# THE TOTAL DELIVERED COST OF SIEVED RED RASPBERRIES: A PROCUREMENT OPTIMIZATION MODEL

by

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**ABSTRACT**

The United States was the world's third largest producer of raspberries (by pounds) in 2013, behind Russia and Poland. Raspberries are the third most popular berry in the United States behind strawberries and blueberries. Most U.S. production of red raspberries occurs in the states of Washington and Oregon during July and August depending on variety. Harvest and production for industrial pack typically runs for five weeks.

Sieved red raspberries or single strength red raspberry puree is one of many industrial packs produced in the Pacific Northwest of the United States. Sieved red raspberries are produced by forcing fresh, cleaned and sorted red raspberries and red raspberry crumbles and pieces through a mesh screen, collected in drums or pails and stored for use in further processed products such as pies, confectioneries and other consumer food products. For this thesis, sieved berries are packed in 55-gallon steel drums lined with food grade plastic bags. They are shipped from the processing plant to a third party warehouse to be frozen and stored. The final processing plant draws on these stored frozen products for use in the production of the Company's consumer food products.

The purpose of this thesis is to review the Company's current procurement practices of sieved red raspberries and determine how these practices may be improved to reduce its total delivered cost. We use an optimization modelling approach to assess the procurement process used by the Company. The results indicate that it is possible to reduce procurement costs and improve efficiencies by making changes to the current procurement strategy. By implementing the procurement strategy developed in this study, we show that

the Company can save as much as $1.69 million per year, which is equivalent to about 20.3% of the current spend. This would suggest that adopting the optimization strategy could allow the Company to increase its total sieved raspberry utilization by as much as 0.9 million pounds per annum, all other things remaining unchanged.

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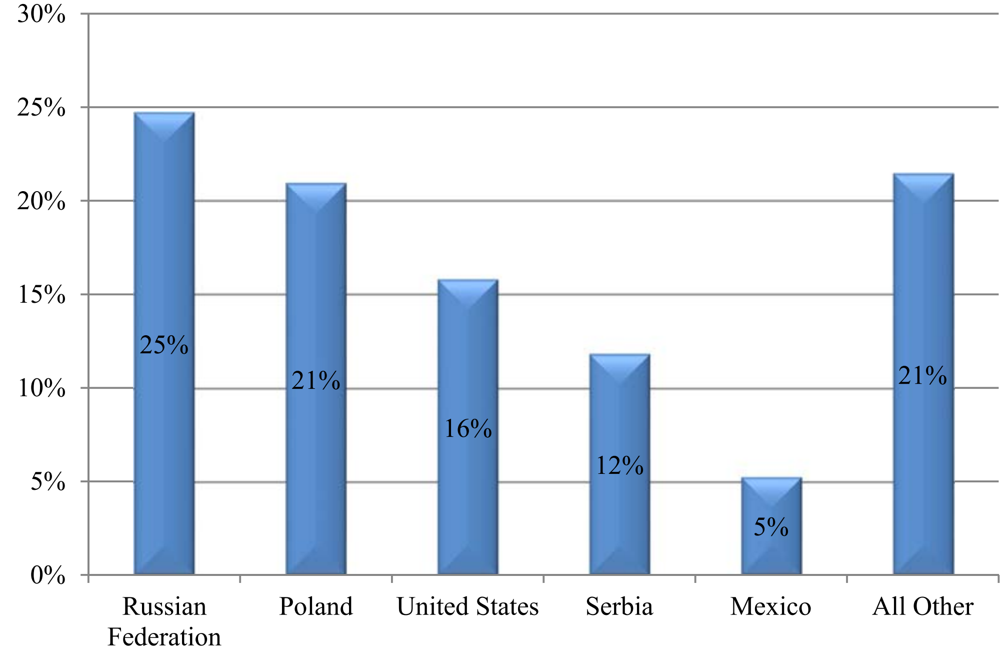
# CHAPTER I: INTRODUCTION

Red raspberries have a long history in the food culture of Europe and North America. It is reported that although they are indigenous to Asia Minor and North America, they were found in Europe during the Roman times and became a royal fruit when King Edward I called for its cultivation (Washington Red Raspberries Commission, 2013). In modern times, red raspberries are grown for consumption as fresh fruit and in frozen desserts. They are also used as ingredients in numerous baked and confectionery goods.

Raspberries are very nutritious and their aggregate fruit structure contributes to their high nutritional value. They are known to have one of the highest dietary fiber contents by weight among whole foods, with about 6% fiber by weight (USDA, n.d.). They are also rich in Vitamin C (32%), manganese (32%), Vitamin K (7%) and have very low glycemic index, with total sugar content of just about 4.4% by weight (USDA, n.d.).

In 2013 the world produced 578,233 metric tons of raspberries. The United States was the third largest producer of red raspberries in the world in 2013 (Figure 1.1). This is an improvement from its fourth position in 2011. This suggests that the global raspberry production is very concentrated in Europe (accounting for 75%) and the Americas (accounting for 23%). The Russian Federation produced 25%, 143,000 metric tons. Poland produced 21%, 121,040 metric ton. The United States produced 16%, 91,300 metric tons. Serbia produced 12%, 30,411 metric tons. Mexico produced 5%, 30,411 metric tons. All other countries in the world produced 21%, 124,024 metric tons.

**Figure 1.1: Distribution of Global Raspberry Output in 2013**

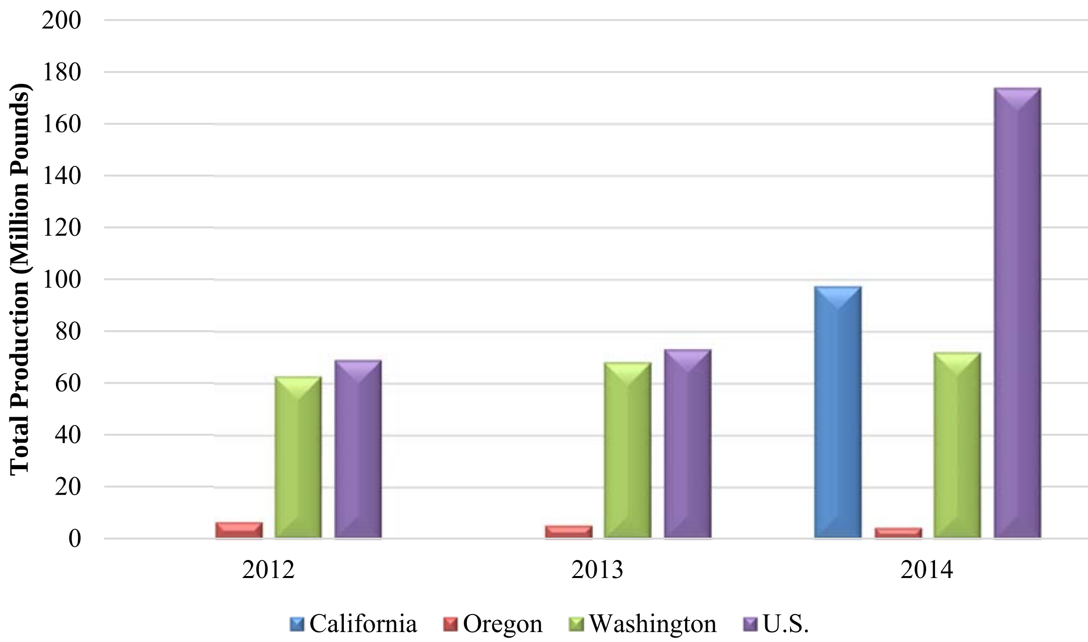



Source: Food and Agriculture Organization FAOStat (http://faostat3.fao.org).

U.S. production of raspberries occurs essentially in three states: California, Oregon and Washington. There are two main types – red and black raspberries. Total red raspberry output in Oregon and Washington in 2012 was about 69.3 million pounds or 34,650 metric tons harvested from an area of about 11,000 acres. Oregon produced about 2.2 million pounds or 1,100 metric tons of black raspberries in 2012 from about 900 acres. All raspberry production from California amounted to about 97.2 million pounds or 48,600 metric tons in 2012 from about 5,400 acres (National Agricultural Statistics Service, 2013).

As with all crops, raspberry production is not linear over time. Figure 1.2 shows that production in California in 2014 was about 97.4 million pounds or 48.700 metric tons, which was an increase in U.S. production by more than 100 million pounds or 50,000 metric tons compared to 2013. The total production is the sum of fresh and processed fruits. The fresh market has traditionally been a small portion of the U.S. market until 2014 when data from California was included in the Non-Citrus Report of NASS. While California dominated the fresh market in 2014, accounting for more than 98% of U.S. fresh raspberries, Oregon and Washington are the primary suppliers of raspberries for processing. Between 2012 and 2014, the average share of total production that was processed in Washington and Oregon was 87% and 99% respectively, in contrast to 15% for California.

**Figure 1.2: Total Production of Raspberries in the US by State**




Source: National Agricultural Statistics Service (NASS) Non-Citrus Report, January 2015.

Processing raspberries may be completed by freezing, known as individually quick frozen or IQF, straight pack drums and pails or sieved drums and pails. They may also be processed to remove their seeds, so that they are seedless and stored in drums and pails or processed into concentrates and juices. For confectioneries and baked goods, the preferred raspberry type is sieved. They are also preferred in making of products that require everything about the raspberry including the seed. The sieved raspberry with seeds is studied in this thesis. Its production involves forcing fresh, cleaned and sorted red raspberries and red raspberry crumbles and pieces through a mesh screen and collecting the puree with seeds in steel drums lined with food grade plastic bags. They are stored frozen in temperature-controlled environments for use in further processed products, such as pies and confectioneries. For this thesis, sieved berries are collected in 55-gallon steel drums lined with food grade plastic bags and then frozen. These drums are stored in specific locations until they are needed by final users.

### 1.1 Problem Definition

The previous discussion shows how concentrated the growing region for processing red raspberry industry is within an area of the U.S. This means that companies using sieved raspberries as inputs in their products compete with all the other companies using the different types of processed products as ingredients in their production. Building the right alliances and organizing the procurement process can make significant difference in the profitability of a company's procurement process.

