, pairwise comparisons of both suppliers with respect to the sub-criteria were conducted to determine the local priorities. This process is similar to the AHP methodology used to determine the criteria and sub-criteria weights. This was achieved by sending a questionnaire, which contained the supplier details shown in Table 12, to the various stakeholders. This questionnaire can be found in Appendix D. The stakeholders would select their

preferred supplier with respect to each criterion or sub-criteria. The final list of criteria and sub-criteria are shown in Table 13.

Table 13 – Final Criteria and Sub-Criteria

Rank	Criteria	Global Priorities
1	Total Cost of Ownership	0.410
2	Quality Control	0.165
3	On-Time Delivery	0.130
4	Percent Defects	0.093
5	Warranty	0.076
6	Issue Resolution	0.044
7	Quantity Compliance	0.035
8	Negotiability	0.022
9	React to Order Changes	0.018
10	Lead-Time Flexibility	0.008

Since numerous stakeholders were consulted, the average weights resulting from the questionnaires were calculated. A sample calculation of the supplier weights with respect to each sub-criterion can be found in Appendix E. Finally, the overall score of the suppliers were calculated by multiplying the supplier weights with respect to each criterion by the global priorities that were previously calculated for each group. The formula is as follows:

Supplier Score = $\sum_{i}^{n} w_i A_{ij}$

where

w_i = the weight of criteria I;

n = the number of criteria;

A_{ij} = the weight of criteria i with respect to alternative j.

The final decision resulted in Supplier A having the highest score. Therefore, ABC Company should choose Supplier A as their strategic supplier to supply them with the pie dish. The results are shown in Table 14. These results will be discussed further in the next section.

Table 14 –Supplier Scores

SUPPLIER A	SUPPLIER B
0.73	0.27

10.0 Conclusion and Future Considerations

According to the current supplier selection process, ABC Company would have chosen the offshore Supplier B due to the perceived low cost of $3.67 per unit. However, by utilizing the TCO model and considering all costs associated with purchasing the item, the domestic Supplier A is the preferred supplier. The initial landed cost difference between the suppliers was $1.33 but was later found to be $0.51. Furthermore, the DC and opportunity costs for Supplier B were significantly greater than Supplier A which resulted in a much higher TCO for Supplier B. This was a result of the high MOQ, long lead time, demand, and payment terms. In order to reduce the DC costs for Supplier B, the MOQ would need to be reduced and the average weekly demand would need to be increased. Hence, low demand items with high offshore MOQs should be sourced domestically. Moreover, since there is not much room to reduce the lead time, increasing the number of days to pay the supplier would result in a decrease of opportunity costs. Therefore, the TCO model can be used as a tool to improve negotiations with suppliers, as well as provide insight into sourcing decisions based on various parameters. The company will be able to assess the various costs to determine which policies need to be renegotiated to improve profitability and reduce costs.

Additionally, Supplier A was preferred over Supplier B with respect to the majority of supplier selection criteria and sub-criteria. This was based on the preferences of the Sourcing department. These preferences take into consideration ABC Company's supply chain capabilities, as well as supplier capabilities. Offshore sourcing business capabilities such as efficient global structures and processes are required to effectively manage offshore purchasing (Petersen et al., 2000). The capabilities will be reflected in the various criteria and sub-criteria. In the case of ABC Company, it is evident that their global sourcing capabilities are not as efficient as their domestic capabilities. This translates into lower service levels and flexibility. Offshore sourcing requires close collaboration between all stakeholders in order to reduce the associated risks and hidden costs. If a company has efficient global sourcing capabilities, both domestic and offshore metrics would be similar, and the attitudes of the stakeholders would be captured when determining the weights. Therefore, this model provides a valuable tool for companies selecting strategic suppliers as opposed to low cost suppliers. Furthermore, it can help companies evaluate their suppliers, as well as provide pertinent information for supplier negotiations. Additionally, the company will be able to assess how certain variables impact supplier selection which can be used to determine optimal ordering strategies. For example, if an item is seasonal where demand is very high at a certain point in time but eventually drops, the model could recommend an offshore

supplier during the high season but, when demand drops, it would recommend a domestic supplier. Therefore, a hybrid purchasing strategy would be implemented for this item.

