BANANA TRANSSHIPMENT MODEL

by

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ABSTRACT

Bananas are the number one selling produce item in the grocery store. On average, bananas account for 6% of produce department sales and 1% of total grocery store sales. According to The Packer's "2010 Fresh Trends", 88% of consumers in all categories purchase bananas. Also, 94% of consumers in the study purchased bananas within the last twelve months.

Over the last decade, fuel prices have increased to a point where logistics and shipping have become more important than ever to the banana industry. This logistics challenge is compounded because there are no bananas grown in the United States and the fruit has to be shipped from around the world. Fuel is used at high rates via the ocean cargo and trucking shipments to meet yearly demand. To manage these logistical challenges, this thesis analyzes the optimal shipping route for bananas arriving to the west coast from Central and South America to various markets using a transshipment model. The goal of the transshipment model estimates the supply chain that creates the lowest cost. Through analysis of fuel, trucking, and shipping markets, the model makes the optimal decision regarding transportation routing. The model is limited to transportation costs only. However, items such as fruit costs and other additional up charges could be analyzed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER I: INTRODUCTION

Dole Food Company based in Westlake Village, CA is the largest producer of fruit and vegetables in the world. Dole was founded in 1851 by James Dole with the core competency of growing and canning pineapple. James Dole's goal was to make pineapple available to all grocery stores around the United States. In 1964, James Dole's Hawaiian Pineapple Company was acquired by the Castle and Cook Corporation along with Standard Fruit and Steamship Company to give Castle and Cook product leadership in both the pineapple and banana industry. In 1991, Castle and Cook officially changed its name to the Dole Food Company. Dole now conducts business in 90 countries and employees 36,000 full-time, regular employees and an additional 23,000 full-time seasonal or temporary employees, worldwide. Dole's mission statement is to "supply the consumer and our customers with the finest, high-quality products and to lead the industry in nutrition research and education."

1.1 Products and Distribution

According to Hoovers 2012, some 200 products are sourced, grown, processed, marketed, and distributed by Dole in more than 90 countries; and sold to supermarkets, mass merchandisers, wholesalers, and foodservice operators worldwide. Dole owns 14,800 refrigerated containers, 11 vessels, 122,000 acres of farms and other holdings including 26,000 acres of farmland in Hawaii. Dole Food Company is divided into three divisions: fresh fruit, fresh vegetables, and packaged foods. According to Hoovers, in North America, Dole fresh fruit holds the top market share in bananas. On an annual basis, Dole produces about 165 million boxes. Dole leads the United States banana market with more than 35% share; in Japan, Dole has a 31% market share. Dole ships a variety of fruits from Central and South America to five ports in the US; Gulfport (MS), Freeport (TX), Port Everglades (FL), Port of San Diego (CA), and Port Wilmington (DE).

Dole Fresh Vegetables focuses on sourcing, harvesting, cooling, distributing, and marketing various fresh and fresh-cut vegetables. Products in the vegetable lineup include: iceberg lettuce, red and green leaf lettuce, romaine lettuce, butter lettuce, celery, cauliflower, broccoli, carrots, brussel sprouts, green onions, asparagus, snow peas, artichokes, and radishes, as well as fresh strawberries and raspberries. This segment also processes and markets value-added vegetable products. Dole holds the number one position in cauliflower, celery, and iceberg lettuce (Hoovers). Dole Fresh Vegetables sources a majority of their products from the US. The number one selling product is bagged salads sourced from plants located in Salinas (CA); Springfield (OH); and Bessemer City (NC). Worldwide, the company owns more than 1 million sq. ft. of vegetable processing facilities.

Dole's packaged food branch produces and markets canned pineapples, canned pineapple juice, fruit juice concentrate, fruit parfaits, snack foods, frozen fruits, as well as fruits in plastic cups, jars, and pouches. The packaged food branch has 1.9 million sq. ft. of manufacturing facilities. The primary focus is the marketing and sale of value-added products. A majority of Dole's fruit is sourced from the Philippines due to raw fruit costs. It is cheaper to source packaging in East Asia. Dole packaging also markets its name to PepsiCo for the marketing and branding of Dole fruit juice, though it does not handle fruit juice.

1.2 Banana Quality

Dole Fresh Fruit is Dole Food Company's largest division and Dole's market niche is to focus on quality. Dole fresh bananas are sourced from six countries; Colombia, Costa Rica, Ecuador, Guatemala, Honduras, and Peru (Organic bananas). Bananas arrive fully containerized and are stored between 56^0 and 65^0F. If bananas are stored below 56^0F, the peel will deteriorate and turn black; this is referred to as "chill damage". If bananas are stored above 65^0F, the pulp will begin to mature at an advanced rate and will become mushy. The peel will also show black spots.

Bananas are removed from the container and placed in a ripening room. The fruit is then exposed to ethylene gas and heat which brings bananas to the desired color that retailers wish to sell at their stores. Dole's focus is to get the highest quality banana to the consumer.

1.3 Banana Competitors

Dole Fresh fruit faces heavy competition from two major multinational companies; Chiquita and Del Monte Fresh. Dole is also facing competition from companies working directly with farmers in the tropics that ship their fruit on third party vessels like Maersk and Hamburg Sud.

1.3.1 Chiquita

Chiquita Brands International is based out of Cincinnati Ohio and is Dole's primary competitor in the banana market. The key difference between Dole and Chiquita is company marketing. Chiquita has built strong brand awareness across the world using the infamous Chiquita banana lady. They have also spent advertising dollars to brand their product with "catchy" jingles. Chiquita competes with Dole Salads under the brand Fresh Express, and holds the dominant position in bagged salads. Chiquita's strategy is to "provide more convenient, healthy-food options to meet the needs of consumers" (Hoovers).

Bananas account for 60% of Chiquita's total sales. Its other offerings include whole citrus fruits, melons, grapes, apples, and tomatoes, as well as packaged fresh-cut items, processed fruit ingredients, and juices. The firm's Fresh Express segment generates about a third of its sales and is the leading US seller of packaged ready-to-eat salads. Chiquita's products are sold in nearly 70 countries, mainly in North America and Europe. Lesser markets include the Middle East, Japan, and Korea (Hoovers).

Chiquita's business has a global reach. Company-owned farms produce one-third of Chiquita's bananas. Like Dole, to satisfy demand, the company looks to third-party growers in Ecuador, Costa Rica, Guatemala, Colombia, Panama, Honduras, Mexico, Nicaragua, and the Philippines for the balance of its bananas.

1.3.2 Del Monte

Fresh Del Monte fruit currently is the third largest company in terms of banana sales, however, they continue to grow and are becoming threat to both Dole and Chiquita. Del Monte focuses on having the lowest price point. They achieve the low price point using less debt than the other two companies due to a vertically integrated supply chain that includes ripening centers. These ripening centers allow Del Monte to work directly with retailers such as Costco and Trader Joes.

Fresh Del Monte's brand names include Del Monte, Rosy, and UTC. Its prepared and fresh-cut foods include potato salad, cole slaw, bagged sliced products, fruit juices and fruit drinks (Hoovers). Fresh Del Monte sells its fruit and vegetables in more than 100 countries.

The company grows and sources its produce primarily in the same locations as Dole and Chiquita. In 2010, 45% of the fresh produce sold was grown on company-controlled (owned or leased) farms (Hoovers). This is the highest figure among the top three banana companies. North America is Del Monte's largest market, accounting for nearly 50% of its sales. Bananas are Fresh Del Monte Produce's biggest product segment and made up 46% of its 2010 sales.