The research problem for this thesis is this: How can the procurement of sieved red raspberries be structured to minimize the overall procurement costs?  The Company must address this problem because it has recently acquired a company that depends on sieved red raspberries as a major ingredient in its production process. The procurement is done annually from the Pacific Northwest, where the product is produced, and shipped to the processing facility in the Midwest. The specific problem facing the Company is how to organize the procurement, storage and transportation processes involved with sieved red raspberries to ensure optimal operations of its processing facilities. The challenge for the Company is that procurement must be completed between four to six weeks starting in the middle of July, when harvesting begins. Missing this window could mean having to purchase under conditions of stressed supply, which could imply paying premiums for the product.

### 1.2 Objectives

The overall objective of this thesis is to develop an optimization solution to the procurement of sieved red raspberries to enhance operations at the Company's manufacturing facilities. The specific objectives are as follows:

1. Develop a linear optimization model to find the best procurement strategy for the Company's sieved red raspberry business
2. Estimate the cost savings that would arise from the best procurement strategy relative to the status quo.

The solution would be useful to the Company because the solution can be leveraged to other ingredient purchases that are undertaken by the Company. To this end, this research may be seen as the beginning of reorienting the Company's procurement strategy to minimize costs along the procurement chain – from raw material purchases, primary processing, storage, transportation and delivery to the final product manufacturing plant.

### 1.3 Methods

We employ the Microsoft Excel macros to solve the optimization model developed. It is assumed the Company may use two approaches to contract fruit. The first option is to have the Company use a Supplier Managed Inventory (SMI) approach. In this approach, the processor holds a specified amount of fruit in storage until an agreed upon time and pays a storage and handling fee to the processor with each release of product. The second option involves immediate transfer. Under this approach, the Company takes physical ownership of the fruit upon paying for it and the fruit is transferred from the processor to the company. Having taken ownership of the fruit, the company may leave the fruit at the processor's warehouse or move the fruit to a warehouse close to the Company's production plant. In either of these options, the Company pays a monthly storage fee to the warehouse. These are the Company's two storage options because it does not own storage facilities appropriate for sieved red raspberries.

## 1.4 Thesis Outline

The next chapter provides an overview of the literature. Chapter 3 provides a description of the Company's operations vis-à-vis the procurement of sieved red raspberries. It also describes the theoretical frame of the optimization model used in the thesis and the sources of the data. Chapter 4 presents and discusses the results from the optimization exercise. The final chapter summarizes the results and provides the conclusions of the study. The steps that may be used to execute the optimization model are also presented in the final chapter.

# CHAPTER II: LITERATURE REVIEW

## 2.1 The Supply Chain

What is a supply chain? It is a sequence of processes and activities associated with the production and distribution of goods and services to customers. Supply chains are systems of organizations. In this sense, they involve people, processes, information, and various assets that ensure suppliers effectively get products and services to consumers. Chopra and Meindl (2013) simply defined a supply chain as all the parties involved in fulfilling a customer's request. They argue that a supply chain is dynamic – a constant multi-directional flow of information, products and funds in which the customer is an integral part. The purpose and objective of a supply chain is to satisfy customer needs while maximizing the overall value of goods and services. Although supply chains are not directly focused on the profitability of the organizations, they make direct contributions to profitability by efficiently delivering good and services to customers.

Another way to look at the supply chain is a series of steps to get products from suppliers to customers. The process can be very complex and hence there has emerged supply chain management. Supply chain management encompasses the activities organizations use to effectively manage the processes involved in moving goods from suppliers to customers. It is, essentially, the management of the flow of goods and services (Harland, 1996).

Supply chains can be very complex. As such, their management is sometimes more efficiently accomplished with technology. There has been an increase in the number and diversity of technologies available for supply chain management. Electronic data interchange (EDI) in the 1960s evolved with improving technologies into enterprise resource planning (ERP) tools in the 1990s. Currently, internet-based collaborative tools and systems are being used by numerous organizations to effectively manage their supply chains to reduce cost, increase efficiency and enhance operational excellence and competitive advantage (Stock 2013).

### 2.2 The Importance of Total Delivered Cost

Total delivered cost (TDC) is the total amount it costs a company to manufacture and deliver a product, service or their combination to a customer. It involves all the costs incurred up to and inclusive of final products/services delivered to the customer. This implies that TDC is directly related to the concepts of supply chains. A review of works discussing the importance of knowing total delivered cost (TDC) was completed. Schaefer and Kosansky (2014) suggest that in order to develop an accurate forward-looking supply chain plan that captures the cost of sourcing, producing and delivering finish goods, an organization should consider using TDC as the metric. A TDC model includes the cost of sourcing raw materials, manufacturing bulk and intermediate products, manufacturing final products, packaging of finished goods, inventory holding cost, transportation, distribution and final delivery to the customer (Schaefer and Kosansky 2014).

Lapinskaite and Kuckailyte (2014) note that the overall supply chain must be in a state of continuous improvement to stay competitive. They estimate that the supply chain cost component is around 55% of the total product cost. This project examines one specific area of TDC within the supply chain; the sourcing activity of sieved red raspberries to be used in the production of consumer food products. By using technology and an optimization tool, procurement is able to provide the company with an accurate raw material cost. The TDC can be captured even though there are multiple raw material suppliers with several variables and constraints. These data can be used to price finished cases of consumer food products. Long term, having data that supports fact based discussions with customers will reduce cost and lead to better supply chain planning. Incoming raw material costs no longer have to be inaccurate incomplete estimates based on the buyer's best guess but forward looking estimates that are accurate and complete. This will drive success for the company and its shareholders (Schaefer and Kosansky 2014).

**2.3 The Optimization Model and Decision Tree**

To maximize the overall value of the supply chain and keep the business competitive optimization technology is utilized. This is done by formulating a linear equation and using Solver in Microsoft Excel 2010. A review of the research around problem formulation was conducted for this thesis. Matsui et al. (2013) examine purchase and transportation planning to formulate a decision problem as a linear programming problem that maximizes profit for a food retailer in Japan. Falasca et al. (2011) offered insights into procurement and linear programming where there are a high number of uncertainties being modeled using a set of scenarios with associated probabilities of occurrence around disasters and disaster relief. Lastly, Lapinskaitė and Kuckailyte (2014) discussed the strengths and weaknesses of linear programing and its importance for managing cost. They observe among the strengths of the linear programming model, one of the common optimization processes, the fact that there is no limit to the model's size. That means the number of products and services that may be included in any model is technically only limited by the processing capacity of the software being employed to solve the model. It can also undertake integer and continuous variables as well as semi-continuous variables. Its major weakness, Kuckailyte and Lapinskaitė (2014) note is the difficulty of defining contraints and the defining of parameters. The programming model is useful under conditions of certainty, even though it has been employed to explore uncertainty in some studies, such as those involving stochastic programming model (Turvey and Amanor-Boadu 1989).

The supply network decision tree is used for data analysis. It is useful in evaluating decisions under uncertainty. It allows managers to visualize the problem based on a time period, factors that influence the value of the decision that may fluctuate, what distribution to use, and the periodic discount rate (Chopra and Meindl 2013).

**2.4 Capturing Risk and Risk Mitigation**

There are risks that should be noted and considered for the optimization model. A few include over booking or under booking due to poor forecasting, damage to the raw materials, long transit time, poor supplier performance due to quality issues, poor supplier planning, long lead times, natural disasters and seasonality (Olsen and Wu 2010).

Risk of excess raw material is a great concern to the Company. The Company has customers who bid out business annually. The model covers a fifteen month demand. This is done to cover a slightly longer than the twelve month harvest cycle. In years where the prices are at record lows the buyer may wish to extend coverage out past fifteen months. The fruit has a twenty four month shelf life. A bigger issue becomes the cost of carrying the inventory than having the new crop come in at a lower price than the fruit from the previous year. In, "A Review of Enterprise Risk Management in Supply Chain", Olsen (2010) states that:

> "All organizations need to prepare themselves to cope with crises from whatever source. In an ideal world, managers would identify everything bad that could happen to them, and develop a contingency plan for each of these sources of crisis. It is a good idea to be prepared. However, crises by definition are almost always the result of nature, malicious humans, or systems catching us unprepared (otherwise there may not have been a crisis). We need to consider what could go wrong, and think about what we might do to avoid problems. We cannot expect to cope with every contingency, however, and need to be able to respond to new challenges."

Again, the Company may not be able to avoid every problem but it is a good idea to consider the issues and problems that could potentially occur during harvest, warehousing and shipping across country. In addition to these risks, there are always such risks as losing business or being asked to increase volume after the crop is packed and raw materials are sold out.

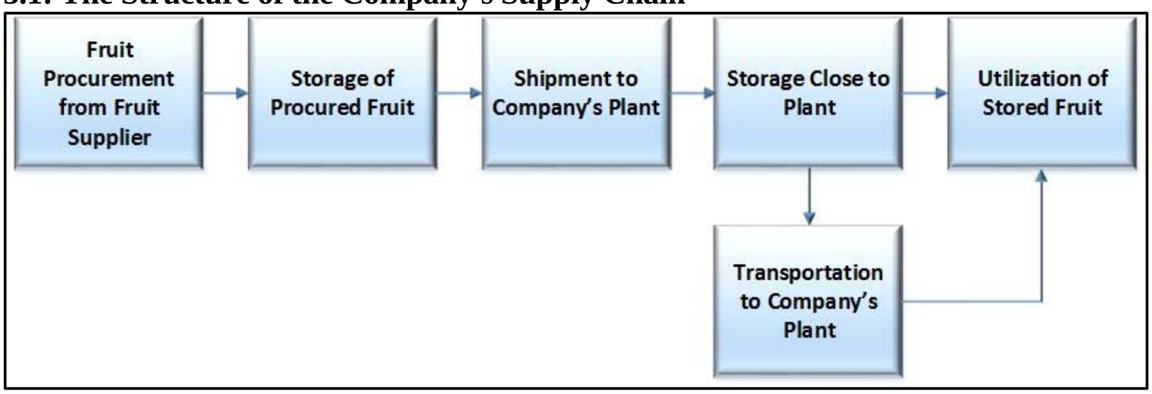
## CHAPTER III: DATA AND METHODS

In this chapter, an overview of the Company's operational reality and a discussion of the data and the methods used is provided. The operational reality is limited to the fruit procurement and management operations only. Finally, we provide an overview of the optimization model used in the study.