However, there are some limitations associated with this model. It is heavily based on the attitudes, experience, knowledge and judgment of the decision makers. This methodology is also ineffective at taking into account risk and uncertainty. In addition, the lack of readily available accounting and costing data in many organizations poses a problem when adopting TCO. Furthermore, it requires a cultural change from focusing on the price of an item to adopting a total cost understanding (Ellram, 1995; Bremen et al. 2007). Future enhancements to the model proposed in this project would include the quantification of risks and hidden costs. These costs can be incorporated into the TCO model. Although they are uncertain and vary on a case by case basis, they can prove to be valuable when determining which risks have the highest impact on profitability. Furthermore, environmental impacts of sourcing decisions can also be incorporated into the model to help companies choose ordering strategies that are better for the environment.

References

Amid, A., Ghodsypour, S.H. and O'Brien, C. (2006). Fuzzy multiobjective linear model for supplier selection in a supply chain. *International Journal of Production Economics.* 104(2), 394-407.

Barbarosoglu, G. and Yazgac, T. (1997). An application of the analytic hierarchy process to the supplier selection problem. *Production and Inventory Management Journal,* 38(1), 14-21.

Basu, K. (1999). Child labor: Cause, consequence, and cure, with remarks on international labor standards. *Journal of Economic Literature,* 37(3), 1083-1119.

Bayazit, O. (2006). Use of analytic network process in vendor selection decisions. *Benchmarking: An International Journal,* 13(5), 566-579.

Bhutta, K. S. and Huq, F. (2002). Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches. *Supply Chain Management: An International Journal,* 7(3), 126-135.

Bremen, P., Oehmen, J., & Alard, R.(2007). Cost-transparent sourcing in China applying total cost of ownership. *Industrial Engineering and Engineering Management,* 2(4), 262 – 266.

Chan, F. T. S. (2003). Interactive selection model for supplier selection process: an analytical hierarchy process approach. *International Journal of Production Research,* 41(15), 3549 – 3579.

Chen, C., Lin, C. and Huang, S. (2006). Fuzzy approach for supplier evaluation and selection in supply chain management. *International Journal of Production Economics,* 102(2), 289-301.

Cheung, S., Lam, T., Leung, M. and Wan, Y. (2001). An analytical hierarchy process based procurement selection method. *Construction Management and Economics,* 19(4), 427–437.

Choi, T. Y. and Hartley, J. L. (1996). An exploration of supplier selection practices across the supply chain. *Journal of Operations Management,* 14(4), 333-343.

Degraeve, Z, Roodhooft, F. & van Doveren, B. (2005). The use of total cost of ownership for strategic procurement: a company-wide management information system. *Journal of the Operational Research Society,* 56(1), 51–59.

Degraeve, Z., Roodhooft, F. (1999a). Effectively selecting suppliers using total cost of ownership. *Journal of Supply Chain Management,* 35(1), 5-10.

Degraeve, Z., Roodhooft, F. (1999b). Improving the efficiency of the purchasing process using total cost of ownership information: The case of heating electrodes at Cockerill Sambre S.A. *European Journal of Operational Research,* 112(1), 42-53.

Dickson, G.W. (1966). An analysis of vendor selection systems and decisions. *Journal of Purchasing,* 2(1), 5-17.

Ding, H., Benyoucef, L., and Xie, X. (2005). A simulation optimization methodology for supplier selection problem. *International Journal of Computer Integrated Manufacturing,* 18(2 & 3), 210 – 224.