The company transports its fresh produce to markets using a fleet of more than 25 refrigerated vessels and operates four port facilities in the US.

1.3.3 Direct Imports

A new threat is beginning to develop from farmers that are willing to direct ship product to major retail accounts. Farmers are taking the banana customer lists and reaching out to those companies. The farmers ship full containers of bananas by collaborating with shipping lines such as Maersk and Hamburg Sud that ship the container directly to the port closest to the retail market. Without the need for a container vessel, these direct importers have flexibility in shipping product. The other issue is that the direct importers have an advantage the major banana shippers do not have because they do not have the financial obligations of owning their ships.

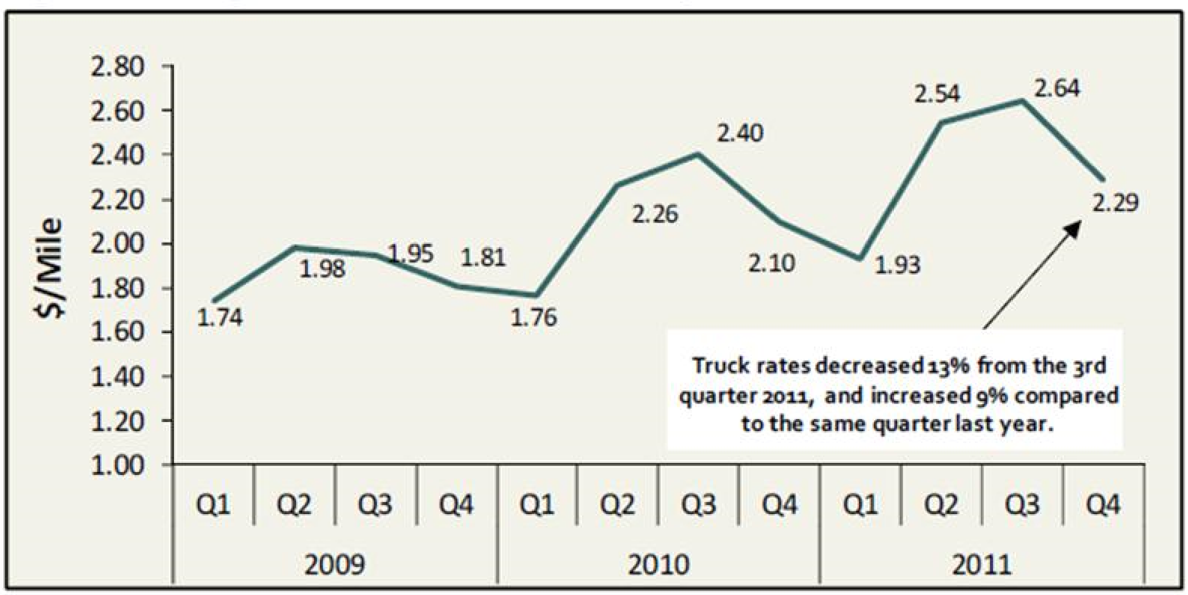
The challenge direct-import companies face is that they are new to shipping fresh fruit product and many times fruit transport gets slowed going through customs. These companies are still relatively small and rely on the shipping companies and to get their product off the vessel in a timely manner.

1.4 Transportation

Over the last decade, the US has experienced fuel price increases that are some of the highest in recent history. These fuel price increases have put additional stress on companies to lower production costs, and minimize transport costs. To understand why transportation costs have increased over time, consider the price of diesel fuel. A 53 foot truck averages between 5 and 6 miles per gallon. The farther you get away from the port, the more cost is put on the retailer. Consumers do not react well to price changes due to transportation cost.

Figure 1.1 is from the USDA's Agricultural Refrigerated Truck Quarterly that shows the national average truck rate per mile for carriers shipping agricultural products.

Figure 1.1: Average Truck Rates for Selected Long-Haul Routes ($/mile)



Source: Agricultural Refrigerated Truck Quarterly:Q4 2011

1.5 Problem Statement

This thesis analyses the optimal shipping route for product arriving to the west coast of the US from Central and South America using a transshipment model. The model takes the cost of shipping the banana containers throughout the supply chain and seeks to minimize total transportation cost. The model is limited to transportation costs only, though items such as fruit cost and other charges could be analyzed for a comprehensive cost analysis. Two possible choices are considered for entry of bananas into the US: San Diego and Seattle. Even though it takes more time to ship fruit to Seattle, the time interval is not an issue because it takes roughly the same amount of time as San Diego once you add inland freight time.

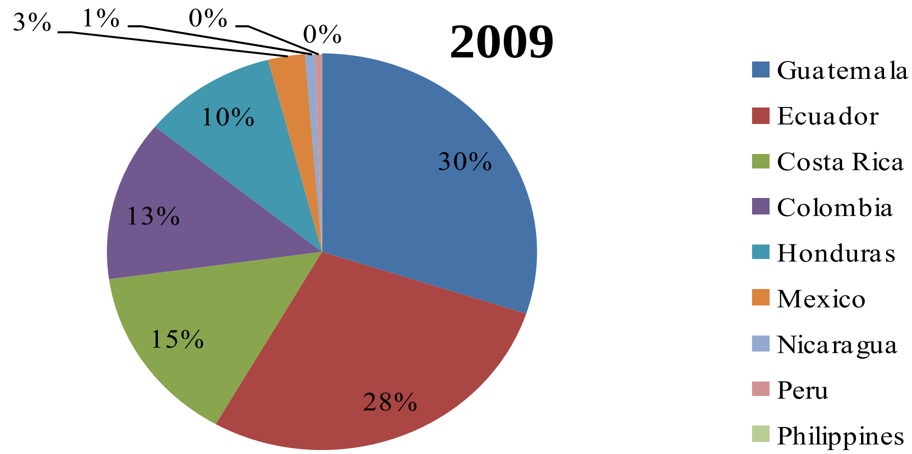
CHAPTER II: THE BANANA MARKET

Bananas are the number one selling produce item in the grocery store. On average, bananas account for 6% of produce department sales (Dole Retail Handling Guide) and 1% of total grocery store sales. Typically, bananas are marketed as a "loss leader" to draw consumers into the store. According to The Packer's "2010 FreshTrends", 88% of consumers in all categories purchase bananas. Also, 94% of consumers in the study purchased bananas within the last twelve months. The demographic that purchased the most bananas were parents with young children. Consumers with higher incomes had a higher likelihood of purchasing bananas than those who earned less than $25,000/ year. Regarding consumption habits, 77% of consumers felt that they were capable of picking ripe fruit for immediate consumption.

2.1 Banana Exports

Although Dole brings in fruit from six countries, competitors source bananas from additional countries. These countries include Mexico, Nicaragua and the Philippines. During 2009, Guatemala was the largest exporter of bananas to the US. According to the Department of Commerce, Foreign Trade Statistics, Guatemala exported 1,162,166 metric tonnes of bananas to the US (Figure 2.1). The next closest supplier was Ecuador with 1,085,770 metric tonnes of bananas exported to the US. Peru had the smallest amount of bananas exported to the US in 2009 with 19,677 metric tonnes.