### 3.1 Operational Overview

Figure 3.1 shows the supply chain layout of the Company's operations. It shows that the Company procures fruit from a fruit supplier. The preferred fruit is the sieved red raspberries that are stored in 55-gallon drums. They are stored frozen and may be kept for 24 months. The Company needs about 400,000 pounds of fruits per annum. However, the Company does not have its own storage warehouses for this quantity of fruit. Therefore, it stores its fruit either with vendors from whom it purchases the fruit or with commercial warehouses, based on space availability and cost.

**Figure 3.1: The Structure of the Company's Supply Chain**




Once a demand is triggered for stored fruit, it must be transported from the storage location to the Company's manufacturing facility. Given that the point of procurement is Washington State, the storage at vendors' storage facilities implies that fruit must be moved from Washington State to the Company's plant. The plant cannot use frozen fruit. Therefore, it has to be brought into the plant four to six days prior to production runs to facilitate thawing. The fruit does not move from Washington to the production plant directly because the plant cannot take the economical quantities of shipped fruits. Therefore, the Company would ship the fruit from Washington to a warehouse that is near the Company's plant. Fruit typically travels by rail and not truck. However, the plant does not have a rail spur so all incoming loads go to the nearby warehouse for offloading and are trucked in required quantities to the plant for use. The trucking begins once the plant is ready to start the thaw process for production. A spotter or short haul truck will pick-up and deliver the raspberries needed to complete the upcoming production. The production layout increases the required lead-time from seven days plus thaw time to 45 days plus thaw time.

If the Company takes the ownership of the fruit immediately, working capital is adversely increased. Additionally, the storage price causes the total cost of fruit to increase with each month of storage. If the Company decides to have the processors hold the fruit, then the processors own the fruit, and there is no impact to working capital. However, the cost per pound increases by $.015 with every month of storage. There is also the risk of a processor in need of cash selling the fruit on the spot market, thereby increasing the risk of unavailability of fruit by the Company when needed. The option that is economically sensible to the Company should be a fact-based strategic business decision that secures quality fruit, insures year over year supply and gets the Company the best cost possible.

### 3.2 Data

The data to complete the research was obtained through phone conversations, emails and face-to-face meetings. The type of data and its collection method are found in Table 3.1. Seven approaches were used in the collection of the data. They were contract review, email to managers, face-to-face meeting, internet data, specification document review, phone conversations with suppliers, and phone call in addition to contract review. Table 3.1 shows that of the 31 unique information items, seven of them were collected through the review of contracts with three collected through emails to plant finance and transportation managers, eight involved face-to-face meetings with transportation and warehouse managers, six types of information were collected through phone calls to suppliers, and five others were collected through a combination of supplier phone calls and review of contracts.

Phone conversations were held with all suppliers to understand the production flow of product from the processing plant to the warehouse. Each supplier was asked t0 verify the warehouse being used, origin of the warehouse, truck and rail car capacity and rates, price of the sieved raspberries, the volume constraints and if they offer a supplier managed inventory (SMI) program. Each of the Company's contracts were reviewed in conjunction with the supplier phone call. Emails were sent to two managers within the Company to obtain data on freight rates between locations. Information on distances between locations was obtained using internet tools such as MapQuest (www.mapquest.com).

The data collected covered rail and truck freight costs from particular storage locations to the Midwestern warehouse, monthly storage cost, gross weight of fruit per rail car and truck; the freight costs were from both suppliers and the Company as were the gross weight of rail cars and trucks. This ensured that quotes were verified for congruence.

**Table 3.1: Data and Data Collection Methods**

| # | Variable | Data Collection Method/Source |
|---|---|---|
| 1 | Pounds Contracted in 2014 | Contract Review |
| 2 | Destination Zip Code | Contract Review |
| 3 | Months In Supplier Storage | Contract Review |
| 4 | Impact of VMI | Contract Review |
| 5 | Net Weight of Pallet in Pounds | Contract Review |
| 6 | Max Amount of Company Paid Storage After Transfer (Months in Storage * Monthly Rate) | Contract Review |
| 7 | Transfer date | Contract Review |
| 8 | Shuttle Truck Cost Per Pound From Storage to Plant | Email to Plant Finance Manager |
| 9 | Company Truck Fright Cost Quote Per Truck | Email to Transportation Manager |
| 10 | Company Truck Freight Cost Quote Per Pound | Email to Transportation Manager |
| 11 | Net Weight of Rail Car - Company | Face-to-Face Meeting with Transportation Manager |
| 12 | Net Weight of Truck | Face-to-Face Meeting with Transportation Manager |
| 13 | Company Rail Freight Cost Per Car Quote | Face-to-Face Meeting with Transportation Manager |
| 14 | Company Rail Freight Cost Per Pound Quote | Face-to-Face Meeting with Transportation Manager |
| 15 | Monthly Storage Rate Per Pound After the Transfer | Face-to-Face Meeting with Warehousing Manager |
| 16 | Monthly Storage Rate Per Pallet After the Transfer | Face-to-Face Meeting with Warehousing Manager |
| 17 | Current Storage Rate - Buffer Warehouse A. Per Pound | Face-to-Face Meeting with Warehousing Manager |
| 18 | Alt. Storage Location - Buffer Warehouse B per pound | Face-to-Face Meeting with Warehousing Manager |
| 19 | Mileage From Origin to Destination | Internet Database |
| 20 | Shelf Life of the Fruit | Spec Review |
| 21 | Net Weight of Rail Car - Supplier | Supplier Phone Call |
| 22 | Truck Freight Supplier Quote Per Truck | Supplier Phone Call |
| 23 | Truck Freight Cost Supplier Quote Per Pound | Supplier Phone Call |
| 24 | Rail Freight Cost Per Car Supplier Quote | Supplier Phone Call |
| 25 | Rail Freight Cost Per Pound Supplier Quote | Supplier Phone Call |
| 26 | Supplier Volume Offer For 2015 | Supplier Phone Call |
| 27 | Origin Warehouse | Supplier Phone Call and Contract Review |
| 28 | Origin Zip Code | Supplier Phone Call and Contract Review |
| 29 | FOB Cost Per Pound | Supplier Phone Call and Contract Review |
| 30 | VMI Monthly Storage Per Pound | Supplier Phone Call and Contract Review |
| 31 | VMI program | Supplier Phone Call and Contract Review |

The Company uses five suppliers and six transportation routes to get product to the manufacturing plant. Let the five suppliers be labeled A through E. Table 3.2 summarizes the production capacity for each supplier, transportation cost and the buffer warehouse rate and shuttle truck rate from the buffer warehouse to the manufacturing plant. The product price was $1.55 per pound for Suppliers A, B, C and E and $1.54 per pound for Supplier D. The monthly storage rate after transferring ownership to the Company was the same for Suppliers B, C and D at $0.005775 per pound, $0.005475 for Supplier A and $0.008344 for Supplier E. The buffer warehouse was not used on transportation routes 3 and 4. The rate was the same for the same routes used regardless of which supplier's product is received at the buffer warehouse. For Route 1 and 2, the rate was quoted by the warehouse manager as $0.009375 per pound. For Route 5 and 6, the rate was $0.007188 per pound. The data in Table 3.2 provided the inputs for the programming model.

**Table 3.2: Supplier Price and Route Rate by Destination (in $/pound)**

| Route | Ownership at Shipping Time | Product Price | Transportation Rates | Buffer Warehouse Rates | Shuttle Truck Rate | Monthly Storage Rate (After Transfer) | Supplier Managed Inventory Rate Per Month |
|---|---|---|---|---|---|---|---|
| **Supplier A with 2 million pounds production capacity** | | | | | | | **No SMI Program** |
| A Route 1 | Supplier | $1.550000 | $0.111218 | $0.009375 | $0.009375 | $0.005475 | |
| A Route 2 | Company | $1.550000 | $0.113103 | $0.009375 | $0.009375 | $0.005475 | |
| A Route 3 | Company | $1.550000 | $0.118000 | $- | $- | $0.005475 | |
| A Route 4 | Supplier | $1.550000 | $0.128700 | $- | $- | $0.005475 | |
| A Route 5 | Company | $1.550000 | $0.113103 | $0.007188 | $0.009375 | $0.005475 | |
| A Route 6 | Supplier | $1.550000 | $0.111218 | $0.007188 | $0.009375 | $0.005475 | |
| **Supplier B with 240 thousand pounds production capacity** | | | | | | | **Q1-Q3** |
| B Route 1 | Supplier | $1.550000 | $0.099826 | $0.009375 | $0.009375 | $0.005775 | $0.015000 |
| B Route 2 | Company | $1.550000 | $0.087243 | $0.009375 | $0.009375 | $0.005775 | $0.015000 |
| B Route 3 | Supplier | $1.550000 | $0.141875 | $- | $- | $0.005775 | $0.015000 |
| B Route 4 | Company | $1.550000 | $0.118125 | $- | $- | $0.005775 | $0.015000 |
| B Route 5 | Supplier | $1.550000 | $0.099826 | $0.007188 | $0.009375 | $0.005775 | $0.015000 |
| B Route 6 | Company | $1.550000 | $0.087243 | $0.007188 | $0.009375 | $0.005775 | $0.015000 |
| **Supplier C with 1.2 million pounds production capacity** | | | | | | | **Q1-Q3** |
| C Route 1 | Supplier | $1.550000 | $0.099826 | $0.009375 | $0.009375 | $0.005775 | $0.015000 |
| C Route 2 | Company | $1.550000 | $0.087243 | $0.009375 | $0.009375 | $0.005775 | $0.015000 |
| C Route 3 | Supplier | $1.550000 | $0.141875 | $- | $- | $0.005775 | $0.015000 |
| C Route 4 | Company | $1.550000 | $0.118125 | $- | $- | $0.005775 | $0.015000 |
| C Route 5 | Supplier | $1.550000 | $0.099826 | $0.007188 | $0.009375 | $0.005775 | $0.015000 |
| C Route 6 | Company | $1.550000 | $0.087243 | $0.007188 | $0.009375 | $0.005775 | $0.015000 |
| **Supplier D with 2 million pounds production capacity** | | | | | | | **Q1-Q3** |