Wall, M. and Heslop, L.A. (1986). Consumer Attitudes Toward Canadian-Made Versus Imported Products. *Journal of the Academy of Marketing Science*, 14(27), 27–36.

Weber, C. A., Current, J. R. and Benton, W.C. (1991). Vendor selection criteria and methods. *European Journal of Operational Research*, 50(1), 2 - 18.

Wouters, M., Anderson, J. C., & Wynstra, F. (2005). The adoption of total cost of ownership for sourcing decisions—a structural equations analysis. *Accounting, Organizations and Society*, 30(2), 167–191.

Xia, W. and Wu, Z. (2007). Supplier selection with multiple criteria in volume discount environments. *Omega*, 35(5), 494-504.

Yahya, S. and Kingsman, B. (1999). Vendor rating for an entrepreneur development programme: a case study using the analytic hierarchy process method. *Journal of the Operational Research Society*, 50(9), 916-930.

Appendices

Appendix A – Sample of Current Quote Sheet

DATE : 4-Mar-09				EXCHANGE RATE : 1.15				
PLEASE FILL IN ALL CELLS HIGHLIGHTED IN GOLD. PLEASE DO NOT EDIT ANY OTHER CELLS						PAGE:		
FOB PORT : ningbo	FOB COUNTRY : china			QUOTE VALID UNTIL:		(MM/ DD/ YY)		
PRODUCT # :				VENDOR ITEM NO:				
CATEGORY MANAGER :					VENDOR UPC NO.:			
VENDOR :					MIN. ODR.QTY	25,000	UNITS	
VENDOR CONTACT :					EST.QTY/ CNTR:	3,200	UNITS / 20' CY	
CONTACT EMAIL :						7,680	UNITS / 40' CY	
						11,520	UNITS / 40' HC CY	
INNERS/ MASTER : 1	(MUST BE 1 OR GREATER)			UNITS/ INNER : 20				
	Length	Width	Height	UNITS/ MSTR : 20	EST. CUBE/ CNTR	EST. WT/ CNTR		
RETAIL UNIT DIM :	4.000	4.000	13.500 inches		377.60	1200.00	/20' CY	
INNER BOX DIM :	0.000	0.000	0.000 inches		906.24	2880.00	/40' CY	
MASTER PACK DIM :	19.290	15.350	13.780 inches	CUBE : 2.36 CUFT	1359.36	4320.00	/40' HC CY	
NET WT : 0.00	LBS			GROSS WT : 7.50	LBS			
LEAD TIME :	DAYS AFTER QUANTITIES CONFIRMED			PAYMENT TERM :				

FOB COST (USD)			$0.84 / UNIT	
DUTY	:	3%	$0.03	
CANADIAN TARIFF NO.	:	0000.00.00.00		
INLAND FREIGHT / 40' CY	:	$0.00	$0.00	
OCEAN FREIGHT / 40' CY	:	$3.09	$0.36	
COMMISSION	:	5%	$0.04	
ROYALTIES	:	0%	$0.00	
EST.LANDED COST (USD)	:		$1.27	EST. LANDED COST (CDN) : $1.46

PACKAGING :

ITEM DESCRIPTION:

PLACE PICTURE OF ITEM HERE

VENDOR COMMENTS:

NOTATIONS:

Landed costs are estimated only. The category manager is responsible to follow up for the specific verification of duty and freight, please contact your offshore procurement manager for this verification.

Appendix B – Supplier Criteria Questionnaire

Name: _____ (Optional)

Date: _____

SUPPLIER SELECTION CRITERIA PREFERENCE QUESTIONNAIRE

The Fundamental Scale for Pairwise Comparisons

Intensity of Importance	Definition	Explanation
1	Equally preferred	Two elements contribute equaly to the objective
3	Moderately preferred	Experience and judgement slightly favor one element over another
5	Strongly preferred	Experience and judgement strongly favor one element over another
7	Very Strongly preferred	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extremely preferred	The evidence favoring one element over another is of the highest possible order of affirmation
2, 4, 6, and 8	Intermediate values between two adjacent judgements	

In the tables below, please specify your preference between criteria A or criteria B in the "More Important" column using the drop down menu. Once you have specified which criteria is preferred, use the drop down menu in the "Intensity" column to select a level based on the table above.