Figure 2.1: Percentage of Banana Exports by Country to the US in 2009

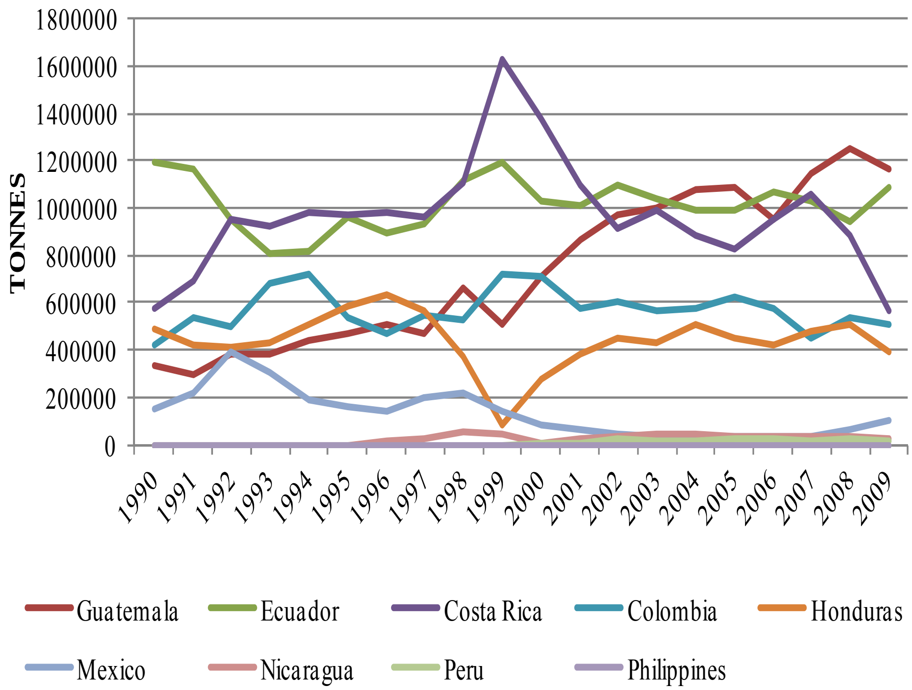


Source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics 2011

2.2 Banana export market growth

Guatemala is a major player in the banana export market to the US, however, this has not always been the case (Figure 2.2). Guatemala was able to increase banana production due to its port infrastructure that allows companies to ship out of the Gulf of Mexico and the Pacific Ocean. The country has also developed a strong labor pool through education that has increased fruit yields. In 1990, it was the smallest of the major banana producing countries, producing only 334,006 metric tonnes of bananas (Table 2.1). On the other hand, Costa Rica went from being the top banana exporter in the late 1990s to the third highest producing country. Costa Rica continues to grow and become a more developed country, moving workers out of agriculture. Thus, Costa Rica has seen rising production costs due to higher fertilizer, labor, and land costs.

Figure 2.2: Total Banana Exports to the US by Country



Source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics 2011

Table 2.1: Total Bananas Exported to the US (in Metric Tonnes)

Year	Guatemala	Ecuador	Costa Rica	Colombia	Honduras	Mexico	Nicaragua	Peru	Philippines
1990	334,006.70	1,189,617.90	574,447.30	424,510.60	487,990.10	151,849.50	0	0	0
1991	295,048.20	1,162,787.20	688,565.00	537,960.50	417,541.80	215,569.20	0	0	0
1992	382,271.20	953,356.00	956,750.80	495,697.00	413,275.70	396,133.10	0	0	0
1993	377,787.10	807,232.70	926,821.70	683,094.30	428,909.60	308,744.10	19	0	0
1994	444,773.70	815,708.60	982,265.90	724,751.10	503,319.60	191,903.80	0	0	0
1995	465,003.50	966,383.80	968,322.50	535,891.70	584,107.70	156,196.80	596.8	0	0
1996	506,904.70	896,229.60	979,996.30	467,987.90	634,712.30	142,298.50	19,207.50	0	0
1997	466,218.80	929,880.90	962,256.80	543,499.30	564,820.70	203,075.30	22,537.90	0	0
1998	661,901.80	1,117,698.70	1,105,961.10	527,348.70	377,181.30	221,219.90	57,754.80	0	0
1999	512,181.50	1,197,655.20	1,632,979.20	722,491.80	83,692.90	140,814.30	39,711.50	0	18.3
2000	708,951.50	1,027,057.70	1,377,996.80	708,733.20	277,745.50	85,132.30	1,906.20	702.9	20.5
2001	861,402.70	1,006,701.10	1,098,553.00	573,936.30	381,867.10	63,839.00	28,197.80	6,220.70	6.5
2002	968,940.60	1,094,100.30	914,218.10	601,283.40	449,227.40	42,389.70	29,829.70	23,211.60	2.6
2003	997,206.50	1,044,397.10	990,433.80	568,447.50	432,180.60	35,219.50	41,693.60	13,756.30	63.7
2004	1,073,969.90	994,909.80	882,726.40	575,989.10	508,154.40	33,617.80	41,694.50	12,384.00	38.8
2005	1,083,405.60	986,810.70	831,088.00	624,764.70	453,671.70	33,855.70	38,142.60	22,344.80	0
2006	955,733.80	1,072,829.00	949,884.90	572,944.60	423,338.60	38,673.70	30,671.20	25,055.50	0
2007	1,143,653.00	1,030,067.20	1,058,964.00	454,707.60	483,571.20	31,627.40	35,058.80	17,847.70	0
2008	1,248,167.60	942,661.10	883,866.90	534,285.80	507,111.10	66,629.50	35,327.50	22,533.90	0
2009	1,162,166.10	1085770.1	563655.5	506669.8	389377.9	106877.9	28930.6	19677.4	0.0

Source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics

CHAPTER III: THEORY

The banana industry is a complex system due to the fact that bananas must be imported to the United States every week. Major banana suppliers operate their own shipping companies as a means of providing product to consumers. Therefore, efficient shipping is important because each company is focused on delivering fruit quickly and at a reduced cost. Another reason why shipping is so important is that bananas cannot be stored for more than two weeks after they arrive to the US due to quality issues.

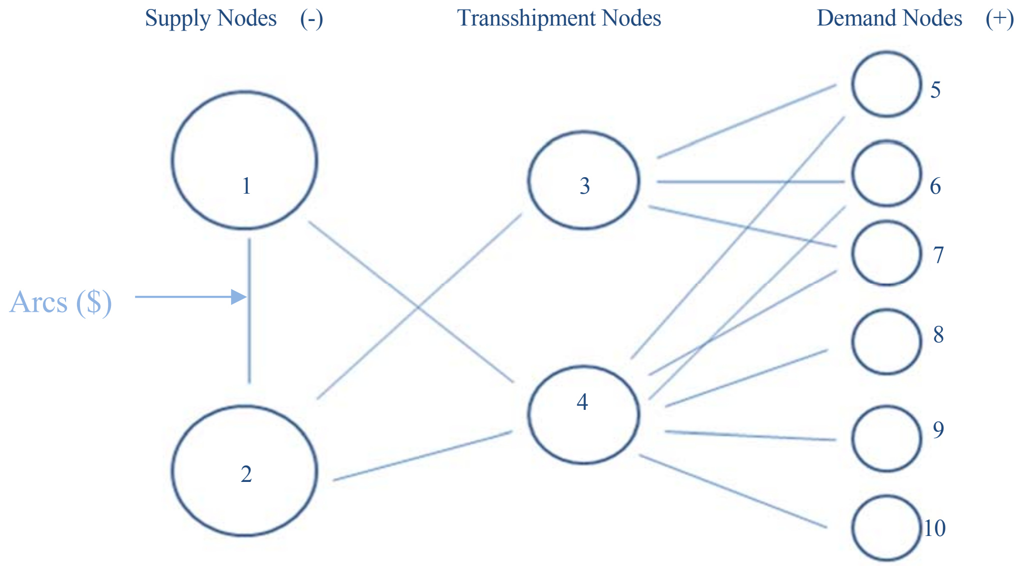
The shipping issue is a network flow problem. Network flow problems include transshipment, shortest path problems, and other considerations. In an effort to provide the most efficient shipping method to get product to customers in North America, a transshipment model was formulated.