| Route | Ownership at Shipping Time | Product Price | Transportation Rates | Buffer Warehouse Rates | Shuttle Truck Rate | Monthly Storage Rate (After Transfer) | Supplier Managed Inventory Rate Per Month |
|---|---|---|---|---|---|---|---|
| D Route 1 | Supplier | $1.540000 | $0.099826 | $0.009375 | $0.009375 | $0.005775 | $0.015000 |
| D Route 2 | Company | $1.540000 | $0.087243 | $0.009375 | $0.009375 | $0.005775 | $0.015000 |
| D Route 3 | Supplier | $1.540000 | $0.141875 | $- | $- | $0.005775 | $0.015000 |
| D Route 4 | Company | $1.540000 | $0.118125 | $- | $- | $0.005775 | $0.015000 |
| D Route 5 | Supplier | $1.540000 | $0.099826 | $0.007188 | $0.009375 | $0.005775 | $0.015000 |
| D Route 6 | Company | $1.540000 | $0.087243 | $0.007188 | $0.009375 | $0.005775 | $0.015000 |
| **Supplier E with 2 million pounds production capacity** | | | | | | | **Q1-Q2** |
| E Route 1 | Supplier | $1.550000 | $0.075631 | $0.009375 | $0.009375 | $0.008344 | $0.015000 |
| E Route 2 | Company | $1.550000 | $0.087143 | $0.009375 | $0.009375 | $0.008344 | $0.015000 |
| E Route 3 | Supplier | $1.550000 | $0.137500 | $- | $- | $0.008344 | $0.015000 |
| E Route 4 | Company | $1.550000 | $0.087143 | $- | $- | $0.008344 | $0.015000 |
| E Route 5 | Supplier | $1.550000 | $0.075631 | $0.007188 | $0.009375 | $0.008344 | $0.015000 |
| E Route 6 | Company | $1.550000 | $0.087243 | $0.007188 | $0.009375 | $0.008344 | $0.015000 |

### 3.2 Methods

Recall that the focus of the problem is to minimize the cost associated with procuring sieved red raspberries for the company from the five suppliers over a 15-month period. A linear programming model is used to achieve this objective. The objective function and the constraints for the procurement model is specified as follows:

$$\begin{aligned}
&\min_{\{q,y\}} C(q) = \sum_{i=1}^{5}\sum_{j=1}^{6}(r_{ij} + w_{ij})q_i + \sum k_i y_i \\
&s.t. \\
&S_{ij} \geq \sum_{j=1}^{6} q_{ij} \\
&V_{ij} \geq \sum_{i=1}^{5} q_{ij} \\
&S_{ij} = V_{ij}
\end{aligned} \tag{3.1}$$

The first line in Equation 3.1 states that the objective is to minimize the cost, C*(q),* of procuring $q_i$ quantity of sieved red raspberries from five suppliers, *i*, where *i* = 1, 2, . ., 5, using six different potential supply routes, *j*, where *j* = 1, 2. . ., 6. The supply routes define the warehouse/storage facilities and transportation solutions to get the product to the Company's manufacturing facility in the Midwest. The parameter, $r_{ij}$, is the per unit price of purchasing, storage and transportation (the total delivered cost) of sieved red raspberries from supplier *i* using route *j* to get the product to the Company's manufacturing facility in the Midwest. Some the suppliers have to move product to the buffer warehouse prior to getting it to the manufacturing facility. The total storage and shuttle cost for the buffer storage, $k_i$, associated with the buffer product quantities, $y_i$, for the respective suppliers is the last part of the first line of Equation 3.1. The parameter $w_i$ describes the extra cost levied by suppliers able to provide SMI services if that supplier is able to provide SMI services, then wi is greater than zero, otherwise it is zero.  Thus, providing SMI services shows that the Company is able to avoid using working capital upon executing the contract to procure but increases monthly holding charges reflected by $w_i$.

The second line stipulates that the total quantity of product procured from Supplier i should be less than or equal to Supplier *i*'s production or storage capacity, $S_i$.  The third line says that the total quantity drawn from all suppliers in each period cannot exceed the processing capacity of the Company's manufacturing capacity in that period, $V_i$. The final line stipulates that the total supply available from all suppliers must equal the Company's total processing capacity.  That implies that supply must equal demand or, in our case, $S_i = V_i$.

In summary, the problem involves solving for the optimum quantities of sieved red raspberries that would move through each of the routes from the different suppliers to produce the lowest cost for the Company. Estimating the optimum total delivery cost involved exploring alternative scenarios of different relationships with suppliers and strategies.  The scenarios and their descriptions are presented in Table 4.12.

# CHAPTER IV: ANALYSIS

An analysis of the current purchasing strategy was conducted to determine cost savings to the Company. The model was ran six different ways resulting in 6 scenarios. Scenario 1 or Base represents the purchases and shipments made during the 2014 crop year. Scenario 2, 2015 Plan A and Scenario 3, 2015 Plan B both represent the model accepting what the buyer was intending to do for the 2015 harvest. Also, the model includes the use of all approved suppliers to mitigate supply risk. Scenario 4, the Transfer Immediately model was run using Excel Solver to pick the supplier, route and amount to be released. Scenario 5, the SMI model was run using Excel Solver to pick the supplier, route and amount to be released. Lastly, Scenario 6 or the Sensitivity Analysis was run using Excel Solver to pick the supplier, route and amount to be released. The FOB price is decreased to $1.25 per pound, the warehouse being used by Supplier E decreases the monthly storage fee and a constraint that each supplier must supply 40,000 pounds so no supplier is excluded.

## 4.1 Base Scenario

The current procurement distribution of sieved red raspberries is represented in Scenario 1 (Table 4.1). Supplier A has a share of 1,520,000 pounds through Warehouse 1/2/3; Supplier B has a share of 120,000 pounds through Warehouse A; Supplier C has a share of 600,000 pounds through Warehouse A; Supplier D has a share of 1,260,000 pounds through warehouse A and Supplier E has a share of 1,000,000 through Warehouse A. The freight and warehouse cost associated with this model is documented in Table 4.2. The total transportation and warehouse (T&W) cost is the baseline for calculating savings, $1,350,936. All five suppliers are used in this model. The cost associated with Supplier

A’s transportation and warehousing (T&W) is $481,909; the cost associated with Supplier B’s T&W is $18,504; the cost associated with Supplier C’s T&W is $317,834; the cost associated with supplier D’s T&W is $237,493 and the cost associated with Supplier E’s T&W is $295,195.

**Table 4.1: Base Scenario Results (Quantity in Pounds)**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | - | - | 320,000 | 300,000 | 900,000 | 1,520,000 |
| Supplier A Warehouse A | - | - | - | - | - | - |
| Supplier A Warehouse B | - | - | - | - | - | - |
| Supplier B Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier B Warehouse A | 120,000 | - | - | - | - | 120,000 |
| Supplier B Warehouse B | - | - | - | - | - | - |
| Supplier C Warehouse 1/2/3 | - | | - | - | - | - |
| Supplier C Warehouse A | - | | - | 600,000 | - | 600,000 |
| Supplier C Warehouse B | - | - | - | - | - | - |
| Supplier D Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier D Warehouse A | 780,000 | 480,000 | - | - | - | 1,260,000 |
| Supplier D Warehouse B | - | - | - | - | - | - |
| Supplier E Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier E Warehouse A | - | 420,000 | 580,000 | - | - | 1,000,000 |
| Supplier E Warehouse B | - | - | - | - | - | - |
| TOTAL | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 4,500,000 |

**Table 4.2: Transportation and Warehousing (T&W) Cost by Option – Base Scenario**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | $24,966 | $49,932 | $112,658 | $114,240 | $180,113 | $481,909 |
| Supplier A Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier A Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse A | $18,504 | $0 | $0 | $0 | $0 | $18,504 |
| Supplier B Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse A | $27,000 | $54,000 | $81,000 | $155,834 | $0 | $317,834 |
| Supplier C Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse A | $141,877 | $95,616 | $0 | $0 | $0 | $237,493 |
| Supplier D Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse A | $45,000 | $125,703 | $124,493 | $0 | $0 | $295,195 |
| Supplier E Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| TOTAL | $257,347 | $325,251 | $318,151 | $270,074 | $180,113 | $1,350,936 |

Figure 4.1 shows the total costs associated with each of the solutions in the Base Scenario. The highest total cost of about $2.84 million occurred for Supplier A shipping from Warehouse 1/2/3. Supplier B shipping from Warehouse A posted the least cost, only about $204,504. However, the warehouse and freight costs are not distributed in the same manner. For example, while Supplier B shipping from Warehouse A posted FOB cost share of total cost of 90.9%, Supplier C shipping from Warehouse A had the lowest share of FOB cost of total cost, only about 74.5%. The total delivered cost for the season was $8,313,336.