Criteria		More Important	Intensity
A	B		
TCO	Quality		
TCO	Flexibility		
TCO	Service Performance		
Quality	Flexibility		
Quality	Service Performance		
Flexibility	Service Performance		

Quality Sub-Criteria		More Important	Intensity
A	B		
Percent Defects	Quality Control		
Percent Defects	Warranty		
Quality Control	Warranty		

Flexibility Sub-Criteria		More Important	Intensity
A	B		
React to Order Changes	Issue Resolution		
React to Order Changes	Negotiability		
React to Order Changes	Lead-Time Flexibility		
Issue Resolution	Negotiability		
Issue Resolution	Lead-Time Flexibility		
Negotiability	Lead-Time Flexibility		

Service Performance Sub-Criteria		More Important	Intensity
A	B		
On-Time Delivery	Quantity Compliance		

Appendix C – Sample Criteria and Sub-Criteria Calculation

Local Priorities for Criteria

STEP 1

Attributes	TCO	Quality	Flexibility	Service Performance
TCO	1.000	3.000	3.000	3.000
Quality	0.333	1.000	5.000	3.000
Flexibility	0.333	0.200	1.000	0.333
Service Performance	0.333	0.333	3.000	1.000
TOTALS	**2.000**	**4.533**	**12.000**	**7.333**

STEP 2

Attributes	TCO	Quality	Flexibility	Service Performance
TCO	0.500	0.662	0.250	0.409
Quality	0.167	0.221	0.417	0.409
Flexibility	0.167	0.044	0.083	0.045
Service Performance	0.167	0.074	0.250	0.136

STEP 3

Local Priorities
0.455
0.303
0.085
0.157

Local & Global Priorities for Subcriteria

Quality Sub-Criteria

Attributes	Percent Defects	Quality Control	Warranty
Percent Defects	1.000	0.200	3.000
Quality Control	5.000	1.000	5.000
Warranty	0.333	0.200	1.000
TOTALS	**6.333**	**1.400**	**9.000**

Attributes	Percent Defects	Quality Control	Warranty	Local Priorities	Global Priorities
Percent Defects	0.158	0.143	0.333	**0.211**	**0.064**
Quality Control	0.789	0.714	0.556	**0.686**	**0.208**
Warranty	0.053	0.143	0.111	**0.102**	**0.031**
				1.000	**0.303**

Flexibility Sub-Criteria

Attributes	React to Order Changes	Issue Resolution	Negotiability	Lead-Time Flexibility
React to Order Changes	1.000	0.200	3.000	3.000
Issue Resolution	5.000	1.000	3.000	3.000
Negotiability	0.333	0.333	1.000	5.000
Lead-Time Flexibility	0.333	0.333	0.200	1.000
TOTALS	**6.667**	**1.867**	**7.200**	**12.000**

Attributes	React to Order Changes	Issue Resolution	Negotiability	Lead-Time Flexibility	Local Priorities	Global Priorities
React to Order Changes	0.150	0.107	0.417	0.250	**0.231**	**0.020**
Issue Resolution	0.750	0.536	0.417	0.250	**0.488**	**0.041**
Negotiability	0.050	0.179	0.139	0.417	**0.196**	**0.017**
Lead-Time Flexibility	0.050	0.179	0.028	0.083	**0.085**	**0.007**
					1.000	**0.085**

Service Performance Sub-Criteria

Attributes	On-Time Delivery	Quantity Compliance
On-Time Delivery	1.000	5.000
Quantity Compliance	0.200	1.000
TOTALS	**1.200**	**6.000**