3.1 Nodes and Arcs

Transshipment models have shipping or supply nodes that represent the locations that are able to send and receive product (Figure 3.1). Transshipment nodes must be greater or equal to zero. Demand nodes represent the final destination for product. Demand nodes are represented by a positive number, while supply nodesare represented by a negative number.

The shipping lines that are used to move product between nodes are called arcs (Figure 3.1). These arcs provide the overall cost to move product. Each arc is given a dollar value to determine the cost of shipping between two nodes in the network.

Figure 3.1: Network Flow Model



3.2 Goal of Transshipment Model

The goal of transshipment models is to identify the optimal shipping routes for products through the network. For this analysis, the goal is to minimize the shipping cost of shipping product from supply nodes to demand nodes.

When applying this concept using formulas, each node to node transfer is defined as:

X_{ij} = the number of products shipped from node *i* to node *j*

For this analysis, the products being shipped are containers of bananas from different countries or markets. For example *i* could be a country in South America and *j* could be a port in the United States or *i* could be a port and *j* could be a market that demands bananas. An example of this transfer would be:

X_{14} = Number of banana containers shipped from supply *node 1* to transshipment *node 4*

3.3 Objective function

As stated earlier, the goal of this model is to estimate a minimum cost network flow problem. To complete this model, transportation costs for each arc are established to determine the minimum cost. Each arc is assigned transportation cost to allow the model to find the most optimal way to get product to a market. Each node to node transfer would look like:

$\mathbf{C}_{ij}$ is the Cost of the number of banana containers shipped from *i* to *j*

The objective function to get product to demand nodes from the transshipment nodes for this problem is:

$$\text{Min } \sum_i \sum_j C_{ij} X_{ij}$$

3.4 Constraints

Even with the minimum cost for each node to node transfer, there is still another issue. There is only a finite amount of product to ship and markets only require so much product. Otherwise you would ship all product from a supply node to a demand node along the cheapest route, which could be the only market. To ensure that this does not occur, constraints are established in the network flow problem.

Supply Constraint: $\sum X_{ij} \leq S_i$ for all I, where S_i is the supply at node *i*.

Demand constraints: $\sum X_{ij} \geq D_j$ for all J, where D_j is the demand at node *j*

$X_{ij} \geq 0$ is required for nonnegativity.

Once constraints are established for all nodes, the model is solved.

CHAPTER IV: METHODS

4.1 Data

The data for the transshipment model came from a variety of sources. Transportation data for trucks were derived from USDA's Agriculture Refrigerated Truck Quarterly report. The freight cost/ mile was combined with distance travelled to determine transportation cost. The amount of fuel burned per day on a container vessel was taken from wtsacarriers.org (Westbound Transpacific Stabilization Agreement). The average fuel burned per day is multiplied by the number of days it takes to get from Central/South America to San Diego. The number of days travelled is derived from nautical miles between ports multiplied by the number of miles the vessel travels in a day. Bunker fuel price was taken from Bunkerworld.com (Bunkerworld Prices). The cost to ship a container from Puerto Quetzal, Guatemala was an estimated number. Finally, market demand was to ensure the vessel is operating at its maximum capacity.

4.1.1 Transportation Data

The transportation cost of $2.54/ mile was collected from 2011 Second quarter data from the USDA's "Agricultural Refrigerated Truck Quarterly". The high transportation cost is a result of traffic in Southern California. The driver may only be travelling a short distance; however that distance may take several hours to maneuver due to the extreme traffic congestion between San Diego and Los Angeles.

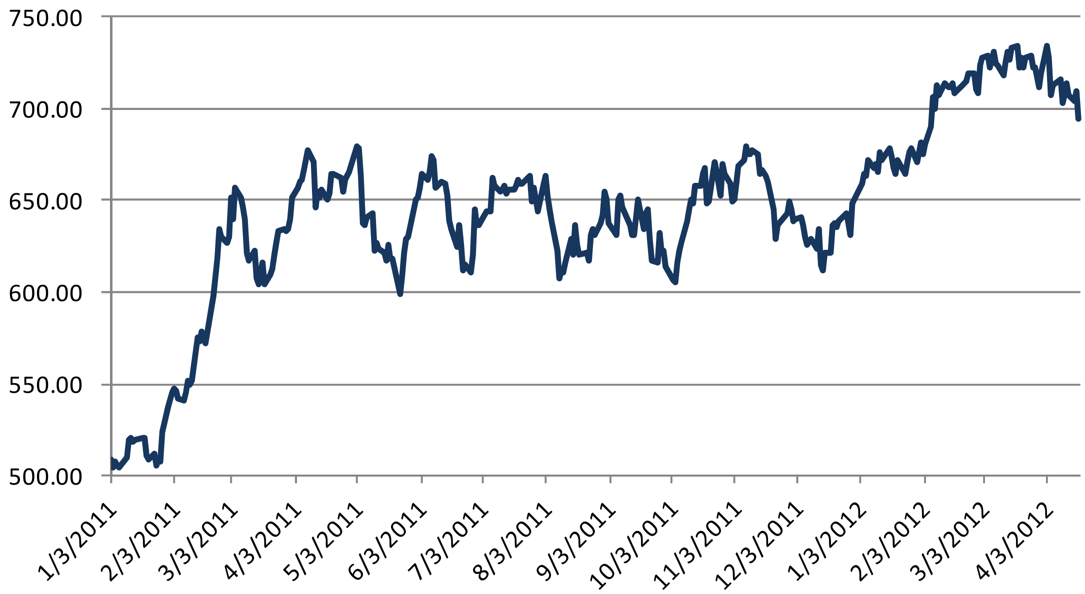
4.1.2 Fuel Cost Per Voyage

The amount of 127 tonnes of bunker burned/ day comes from the WTSA. According to their website, "The Westbound Transpacific Stabilization Agreement is a research and discussion forum of 11 major ocean container shipping lines that carry cargo from ports and inland points in the US to destinations throughout Asia (WTSA)."

4.1.3 Bunker Fuel Cost

The price of $527/metric tonne was the mean price for Houston ISO380 that was derived from analyzing Houston IFO 380 bunker fuel prices from January 1st, 2011 through April 10th, 2012. Bunker fuel closing prices were taken from BunkerWorld.com. Banana companies typically use "swaps" as a risk management tool and a swap would have been made at the beginning of the quarter. Swaps are used to set a standard price for a period of time. If the price of bunker goes over the set price, one side pays the other the difference. If the price goes under the set "swap price", the banana company pays the other side. The average price for Bunker fuel during the time studied was $644/metric tonne and the price ranged from $504 to $734 per metric tonne (Table 4.1).