**Figure 4.1: FOB, Transportation and Warehouse Cost under the Base Scenario**

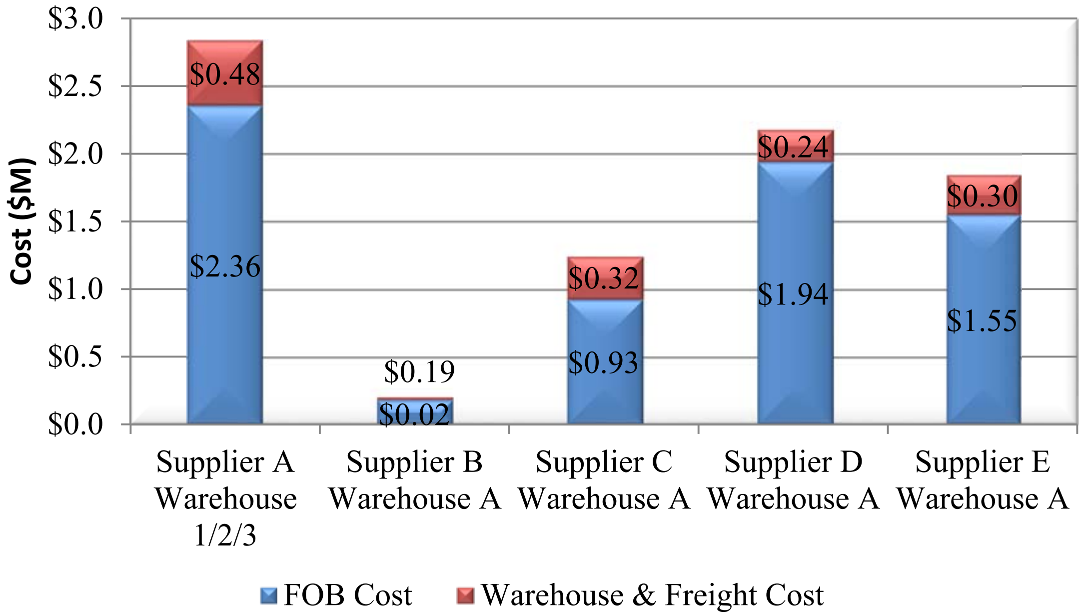


**Table 4.3: Scenario 2 – 2015 Plan A- Results (Quantity in Pounds)**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier A Warehouse A | | - | - | 600,000 | 600,000 | 1,200,000 |
| Supplier A Warehouse B | - | - | - | - | - | - |
| Supplier B Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier B Warehouse A | | 240,000 | - | - | - | 240,000 |
| Supplier B Warehouse B | | | - | - | - | - |
| Supplier C Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier C Warehouse A | | 360,000 | 300,000 | - | - | 660,000 |
| Supplier C Warehouse B | - | | - | - | - | - |
| Supplier D Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier D Warehouse A | - | - | 600,000 | 300,000 | 300,000 | 1,200,000 |
| Supplier D Warehouse B | - | - | | - | - | - |
| Supplier E Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier E Warehouse A | 900,000 | 300,000 | - | | - | 1,200,000 |
| Supplier E Warehouse B | - | - | - | | - | - |
| TOTAL | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 4,500,000 |

**Table 4.4: Transportation and Warehouse (T&W) Cost by Option - Scenario 2 – 2015 Plan A**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier A Warehouse A | $33,750 | $67,500 | $101,250 | $208,487 | $157,862 | $568,849 |
| Supplier A Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse A | $6,750 | $41,864 | $0 | $0 | $0 | $48,614 |
| Supplier B Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse A | $18,563 | $82,032 | $62,735 | $0 | $0 | $163,330 |
| Supplier C Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse A | $33,750 | $67,500 | $164,846 | $99,298 | $73,985 | $439,379 |
| Supplier D Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse A | $120,616 | $48,643 | $0 | $0 | $0 | $169,259 |
| Supplier E Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| TOTAL | $213,429 | $307,539 | $328,831 | $307,785 | $231,847 | $1,389,430 |

### 4.2 Scenario 2 – 2015 Plan A

Table 4.3 represents the quarterly releases for one of two plans the buyer intended to implement in 2015. This model does not use an optimization program; only the buyers bias. The Scenario 2 total delivered cost for the season is $8,352,430. This model assumes there are no changes in the warehouse or warehouse rates from the Base, Scenario 1. The difference between Scenario 1 and Scenario 2 is the volume awarded to suppliers and the release timing. All five suppliers are used in both Scenario 1 and Scenario 2. There is an immediate transfer of ownership; no Supplier Managed Inventory program is used by the Company and all the raspberries come into Warehouse A for storage. When compared to Scenario 1 the total amount spent increases by $39,095. The total T&W spend increases by $38,495 (Figure 4.9). In addition to the cost increase there is an impact to the Company's working capital. The highest transportation and warehousing (T&W) cost of the season is $568,849 from Supplier A. The lowest T&W cost of the season is $48,614 from Supplier B. The fluctuation is due to amount of time in storage and volume awarded. The release in Q1 is from Supplier E through Warehouse A for 900,000 pounds (Table 4.3). The total cost for T&W in Q1 is $213,429 (Table 4.4). In Q2 there are three releases; 240,000 pounds from Supplier B through Warehouse A, 360,000 pounds from Supplier C through Warehouse A and 300,000 pounds from Supplier E through Warehouse A (Table 4.3). The total T&W cost in Q2 is $307,539 (Table 4.4). In Q3 there are two releases. The balance of Supplier C's product is released, 300,000 pounds. In addition, 600,000 pounds from Supplier D's 1,200,000 pound contract (Table 4.3) is released. The total T&W cost for Q3 is $328,831(Table 4.4). In Q4 and Q5 the releases are the same. Supplier A's product is released, 600,000 pounds each quarter and Supplier

D's product is released, 300,000 pounds each quarter (Table 4.3). The total cost of T&W for Q4 is $307,785 and Q5 is $231,847 (Table 4.4). The seasonal total T&W cost for Scenario 2 is $1,389,430 (Table 4.4)

**Figure 4.2: Scenario 2 – 2015 Plan A**

**Table 4.5: Scenario 3 – 2015 Plan B - Results (Quantity in Pounds)**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier A Warehouse A | | - | - | | | - |
| Supplier A Warehouse B | - | - | - | 600,000 | 600,000 | 1,200,000 |
| Supplier B Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier B Warehouse A | | | - | - | - | - |
| Supplier B Warehouse B | | 240,000 | - | - | - | 240,000 |
| Supplier C Warehouse 1/2/3 | - | | - | - | - | - |
| Supplier C Warehouse A | | | | - | - | - |
| Supplier C Warehouse B | - | 360,000 | 300,000 | - | - | 660,000 |
| Supplier D Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier D Warehouse A | - | - | | | | - |
| Supplier D Warehouse B | - | - | 600,000 | 300,000 | 300,000 | 1,200,000 |
| Supplier E Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier E Warehouse A | | | - | | - | - |
| Supplier E Warehouse B | 900,000 | 300,000 | - | | - | 1,200,000 |
| TOTAL | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 4,500,000 |

**Table 4.6: Transportation and Warehouse Cost by Option - Scenario 3 – 2015 Plan B**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier A Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier A Warehouse B | $25,876 | $51,753 | $77,630 | $176,994 | $138,178 | $470,434 |
| Supplier B Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse A | $0.00 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse B | $5,175 | $40,289 | $0 | $0 | $0 | $45,464 |
| Supplier C Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse B | $14,232 | $71,009 | $54,861 | $0 | $0 | $140,104 |
| Supplier D Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse B | $25,876 | $51,753 | $139,914 | $82,895 | $63,487 | $363,928 |
| Supplier E Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse B | $112,743 | $44,047 | $0 | $0 | $0 | $156,791 |
| TOTAL | $183,904 | $258,853 | $272,406 | $259,889 | $201,666 | $1,176,720 |

### 4.3 Scenario 3 – 2015 Plan B

Scenario 3 is represented in Figure 4.3 and Tables 4.5 and 4.6. This scenario is similar to Scenario 1and Scenario 2. All five suppliers are used. Volume releases are identical to Plan A but the warehouse is changed from Warehouse A to Warehouse B. The fruit is transferred to the Company shortly after harvest so there isan impact to the Company's working capital. The total delivered cost for the season in this scenario is $8,313,333. The supplier with the highest TDC for the season in this scenario is Supplier A at $2,330,434 (Figure 4.3). The fruit is released to the plant in Q4 and Q5 after multiple months in storage. The volume awarded to Supplier A is 1,200,000 pounds. The lowest total transportation and warehousing (T&W) cost is $45,464 from Supplier B. This is driven by the low volume awarded to the supplier. The volume distribution is the exact same in Scenario 2 and Scenario 3. Suppliers A, D and E are awarded 1,200,000 pounds. Supplier A's fruit is released to production in Q4 and Q5 for a total transportation and warehousing (T&W) cost of $470.434 (Table 4.6). Supplier D's fruit is released through Warehouse B to the plant in Q3, Q4 and Q5. In Q3 600,000 pounds is released. In Q4 and Q5 300,000 pounds of fruit is released to the production plant. The total transportation and warehousing (T&W) cost for these releases is $363,928 (Table 4.6). Supplier E's 1,200,000 pounds is released in Q1 and Q2. In Q1 900,000 pounds is released and in Q2 300,000 pounds is released, each time through Warehouse B. The total T&W cost of these transactions is $156,791(Table 4.6). Supplier B is awarded 240,000 pounds to be released in Q2 through Warehouse B. The total cost of T&W is $45,464 (Table 4.6). Lastly Supplier C is awarded 660,000 pounds. 360,000 pounds in Q2 (Table 4.5) though Warehouse B and 300,000 pounds in Q3 (Table 4.5) though Warehouse B for a total transportation and warehousing (T&W) cost of $140,104 (Table 4.6). The cost incurred from transportation and warehousing (T&W) for Scenario 3 is $1,176,720 (Table 4.6). In comparison with the Base Scenario of $1,350,936 (Table 4.2) there is a savings to the Company of $174,216 on transportation and warehousing (T&W) over the 15 month period. The total delivered cost savings would be $173,616 on a total delivered cost spend of $8,352,430. This savings is the result of using a new warehouse as no optimization program was used on this scenario.