Attributes	On-Time Delivery	Quantity Compliance	Local Priorities	Global Priorities
On-Time Delivery	0.833	0.833	**0.833**	**0.131**
Quantity Compliance	0.167	0.167	**0.167**	**0.026**
			1.000	**0.157**

Appendix D – Supplier Alternatives Questionnaire

The Fundamental Scale for Pairwise Comparisons

Intensity of	Definition	Explanation
1	Equally preferred	Two elements contribute equaly to the objective
3	Moderately preferred	Experience and judgement slightly favor one element over another
5	Strongly preferred	Experience and judgement strongly favor one element over another
7	Very Strongly preferred	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extremely preferred	The evidence favoring one element over another is of the highest possible order of
2, 4, 6, and 8	Intermediate values between two adjacent judgements	

Supplier A versus Supplier B			
Criteria	Sub-criteria	Prefered Supplier	Intensity
TCO	TCO		
Quality	Percent Defects		
	Quality Control		
	Warranty		
Flexibility	React to Order Changes		
	Issue Resolution		
	Negotiability		
	Lead-Time Flexibility		
Service Performance	On-Time Delivery		
	Quantity Compliance		

Appendix E – Sample Calculation of Alternative Preferences

Supplier Preference Weighting

TCO

Attributes	Supplier A	Supplier B
Supplier A	1.000	4.000
Supplier B	0.250	1.000
TOTALS	1.250	5.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.800	0.800	0.800
SupplierB	0.200	0.200	0.200
			1.000

Issue Resolution

Attributes	Supplier A	Supplier B
Supplier A	1.000	6.000
Supplier B	0.167	1.000
TOTALS	1.167	7.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.857	0.857	0.857
SupplierB	0.143	0.143	0.143
			1.000

Percent defects

Attributes	Supplier A	Supplier B
Supplier A	1.000	3.000
Supplier B	0.333	1.000
TOTALS	1.333	4.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.750	0.750	0.750
SupplierB	0.250	0.250	0.250
			1.000

Negotiability

Attributes	Supplier A	Supplier B
Supplier A	1.000	0.167
Supplier B	6.000	1.000
TOTALS	7.000	1.167

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.143	0.143	0.143
SupplierB	0.857	0.857	0.857
			1.000

Quality Control

Attributes	Supplier A	Supplier B
Supplier A	1.000	8.000
Supplier B	0.125	1.000
TOTALS	1.125	9.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.889	0.889	0.889
SupplierB	0.111	0.111	0.111
			1.000

Lead-Time Flexibility

Attributes	Supplier A	Supplier B
Supplier A	1.000	8.000
Supplier B	0.125	1.000
TOTALS	1.125	9.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.889	0.889	0.889
SupplierB	0.111	0.111	0.111
			1.000

Warranty

Attributes	Supplier A	Supplier B
Supplier A	1.000	0.143
Supplier B	7.000	1.000
TOTALS	8.000	1.143

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.125	0.125	0.125
SupplierB	0.875	0.875	0.875
			1.000

On-Time Delivery

Attributes	Supplier A	Supplier B
Supplier A	1.000	5.000
Supplier B	0.200	1.000
TOTALS	1.200	6.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.833	0.833	0.833
SupplierB	0.167	0.167	0.167
			1.000

React to Order Changes

Attributes	Supplier A	Supplier B
Supplier A	1.000	4.000
Supplier B	0.250	1.000
TOTALS	1.250	5.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.800	0.800	0.800
SupplierB	0.200	0.200	0.200
			1.000

Quantity Compliance

Attributes	Supplier A	Supplier B
Supplier A	1.000	1.000
Supplier B	1.000	1.000
TOTALS	2.000	2.000

Attributes	Supplier A	Supplier B	Local Priorities
Supplier A	0.500	0.500	0.500
SupplierB	0.500	0.500	0.500
			1.000