Figure 4.1: Cost of Houston 180 Bunker Fuel from 1/1/11-4/10/12



Source: Bunkerworld.com

Table 4.1: Descriptive statistics for Bunker fuel from January 1, 2011 to April 10, 2012

Mean	644
Median	648
Standard Deviation	50.45
Minimum	504
Maximum	734
Count	325

Source: Bunkerworld.com

4.1.4 Number of Containers on the vessel

This data was provided from the team at the Port of San Diego. The assumption was made that Dole would make sure that the vessel is filled to its capacity by adding commercial cargo to eliminate dead freight costs. The number of containers is then distributed to different markets on the west coast.

4.1.5 Distance and Nautical miles travelled per hour

Distance travelled between each port and the distance traveled from the port to each market is an essential part when calculating the cost of shipping product (Table 4.2 and 4.3). This is where most costs are incurred. The miles per hour travelled is important because it determines how far you go each day. Due to the age of the vessels, a speed of 15.5 MPH was used.

Table 4.2 Number of Miles between Ports

Departure Port	GUAYAQUIL	PUERTO QUETZAL	GUAYAQUIL
Arrival Port	SAN DIEGO	SAN DIEGO	PUERTO QUETZAL
Distance (nautical miles)	2972	1762	1290

Table 4.3 Miles from Port to Each Market

Port	Market	Miles
San Diego	Los Angeles	120
San Diego	Portland	1083
San Diego	Seattle	1255
San Diego	Denver	1100
San Diego	Salt Lake	750
San Diego	Sacramento	500
San Diego	Fresno	336
San Diego	San Fran	500
San Diego	Billings	1297
San Diego	Boise	1314
San Diego	Puyallup	1228
San Diego	Spokane	1303
San Diego	Calgary	1606
San Diego	Vancouver	1395
Seattle	Portland	165
Seattle	Billings	812
Seattle	Boise	505
Seattle	Puyallup	30
Seattle	Spokane	280
Seattle	Calgary	706
Seattle	Vancouver	140

4.2 Cost Determination

To build the model to estimate optimal shipping routes, transportation costs were calculated. Below are the factors used for calculating costs.

BFC	Bunker Fuel Cost
BTB	Bunker burned per day
CPD	Cost per day
CPC	Cost per container
D	Demand for fruit
Dis	Distance
FC	Fuel Cost per trip
FPC	Freight cost per container
FRP	Freight rate per mile
M	# of miles from port
MPD	Miles travelled per day
MPH	Miles travelled per hour
T	Number of days travelled
TCT	Total cost per trip

4.2.1 Miles Travelled per day

First, the distance travelled per day is calculated. The average miles per hour traveled is multiplied by 24 hours.

$$MPD = MPH*24 \text{ hours}.$$

4.2.2 Number of days travelled

The distance to port is divided by the miles travelled per day which provides the total number of days that it takes to get to port.

$$\#T = D/MPD.$$

4.2.3 Cost per day to ship fruit to ports

To calculate cost per day, the miles travelled per day is multiplied by bunker burned per day and by Bunker Fuel cost.

$$CPD = MPD*BTB*BFC.$$

4.2.4 Total cost per trip

The total cost per trip is calculated by multiplying the numbers of days travelled by the cost per day to ship fruit.

$$TCT = CPD*\#T.$$

4.2.5 Freight cost per container

To calculate the cost to get a container to each market, the freight rate per mile is multiplied by the total miles from the port to the market.

$$FPC = M*FRM.$$

4.2.6 Cost of each container

The final amount is the cost per container. To calculate this, the total cost to ship product is divided by the total number of containers demanded for the shipping country.

$$CPC = TCT/D.$$

CHAPTER V: TRANSSHIPMENT MODEL

The model allocates product from the Port of Guayaquil, Ecuador (Node 1) and Puerto Quetzal, Guatemala (Node 2). The inventory on hand at these ports is listed as negatives (Figure 5.1). Guayaquil has a supply of 700 containers and Puerto Quetzal has a supply of 200 containers. The product is then shipped to either the port of San Diego (Node 3) or the Port of Seattle (Node 6). Both of these ports are shipping points to markets across the West coast of the United States. The port that the product is shipped to provides the lowest possible transportation cost to a given market. Bunker fuel consumption per day is set to take advantage of smaller coastal waves that reduce the amount of bunker fuel burned per day opposed to times with high waves. High waves cause more fuel to be burned because the waves knock the vessel off track and more power is be used to maintain a strait path. Distance is listed in nautical miles and calculates the cost of shipping fruit between Guayaquil, Ecuador and Puerto Quetzal, Guatemala and to San Diego and Seattle. Finally, the number of containers demanded is set to reflect actual demand for west coast markets. By decreasing the number of containers demanded, the model updates itself to reflect higher costs per container to ship product from the tropics to the United States.

5.1 Model Explanation

5.1.1 Market Demand

The West Coast banana market is one of the largest in the world. Retailers pull from Southern California and to bring bananas to markets across the west coast. To determine volume, assumptions on total weekly volume reported for one of the major banana companies is listed in the Supply/Demand column (Table 5.2). The numbers of containers was determined by the size and scope of the markets. Total volume demanded on a weekly basis is 410 containers per week. Each market is identified by a node from 3-17.

Table 5.1: Banana Supply

Nodes		Supply
1	GUAYAQUIL	-700
2	PUERTO QUETZAL	-200

Table 5.2: Demand for Bananas

Nodes		Supply/Demand
3	San Diego	0
4	Los Angeles	60
5	Portland	30
6	Seattle	14
7	Denver	30
8	Salt Lake	35
9	Sacramento	40
10	Fresno	25
11	San Fran	50
12	Billings	26
13	Boise	25
14	Puyallup	30
15	Spokane	10
16	Calgary	15
17	Vancouver	20

5.1.2 Market Supply

Given a demand of 410 containers per week, product can be supplied from either Guayaquil (Ecuadorian fruit) or Puerto Quetzal (Guatemalan fruit) (Table 5.1). Seven hundred containers per week are provided from Ecuador because this fruit is only shipped to California. Two hundred containers are allocated to Puerto Quetzal because Guatemalan fruit is shipped all over the United States and is limited on the west coast. Because the vessel must stop in Ecuador to pick up majority fruit and Ecuador is where the vessel originates and has the supply to fill the west coast market, another constraint is added to make sure the product cannot just ship from Guatemala. The number of containers shipped from Guayaquil must be greater than or equal to the numbers of containers shipped from Puerto Quetzal.

5.1.3 Assumptions

To solve the model, assumptions defining how much each voyage would cost are determined from the analysis from Chapter 4. The average cost of Bunker Fuel is $644 per metric tonne. Next, the vessel speed of 15.5 Nautical miles per hour is used (Table 5.3). This allows for the most fuel efficient voyage possible. The nautical miles per day is multiplied by 24 hours to equal 372 miles travelled per day. Finally, a freight rate for trucks of $2.50 per mile travelled from the US port to the market is assumed.

Table 5.3: Components

Bunker fuel	MPH	Miles/day	Truck rate/mile
$ 644.00	15.5	372	$ 2.50

5.1.4 Cost to ship fruit from Central/South America to US Port

Listed below are the components that determine how much each voyage costs using Dole's own vessel. The distance travelled per day is set in Nautical miles. It takes 8 days to go from Guayaquil to San Diego and 8.2 days if the vessel stops in Puerto Quetzal. The price of Bunker fuel is $644/metric tonne. Fuel burned per day is 127 metric tonnes. The cost to run a vessel for 1 day is $81,788. By multiplying the number of days travelled by the cost per day, the cost to run a vessel from Guayaquil to San Diego is $653,425 and the cost to stop in Puerto Quetzal is $671,013 (Table 5.4).