**Figure 4.3: Scenario 3 – 2015 Plan B**

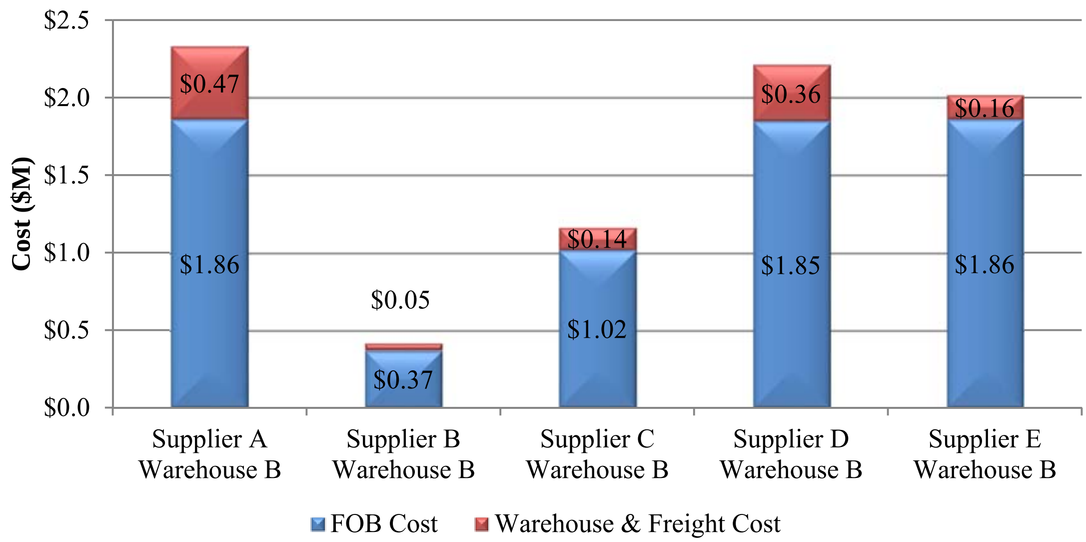


**Table 4.7: Scenario 4 – Transfer Immediately - Results (Quantity in Pounds)**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | - | - | 200,000 | 900,000 | 900,000 | 2,000,000 |
| Supplier A Warehouse A | - | - | - | - | - | - |
| Supplier A Warehouse B | - | - | - | - | - | - |
| Supplier B Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier B Warehouse A | - | - | - | - | - | - |
| Supplier B Warehouse B | - | - | - | - | - | - |
| Supplier C Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier C Warehouse A | - | - | - | - | - | - |
| Supplier C Warehouse B | - | - | - | - | - | - |
| Supplier D Warehouse 1/2/3 | - | - | 700,000 | - | - | 700,000 |
| Supplier D Warehouse A | 400,000 | - | - | - | - | 400,000 |
| Supplier D Warehouse B | - | 900,000 | - | - | - | 900,000 |
| Supplier E Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier E Warehouse A | 500,000 | - | - | - | - | 500,000 |
| Supplier E Warehouse B | - | - | - | - | - | - |
| TOTAL | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 4,500,000 |

**Table 4.8: Transportation and Warehouse (T&W) Cost by Option - Scenario 4 – Immediate Transfer**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | $32,850 | $65,700 | $122,150 | $224,460 | $180,113 | $625,273 |
| Supplier A Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier A Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse 1/2/3 | $12,127 | $24,255 | $119,070 | $0 | $0 | $155,453 |
| Supplier D Warehouse A | $49,897 | $0 | $0 | $0 | $0 | $49,897 |
| Supplier D Warehouse B | $19,407 | $132,241 | $0 | $0 | $0 | $151,648 |
| Supplier E Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse A | $62,321 | $0 | $0 | $0 | $0 | $62,322 |
| Supplier E Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| TOTAL | $176,603 | $222,195 | $241,220 | $224,460 | $180,113 | $1,044,592 |

### 4.4 Scenario 4 – Transfer Immediately

Tables 4.7, 4.8 and Figure 4.4 represent Scenario 4. Scenario 4 utilizes Solver for the optimal solution when the constraints are supplier volume, maximum volume the plant can receive, the maximum amount the plant can release, no SMI program and FOB price is held constant. With this model, Solver indicates the solution should be to award 2,000,000 pounds to Supplier A, 2,000,000 pounds to Supplier D and 500,000 pounds to Supplier E. Supplier A's product would move through Warehouse 1/2/3 in Q3, Q4 and Q5 for a total T&W fee of $625,273 (Table 4.8). Supplier D's 2,000,000 pounds would be moved in Q1, Q2 and Q3. In Q1, 400,000 pounds would move through Warehouse A. In Q2 900,000 pounds would from Warehouse B into the plant and in Q3 700,000 pounds would move through Warehouse 1/2/3 into the plant. Finally, Supplier E's 500,000 pounds would move through Warehouse A in Q1. These plant releases are shown in Table 4.7. This solution produces a total T&W cost of $1,044,592 (Table 4.8). The solution creates a cost saving around T&W of $306,344 (Figure 4.9) and a TDC savings of $313,744 (Figure 4.8). Q3 results in the highest value of releases at $241,220. Q5 is the lowest in this scenario at $180,113. In regards to spend by supplier, Figure 4.4 shows the total delivered cost by supplier. The highest total spend is $3,775,273 with Supplier A through Warehouse 1/2/3. The $3,100,000 along with all other FOB fruit cost is due to the suppliers within 30 days of the fruits transfer. Working capital is affected if this model is used.

**Figure 4.4: Scenario 4 – Transfer Immediately**

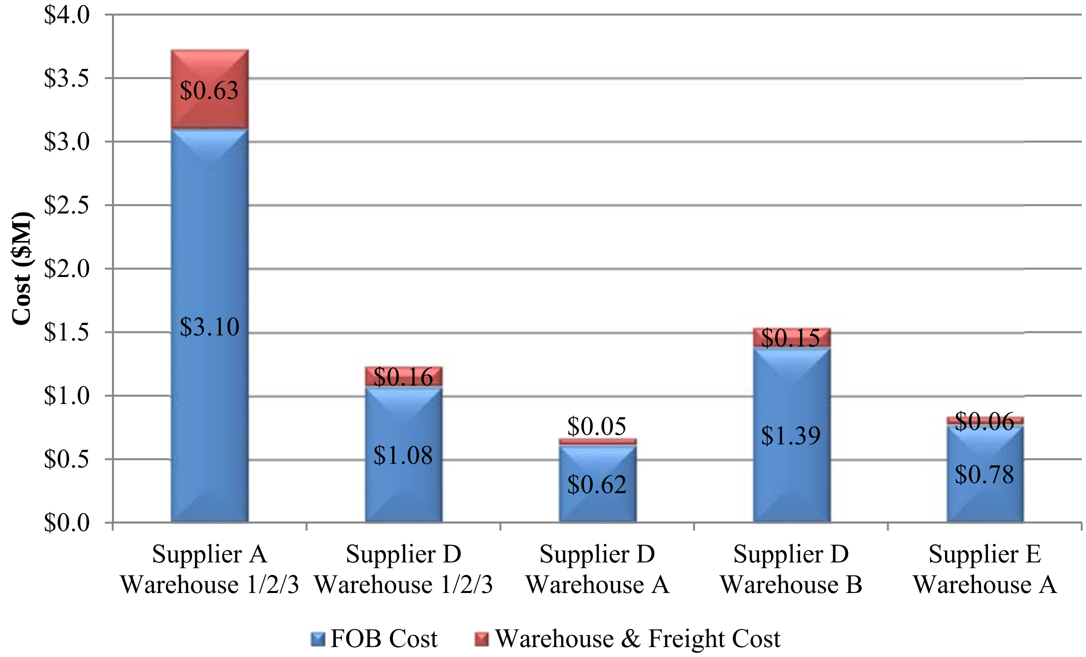


**Table 4.9: Scenario 5 – Supplier Managed Inventory - Results (Quantity in Pounds)**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | - | - | 200,000 | 900,000 | 900,000 | 2,000,000 |
| Supplier A Warehouse A | - | - | - | - | - | - |
| Supplier A Warehouse B | - | - | - | - | - | - |
| Supplier B Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier B Warehouse A | - | - | - | - | - | - |
| Supplier B Warehouse B | - | - | - | - | - | - |
| Supplier C Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier C Warehouse A | - | - | - | - | - | - |
| Supplier C Warehouse B | - | - | - | - | - | - |
| Supplier D Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier D Warehouse A | - | - | 500,000 | - | - | 500,000 |
| Supplier D Warehouse B | - | - | - | - | - | - |
| Supplier E Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier E Warehouse A | 900,000 | 900,000 | 200,000 | - | - | 2,000,000 |
| Supplier E Warehouse B | - | - | - | - | - | - |
| TOTAL | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 4,500,000 |

**Table 4.10: Transportation and Warehouse Cost by Option - Scenario 5 – Supplier Managed Inventory**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | $32,850 | $65,700 | $122,150 | $224,460 | $180,112.50 | $625,272 |
| Supplier A Warehouse A | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier A Warehouse B | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier B Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier B Warehouse A | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier B Warehouse B | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier C Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier C Warehouse A | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier C Warehouse B | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier D Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier D Warehouse A | $22,500 | $45,000 | $122,100 | $0 | $0.00 | $189,600 |
| Supplier D Warehouse B | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier E Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0.00 | $0 |
| Supplier E Warehouse A | $166,505 | $175,505 | $42,928 | $0 | $0.00 | $384,939 |
| Supplier E Warehouse B | $0 | $0 | $0 | $0 | $0.00 | $0 |
| TOTAL | $221,855 | $286,205 | $287,179 | $224,460 | $180,112.50 | $1,199,812 |

### 4.5 Scenario 5 – Supplier Managed Inventory

Scenario 5 utilizes Solver for the optimal solution when the suppliers manage the inventory. This scenario uses three of the suppliers and assumes the suppliers take on the risk of moving and storing the fruit into Warehouse A. This model awards 2,000,000 pounds to Supplier A through Warehouse 1/2/3; 200,000 pounds in Q3, 900,000 in Q4 and lastly 900,000 in Q5 for a total cost of $625,272 (Table 4.10). Supplier D is awarded 500,000 pounds to be released in Q3 through Warehouse A for a total cost of $189,601 (Table 4.10). Supplier E through Warehouse A is awarded 900,000 pounds in Q1, 900,000 pounds in Q2 and 200,000 pounds in Q3 for a total cost of $384,939 (Table 4.10). The Company would not achieve as much saving if this model were used verses the Scenario 4 model. However, Scenario 5 allows the Company to spread out payments as the fruit is released to the plant. By doing this there is no impact working capital. The total cost of T&W in this scenario is $1,199,812 (Table 4.10). This is a savings on T&W from the Base Scenario of $151,123. Total delivered cost for the season come to $8,169,812 (Figure 4.5). The savings on total delivered cost between the Base Scenario and Scenario 5 is $143,523.

**Figure 4.5: Scenario 5 – Supplier Managed Inventory**

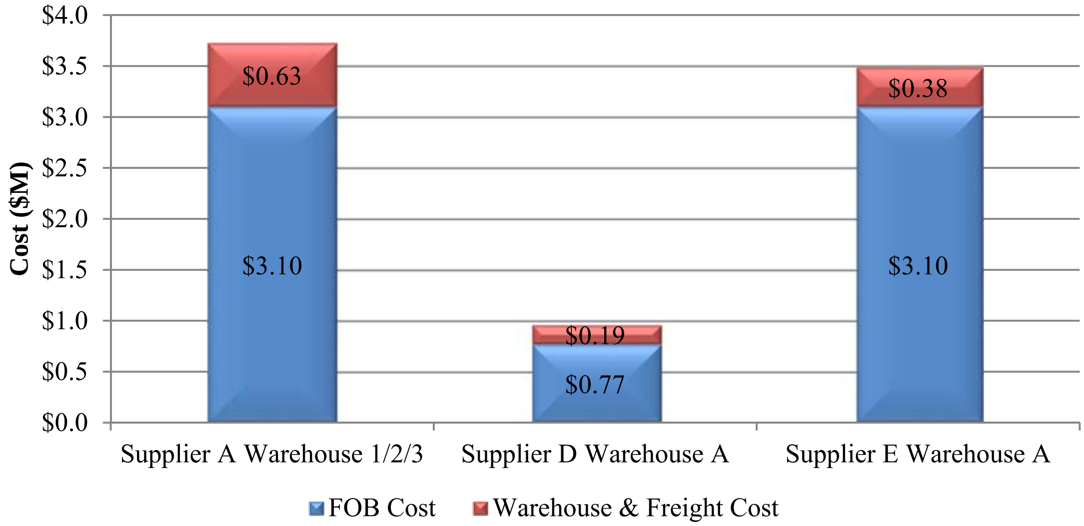


**Table 4.11: Scenario 6 – Sensitivity Analysis - Results (Quantity in Pound**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | - | - | 200,000 | 900,000 | 900,000 | 2,000,000 |
| Supplier A Warehouse A | - | - | - | - | - | - |
| Supplier A Warehouse B | - | - | - | - | - | - |
| Supplier B Warehouse 1/2/3 | - | - | 40,000 | - | - | 40,000 |
| Supplier B Warehouse A | - | - | - | - | - | - |
| Supplier B Warehouse B | - | - | - | - | - | - |
| Supplier C Warehouse 1/2/3 | - | - | 40,000 | - | - | 40,000 |
| Supplier C Warehouse A | - | - | - | - | - | - |
| Supplier C Warehouse B | - | - | - | - | - | - |
| Supplier D Warehouse 1/2/3 | - | - | 620,000 | - | - | 620,000 |
| Supplier D Warehouse A | - | - | - | - | - | - |
| Supplier D Warehouse B | 900,000 | 480,000 | - | - | - | 1,380,000 |
| Supplier E Warehouse 1/2/3 | - | - | - | - | - | - |
| Supplier E Warehouse A | - | - | - | - | - | - |
| Supplier E Warehouse B | - | 420,000 | - | - | - | 420,000 |
| TOTAL | 900,000 | 900,000 | 900,000 | 900,000 | 900,000 | 4,500,000 |

**Table 4.12: Transportation and Warehouse Cost by Option - Scenario 6– Sensitivity Analysis**

| Option | Release Q 1 | Release Q 2 | Release Q 3 | Release Q 4 | Release Q 5 | Total |
|---|---|---|---|---|---|---|
| Supplier A Warehouse 1/2/3 | $32,850 | $65,700 | $122,150 | $224,460 | $180,112 | $625,272 |
| Supplier A Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier A Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse 1/2/3 | $693 | $1,386 | $6,804 | $0 | $0 | $8,883 |
| Supplier B Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier B Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse 1/2/3 | $693 | $1,386 | $6,804 | $0 | $0 | $8,883 |
| Supplier C Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier C Warehouse B | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse 1/2/3 | $10,741 | $21,483 | $105,462 | $0 | $0 | $137,686 |
| Supplier D Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier D Warehouse B | $116,714 | $70,528 | $0 | $0 | $0 | $187,242 |
| Supplier E Warehouse 1/2/3 | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse A | $0 | $0 | $0 | $0 | $0 | $0 |
| Supplier E Warehouse B | $9,056 | $61,666 | $0 | $0 | $0 | $70,723 |
| TOTAL | $170,748 | $222,150 | $241,220 | $224,460 | $180,112 | $1,038,692 |

### 4.6 Scenario 6 – Sensitivity Analysis

In Scenario 6, there are several changes to the constraints made to the model. First, the price per pound is decreased to $1.25 from Suppliers A, B, C and E. Supplier D has an assumed FOB price of $1.23. This is a decrease from the 2014 FOB price of $1.55 from Supplier A, B, C and E and $1.54 from Supplier D. The monthly storage rate associated with Supplier E is decreased. The model was built with the constraint that all 5 approved suppliers are offered at least 40,000 pounds of volume to mitigate potential supply risk. The model assumes that the Company will not use a SMI program so there will be some impact to the Company's working capital.

In this model the cost at harvest to the Company will be $6,623,692 (Figure 4.7). T&W charges for the season will be $1,038,692 (Table 4.11). The Q1 release will come from Supplier D through Warehouse B at a volume of 900,000 pounds for a T&W cost of $170,748 (Table 4.11); Q2 releases will come from Supplier D through Warehouse B at a volume of 480,000 pounds and from Supplier E through Warehouse B for a T&W cost of $222,150 (Table 4.11); Q3 releases will come from Supplier A through Warehouse 1/2/3 at a volume of 200,000 pounds, Supplier B through Warehouse 1/2/3 at a volume of 40,000 pounds, Supplier C through Warehouse 1/2/3 at a volume of 40,000 pounds, Supplier D through Warehouse 1/2/3 at a volume of 620,000 pounds all with a total T&W cost of $241,220 (Table 4.11); the Q4 release would be from Supplier A through Warehouse 1/2/3 at a volume of 900,000 pounds and a total T&W cost of $224,460 (Table 4.11); lastly the Q5 release would be from Supplier A though Warehouse 1/2/3 at a volume of 900,000 pounds for a total T&W cost of $180,112 (Table 4.11). The total savings around T&W between this scenario and the Base Scenario is $312,244 (Figure 4.9) and the total delivered cost saving is $1,689,644 (Figure 4.8).