Table 5.4: Net Costs

	Departure Port	GUAYAQUIL	PUERTO QUETZAL	GUAYAQUIL
	Arrival Port	SAN DIEGO	SAN DIEGO	PUERTO QUETZAL
	Distance(nautical miles)	2972	1762	1290
	# of days travel	8.0	4.7	3.5
	Bunker Fuel Cost/tonnes	$ 644.00	$ 644.00	$ 644.00
Model 1 Low Fuel cost	*Bunker Tonnes Burned/day*	127.00	127.00	127.00
	Cost/day	$ 81,788.00	$ 81,788.00	$ 81,788.00
	Fuel Cost/trip	**$ 653,424.56**	**$ 387,393.70**	**$ 283,619.68**
	Net	**$ 653,424.56**	**$ 387,393.70**	**$ 283,619.68**

5.1.5 Vessel Unit Cost

The cost to ship each container from port to port is a key component when determining the most optimal port to supply from. This figure is calculated by dividing the total cost to ship product between ports by the total number of containers demanded (Table 5.5). The one exception is the Seattle vessel because it has a flat fee that is charged by the third party shipping company and the price does not vary. Figure 5.1 is a map of the proposed supply Change. Currently all produce is shipped through San Diego. Seattle is being examined as an alternative.

Table 5.5: Ocean Freight Costs

From		To		Unit Cost
1	GUAYAQUIL	2	PUERTO QUETZAL	$ 691.76
1	GUAYAQUIL	3	San Diego	$ 1,593.72
2	PUERTO QUETZAL	3	San Diego	$ 944.86
2	PUERTO QUETZAL	6	Seattle	$ 3,500.00

5.1.6 Unit Cost over the road

The unit cost over the road represents the cost associated with shipping product from the port to each market. The cost is $2.50 per mile multiplied by the distance between the port and the market. The only exception is the Seattle, WA to Puyallup, WA because of the cost of delivering product to this arc is a fixed $200.

Figure 5.1: Proposed Supply Chain

Table 5.6: Transportation Freight Costs

From		To		Unit Cost
3	San Diego	5	Portland	$ 2,707.50
3	San Diego	6	Seattle	$ 3,137.50
3	San Diego	11	San Fran	$ 1,250.00
3	San Diego	4	Los Angeles	$ 300.00
3	San Diego	7	Denver	$ 2,750.00
3	San Diego	8	Salt Lake	$ 1,875.00
3	San Diego	9	Sacramento	$ 1,250.00
3	San Diego	10	Fresno	$ 840.00
6	Seattle	5	Portland	$ 412.50
3	San Diego	12	Billings	$ 3,242.50
3	San Diego	13	Boise	$ 3,285.00
6	Seattle	14	Puyallup	$ 200.00
6	Seattle	12	Billings	$ 2,030.00
6	Seattle	13	Boise	$ 1,262.50
6	Seattle	15	Spokane	$ 700.00
6	Seattle	16	Calgary	$ 1,765.00
6	Seattle	17	Vancouver	$ 350.00
3	San Diego	15	Spokane	$ 3,257.50
3	San Diego	16	Calgary	$ 4,015.00
3	San Diego	17	Vancouver	$ 3,487.50

5.1.7 Objective function

The objective is to minimize total transportation cost. Once the model is solved, the lowest cost is determined for the supply chain. To calculate the total cost, the unit cost to ship to port/unit cost over the road is multiplied by the total number of containers being shipped along each arc.

5.1.8 Sample Model Run

To solve the model, solver in Microsoft Excel is used to minimize the total transportation cost where the target cell is the minimum cost.

5.2 Results break down

5.2.1 Demand Results

After solving the model, all demand market nodes in the model received the required fruit (Figure 5.7).

Table 5.7: Net Demand Flow

	Quantity Shipped	Demand
San Diego	0	0
Los Angeles	60	60
Portland	30	30
Seattle	14	14
Denver	30	30
Salt Lake	35	35
Sacramento	40	40
Fresno	25	25
San Fran	50	50
Billings	26	26
Boise	25	25
Puyallup	30	30
Spokane	10	10
Calgary	15	15
Vancouver	20	20

5:2.2 Supply results

Given the constraints, 266 containers are sourced from Guayaquil Ecuador and 144 containers from Puerto Quetzal Guatemala (Table 5.8). The remaining fruit could be sold to a different country or supplier.

Table 5.8: Net Flow of Fruit from the Tropics

	Quantity Shipped	Supply
GUAYAQUIL	-266	-700
PUERTO QUETZAL	-144	-200

5.2.3 Network Flow

The network flow sourced 266 containers from Guayaquil, Ecuador and 144 containers from Puerto Quetzal, Guatemala. Table 5.9 shows that the 266 Guayaquil loads were shipped to San Diego. The markets that the San Diego port will service are San Francisco, Los Angeles, Denver, Billings, Salt Lake City, and Sacramento.

The 144 loads shipped from Puerto Quetzal were shipped to the Port of Seattle and services Boise, Calgary, Seattle, Portland, Puyallup, Vancouver, and Spokane. Figure 5.2 provides a graphical perspective on the optimized supply chain.

Because there were containers removed from the San Diego vessel, the company is now capable of adding new customers in the Southwest because of open space that was taken up by inefficient loads that would have been shipped to the Pacific North West. This is particularly important because the southwest has the highest prices for bananas and are less sensitive to price changes. Overall, this provides an excellent opportunity for a company to grow and expand profits.

Table 5.9: Network Flow

Ship	From		To		Unit Cost
0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 691.76
266	1	GUAYAQUIL	3	San Diego	$ 1,593.72
0	2	PUERTO QUETZAL	3	San Diego	$ 944.86
144	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00

Ship	From		To		Unit Cost
0	3	San Diego	5	Portland	$ 2,707.50
0	3	San Diego	6	Seattle	$ 3,137.50
50	3	San Diego	11	San Fran	$ 1,250.00
60	3	San Diego	4	Los Angeles	$ 300.00
30	3	San Diego	7	Denver	$ 2,750.00
35	3	San Diego	8	Salt Lake	$ 1,875.00
40	3	San Diego	9	Sacramento	$ 1,250.00
25	3	San Diego	10	Fresno	$ 840.00
30	6	Seattle	5	Portland	$ 412.50
26	3	San Diego	12	Billings	$ 3,242.50
0	3	San Diego	13	Boise	$ 3,285.00
30	6	Seattle	14	Puyallup	$ 200.00
0	6	Seattle	12	Billings	$ 2,030.00
25	6	Seattle	13	Boise	$ 1,262.50
10	6	Seattle	15	Spokane	$ 700.00
15	6	Seattle	16	Calgary	$ 1,765.00
20	6	Seattle	17	Vancouver	$ 350.00
0	3	San Diego	15	Spokane	$ 3,257.50
0	3	San Diego	16	Calgary	$ 4,015.00
0	3	San Diego	17	Vancouver	$ 3,487.50

Figure 5.2 Optimized West Coast Supply Chain

5.2.4 Total Cost

If the current supply chain is used and the model solved using Ecuador as a sourcing location(like other major banana distributors), the total supply chain cost is \$1,513,680. The average container would have a delivery charge from South America to the US market of \$3,691.90 or \$3.84 per box. If we were to utilize the Seattle vessel, we would have a total supply chain cost of \$1,402,272. On a weekly basis, this would save \$111,408 per week or \$271 per container. On a per box basis, you would save \$0.28. By shipping containers directly to Seattle over the course of the year, the supply chain would save \$5,793,216.