**Figure 4.6: Scenario 6 – Sensitivity Analysis**

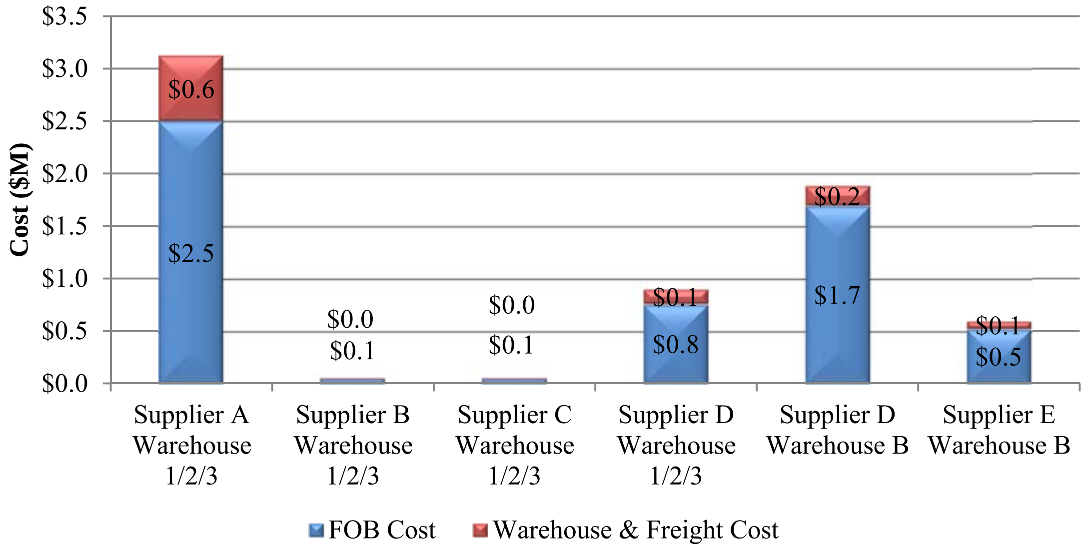



**Figure 4.7: Total Spend – FOB +T&W**

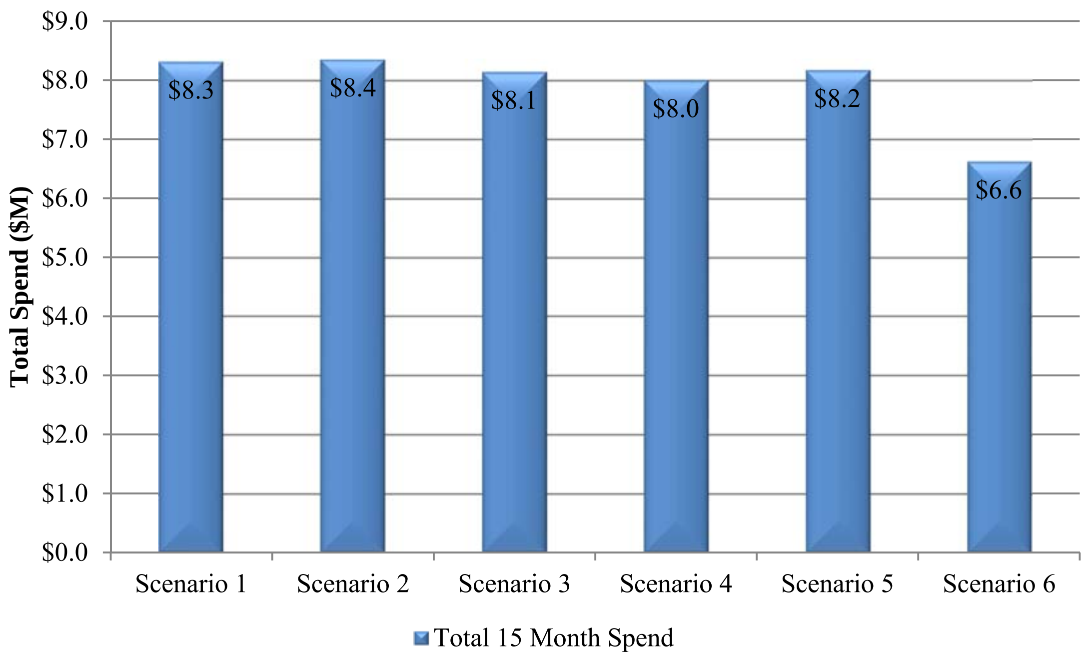


**Figure 4.8: Total Delivered Cost Savings Based on Scenario 1**

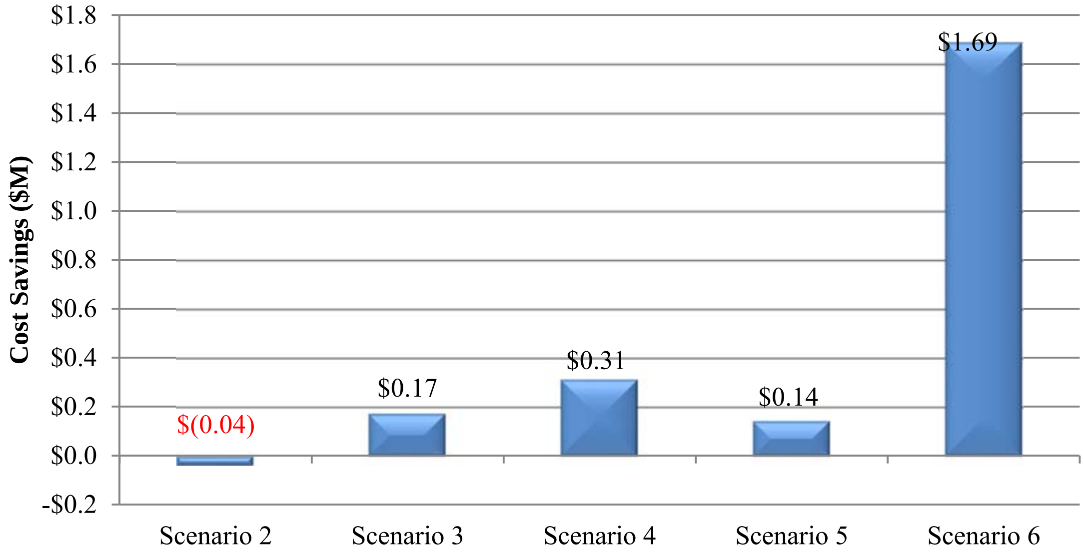



**Figure 4.9: T&W Cost Savings**

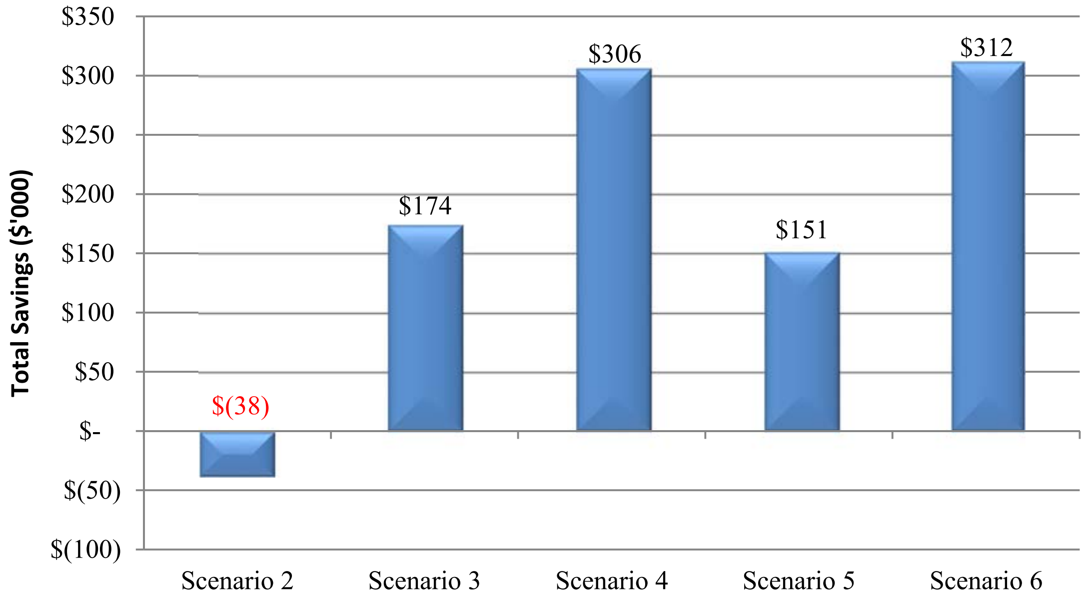


**Table 4.13: Description of Alternative Scenarios Investigated**

| Scenario | Description | Specific Parameters |
|---|---|---|
| 1 | Base Scenario | Utilized all 5 suppliers<br>Buyer driven<br>Immediate Transfer – Supplier A<br>Supplier Managed Inventory- Suppliers B,C,D and E<br>Production plant to release loads randomly<br>All loads are transported via rail through warehouse A |
| 2 | 2015 Plan A | Utilized all 5 suppliers<br>Price is held constant<br>Immediate Transfer – All suppliers<br>Production plant to release loads randomly<br>All loads are transported via rail through Warehouse A |
| 3 | 2015 Plan B | Utilized all 5 suppliers<br>Price is held constant<br>Buyer driven<br>Immediate Transfer – All suppliers<br>Production plant to release loads randomly<br>All loads are transported via rail through Warehouse B |
| 4 | Transfer Immediately | Utilized Suppliers A, D and E<br>Price is held constant<br>Excel Solver driven<br>Immediate Transfer<br>Solver picks volume, route and inventory for releases<br>Loads are mixed between rail, truck and warehouses for optimal cost savings |
| 5 | Supplier Manager Inventory | Utilized Suppliers A, D and E<br>Price is held constant<br>Excel Solver driven<br>Supplier manages the inventory<br>Solver picks volume, route and inventory for releases<br>Loads are mixed between rail, truck and warehouses for optimal cost savings |
| 6 | Sensitivity Analysis | Utilized all suppliers<br>Price is decreased<br>Supplier E's monthly storage rate decreases<br>Excel Solver driven<br>Immediate Transfer<br>Solver picks volume, route and inventory for releases<br>Loads are mixed between rail, truck and warehouses for optimal cost savings |

# CHAPTER V: CONCLUSION AND RECOMMENDATION

The result from this research indicates that cost savings are achievable when a linear optimization model is used as a tool for developing a procurement strategy focused on total delivered cost. The objective of this thesis is to develop an optimization solution to the procurement of sieved red raspberries to enhance operations at the Company's manufacturing facilities. The specific objectives are as follows:

1. Develop a linear optimization model to find the best procurement strategy for the Company's sieved red raspberry business
2. Estimate the cost savings that would arise from the best procurement strategy relative to the status quo.

This study provides a model that can be leveraged in the procurement of other ingredients, not just fruit. The model provides an opportunity to a study where cost savings and efficiencies that are not easily achieved due to harvest cycles, similar supplier pricing and the close proximity of the supply base to each other.

## 5.1 Conclusion

The current buy of sieved red raspberries is represented in Scenario 1. Table 5.1 captures the breakdown of cost and cost savings for each scenario. The Company spent over $8.3 million dollars on Scenario 1 in the 2014 season. Scenarios 2 and 3 did not use an optimization model. Scenario 2 costs the Company nearly $40,000 more than the 2014 season. Scenario 3 is slightly better in that a savings of nearly $174,000 is achieved in comparison to Scenario 1 by changing warehouse locations. Scenarios 4, 5 and 6 use optimization technology and provide savings that are easily achievable if incorporated into the procurement strategy for the 2015 red raspberry season. Scenario 4 produces over

$313,000 in total delivered cost savings, Scenario 5 produces over $143,000 in total delivered cost saving. Scenario 6 produces over $1.6 million in savings mainly driven by a change in the FOB starting price of the sieved red raspberries. Overall, this study is successful in achieving the objectives set forth in Chapter 1.

## 5.2 Recommendation

The recommendation for the 2015 red raspberry season is to use Microsoft Excel OpenSolver for additional monthly detail. This will allow for monthly coordination of raw materials and more visibility around cost per case. A second sensitivity analysis should be conducted; one with a SMI program and one without a SMI program. This data can be presented to leadership and a decision can be made to take the inventory shortly after harvest or have the supplier manage the inventory for a fee. There are potential risks and rewards with each option that decision makers within the organization need to be aware of to make the best decision for the long term success of the Company. The business is structured in such a way that a SMI program can be utilized for the portion of the fruit procured for higher margin items and a non SMI program can be used to show savings in brands with lower margins such as private branded finished goods.

It is recommended that the five approved U.S. based suppliers continue to be used to fulfil the Company's demand. It is also recommended that the Company go outside the U.S. to source sieved red raspberries as part of the overall risk mitigation strategy. Lastly, a strategy of negotiating better net payment terms, improving the specification and developing a score carding metric in the fruit category could also help drive down the total delivered cost.

**Table 5.1: Summary**

| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 |
|---|---|---|---|---|---|---|
| FOB Spend | $ 6,962,400 | $ 6,963,000 | $ 6,963,000 | $ 6,955,000 | $ 6,970,000 | $ 5,585,000 |
| T&W Spend | $ 1,350,936 | $ 1,389,430 | $ 1,176,720 | $ 1,044,592 | $ 1,199,812 | $ 1,038,692 |
| Total Delivered Cost | $ 8,313,336 | $ 8,352,430 | $ 8,139,720 | $ 7,999,592 | $ 8,169,812 | $ 6,623,692 |
| T&W Savings | | $ (38,495) | $ 174,216 | $ 306,344 | $ 151,123 | $ 312,244 |
| Total Delivered Cost Savings | | $ (39,095) | $ 173,616 | $ 313,744 | $ 143,523 | $ 1,689,644 |

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