5.3 Additional models

Due to the volatility of fuel markets, the results of the model can change. To get a better understanding of the effects of these changes, the model can run with different scenarios. Under the appendix section, multiple scenarios are presented that offer different optimal results. Tables A.1 and A.2 present the original model that analyzes a vessel with 491 forty foot containers moving through fewer arcs. The model only analyzed major west coast markets. Tables A.3 and A.4 display a model that has a lower bunker fuel cost. Tables A.5 and A.6 analyze the effects of changes in inland freight rates.

Each model is different; however, the results of the optimization remain the same. By using a northern port, the model continues to produce results suggesting that there will be a reduced transportation cost for the supply chain.

CHAPTER VI: CONCLUSION

The goal of creating a transshipment model was to build an optimal supply chain that creates lower costs and greater value to Dole's customers. Through analysis of fuel, trucking, and shipping markets, the model makes the optimal decision regarding transportation. As stated before, banana companies should ship fruit into two ports for northern markets via a third party shipper because it is cheaper than shipping the product to Southern California and having the customer truck the product north. This provides greater value to customers and results in extra profits from shipping. The second positive is that you can pursue new business that you are not able to currently serve because of the extra vessel space on San Diego shipments. The third positive is that the new business on the west coast could secure vessel spots if the company were looking to purchase new-larger vessels without having to increase prices. By buying new vessels, new cost would have to be added to pay for the financing, if you combined the Seattle business and the increased San Diego business, the per container shipping cost savings could offset the finance charges.

6.1 Considerations

Although, the data justifies using third party shippers, certain issues must be considered. By using your own shipping, you are better able to estimate the time of arrival and when product is going to be removed from the ship. With third party shippers, you are just one of many products and could be delayed. Another consideration is the amount of time a container can be held in the third party shippers "yard" at the port. If this causes extra costs, this should be added to the model. The third consideration results from up charges made by the third party shipper. This could result from increases in bunker fuel or container fees. If these up charges change, it is be important to update the cost of shipping in this model. Another possible consideration is fruit shrink. The model can be amended to calculate how much fruit is lost at each port (if it differs). Sensitivity analysis could be used to understand how shipping decisions would change as economic conditions change. The final consideration is the over the road cost of transport. Freight rates are variable during the course of the year and could have major price swings. If the company were prepared for these swings, you could be able to offer major cost saving to customers.

6.2 Future Models

For the future, it would be beneficial to add product cost to the model. Variability of the price you pay for bananas in each country impacts the minimum cost of product as where the bananas may be sourced from. It would also be helpful to estimate the model with multiple over the road freight rates.

6.3 Summary

By using a transshipment model, we were able to combine the costs that effect container ships and inland freight trucking and optimize them. By using two ports, the company can deliver product to their customers at a cheaper rate. The savings per week in the supply chain was $111,000. On an annual basis, the transportation cost is $5,793,216.

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APPENDIX A: MODELS

Table A.1: Original Model 1

Bunker fuel	MPH	Miles/day	Truck rate/mile
$ 456.00	15.5	372	$ 2.50
Houston ISO380			

Ship	From		To		Unit Cost
0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 500.00
0	1	GUAYAQUIL	3	San Diego	$ 1,175.66
0	2	PUERTO QUETZAL	3	San Diego	$ 697.01
0	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00
0	3	San Diego	5	Portland	$ 2,707.50
0	3	San Diego	6	Seattle	$ 3,137.50
0	3	San Diego	11	San Francisco	$ 1,250.00
0	3	San Diego	4	Los Angeles	$ 300.00
0	3	San Diego	7	Denver	$ 2,750.00
0	3	San Diego	8	Salt Lake	$ 1,875.00
0	3	San Diego	9	Sacramento	$ 1,250.00
0	3	San Diego	10	Fresno	$ 840.00
0	6	Seattle	5	Portland	$ 412.50

Run using data solver

Nodes		Net Flow	Supply/Demand	
1	GUAYAQUIL	0	-700	
2	PUERTO QUETZAL	0	-200	
3	San Diego	0	0	<-shipping hub
4	Los Angeles	0	206	LA includes Phoenix and San Diego.
5	Portland	0	40	
6	Seattle	0	50	
7	Denver	0	45	
8	Salt Lake	0	40	
9	Sacramento	0	30	
10	Fresno	0	20	
11	San Francisco	0	60	
			491	

Total Transportation Cost **$0**

	Departure Port	GUAYAQUIL			PUERTO QUETZAL	
	Arrival Port	San Diego			San Diego	
	Distance		2972	*<Nautical Miles*	1762	*<Nautical Miles*
	# of days travel		8.0		4.7	
	Bunker Fuel Cost/tonnes	$	456.00	$	456.00	
Model 1	*Bunker Tonnes Burned/day*		158.45		158.45	
Low Fuel cost	*Cost/day*	$	72,253.20	$	72,253.20	
	Fuel Cost/trip	***$***	***577,248.68***	***$***	***342,231.55***	

Table A.2: Original Model – Run

Bunker fuel	MPH	Miles/day	Truck rate/mile
$ 456.00	15.5	372	$ 2.50

Houston ISO380

Ship	From		To		Unit Cost
0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 500.00
291	1	GUAYAQUIL	3	San Diego	$ 1,175.66
150	2	PUERTO QUETZAL	3	San Diego	$ 697.01
50	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00
40	3	San Diego	5	Portland	$ 2,707.50
0	3	San Diego	6	Seattle	$ 3,137.50
60	3	San Diego	11	San Francisco	$ 1,250.00
206	3	San Diego	4	Los Angeles	$ 300.00
45	3	San Diego	7	Denver	$ 2,750.00
40	3	San Diego	8	Salt Lake	$ 1,875.00
30	3	San Diego	9	Sacramento	$ 1,250.00
20	3	San Diego	10	Fresno	$ 840.00
0	6	Seattle	5	Portland	$ 412.50

Run using data solver

Nodes		Net Flow	Supply/Demand	
1	GUAYAQUIL	-291	-700	
2	PUERTO QUETZAL	-200	-200	
3	San Diego	0	0	<-shipping hub
4	Los Angeles	206	206	LA includes Phoenix and San Diego.
5	Portland	40	40	
6	Seattle	50	50	
7	Denver	45	45	
8	Salt Lake	40	40	
9	Sacramento	30	30	
10	Fresno	20	20	
11	San Francisco	60	60	
			491	

Total Transportation Cost **$1,119,818**

	Departure Port	GUAYAQUIL	PUERTO QUETZAL
	Arrival Port	San Diego	San Diego
	Distance	2972 *<Nautical Miles*	1762 *<Nautical Miles*
	# of days travel	8.0	4.7
	Bunker Fuel Cost/tonnes	$ 456.00	$ 456.00
Model 1	*Bunker Tonnes Burned/day*	158.45	158.45
Low Fuel cost	*Cost/day*	$ 72,253.20	$ 72,253.20
	Fuel Cost/trip	***$ 577,248.68***	***$ 342,231.55***

Table A.3: Model 2

Bunker fuel	MPH	Miles/day	Truck rate/mile
$ 456.00	15.5	372	$ 2.50
			Houston ISO380

Ship	From		To		Unit Cost
0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 550.20
0	1	GUAYAQUIL	3	San Diego	$ 1,267.60
0	2	PUERTO QUETZAL	3	San Diego	$ 751.52
0	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00
0	3	San Diego	5	Portland	$ 2,707.50
0	3	San Diego	6	Seattle	$ 3,137.50
0	3	San Diego	11	San Fran	$ 1,250.00
0	3	San Diego	4	Los Angeles	$ 300.00
0	3	San Diego	7	Denver	$ 2,750.00
0	3	San Diego	8	Salt Lake	$ 1,875.00
0	3	San Diego	9	Sacramento	$ 1,250.00
0	3	San Diego	10	Fresno	$ 840.00
0	6	Seattle	5	Portland	$ 412.50
0	3	San Diego	12	Billings	$ 3,242.50
0	3	San Diego	13	Boise	$ 3,285.00
0	6	Seattle	14	Puyallup	$ 200.00
0	6	Seattle	12	Billings	$ 2,030.00
0	6	Seattle	13	Boise	$ 1,262.50
0	6	Seattle	15	Spokane	$ 700.00
0	6	Seattle	16	Calgary	$ 1,765.00
0	6	Seattle	17	Vancouver	$ 350.00
0	3	San Diego	15	Spokane	$ 3,257.50
0	3	San Diego	16	Calgary	$ 4,015.00
0	3	San Diego	17	Vancouver	$ 3,487.50

Run using data solver

Nodes		Net Flow	Supply/Demand	
3	San Diego	0	0	<-shipping hub
4	Los Angeles	0	60	LA includes Phoenix
5	Portland	0	30	
6	Seattle	0	14	<-shipping hub
7	Denver	0	30	
8	Salt Lake	0	35	
9	Sacramento	0	40	
10	Fresno	0	25	
11	San Fran	0	50	
12	Billings	0	26	
13	Boise	0	25	
14	Puyallup	0	30	
15	Spokane	0	10	
16	Calgary	0	15	
17	Vancouver	0	20	
			410	

Total Transportation Cost **$0**

	Departure Port	GUAYAQUIL	PUERTO QUETZAL	GUAYAQUIL
	Arrival Port	SAN DIEGO	SAN DIEGO	PUERTO QUETZAL
	Distance(nautical miles)	2972	1762	1290
	# of days travel	8.0	4.7	3.5
	Bunker Fuel Cost/tonnes	$ 456.00	$ 456.00	$ 456.00
Model 1	*Bunker Tonnes Burned/day*	127.00	127.00	127.00
Low Fuel cost	*Cost/day*	$ 57,912.00	$ 57,912.00	$ 57,912.00
	Fuel Cost/trip	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**
	Net	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**

Table A.4: Model 2 – Run

0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 550.20
321	1	GUAYAQUIL	3	San Diego	$ 1,267.60
0	2	PUERTO QUETZAL	3	San Diego	$ 751.52
89	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00
30	3	San Diego	5	Portland	$ 2,707.50
0	3	San Diego	6	Seattle	$ 3,137.50
50	3	San Diego	11	San Fran	$ 1,250.00
60	3	San Diego	4	Los Angeles	$ 300.00
30	3	San Diego	7	Denver	$ 2,750.00
35	3	San Diego	8	Salt Lake	$ 1,875.00
40	3	San Diego	9	Sacramento	$ 1,250.00
25	3	San Diego	10	Fresno	$ 840.00
0	6	Seattle	5	Portland	$ 412.50
26	3	San Diego	12	Billings	$ 3,242.50
25	3	San Diego	13	Boise	$ 3,285.00
30	6	Seattle	14	Puyallup	$ 200.00
0	6	Seattle	12	Billings	$ 2,030.00
0	6	Seattle	13	Boise	$ 1,262.50
10	6	Seattle	15	Spokane	$ 700.00
15	6	Seattle	16	Calgary	$ 1,765.00
20	6	Seattle	17	Vancouver	$ 350.00
0	3	San Diego	15	Spokane	$ 3,257.50
0	3	San Diego	16	Calgary	$ 4,015.00
0	3	San Diego	17	Vancouver	$ 3,487.50

Run using data solver

Nodes		Net Flow	Supply/Demand	
1	GUAYAQUIL	-321	-700	
2	PUERTO QUETZAL	-89	-200	
3	San Diego	0	0	<-shipping hub
4	Los Angeles	60	60	LA includes Phoenix
5	Portland	30	30	
6	Seattle	14	14	<-shipping hub
7	Denver	30	30	
8	Salt Lake	35	35	
9	Sacramento	40	40	
10	Fresno	25	25	
11	San Fran	50	50	
12	Billings	26	26	
13	Boise	25	25	
14	Puyallup	30	30	
15	Spokane	10	10	
16	Calgary	15	15	
17	Vancouver	20	20	
			410	

Total Transportation Cost **$1,312,154**

	Departure Port	GUAYAQUIL	PUERTO QUETZAL	Guayaquil
	Arrival Port	San Diego	San Diego	Port Quetzal
	Distance	2972	1762	1290
	# of days travel	8.0	4.7	3.5
	Bunker Fuel Cost/to	$ 456.00	$ 456.00	$ 456.00
Model 1	*Bunker Tonnes Burne*	127.00	127.00	127.00
Low Fuel cost	*Cost/day*	$ 57,912.00	$ 57,912.00	$ 57,912.00
	Fuel Cost/trip	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**
	Net	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**

Table A.5: Shipping Extremes

Bunker fuel	MPH	Miles/day	Truck rate/mile
$ 456.00	15.5	372	$ 1.89

Houston ISO380

Ship	From	Port	To	Market	Unit Cost
0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 489.81
376	1	GUAYAQUIL	3	San Diego	$ 1,128.47
0	2	PUERTO QUETZAL	3	San Diego	$ 669.03
34	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00
60	3	San Diego	4	Los Angeles	$ 226.80
30	3	San Diego	5	Portland	$ 2,046.87
0	3	San Diego	6	Seattle	$ 2,371.95
30	3	San Diego	7	Denver	$ 2,079.00
35	3	San Diego	8	Salt Lake	$ 1,417.50
40	3	San Diego	9	Sacramento	$ 945.00
25	3	San Diego	10	Fresno	$ 635.04
50	3	San Diego	11	San Fran	$ 945.00
26	3	San Diego	12	Billings	$ 2,451.33
25	3	San Diego	13	Boise	$ 2,483.46
30	3	San Diego	14	Puyallup	$ 2,320.92
10	3	San Diego	15	Spokane	$ 2,462.67
15	3	San Diego	16	Calgary	$ 3,035.34
0	3	San Diego	17	Vancouver	$ 2,636.55
0	6	Seattle	5	Portland	$ 311.85
0	6	Seattle	12	Billings	$ 1,534.68
0	6	Seattle	13	Boise	$ 954.45
0	6	Seattle	14	Puyallup	$ 200.00
0	6	Seattle	15	Spokane	$ 529.20
0	6	Seattle	16	Calgary	$ 1,334.34
20	6	Seattle	17	Vancouver	$ 264.60

Run using data solver

Nodes	Market	Net Flow	Supply/Demand	
1	GUAYAQUIL	-376	-700	
2	PUERTO QUETZAL	-34	-200	
3	San Diego	0	0	<-shipping hub
4	Los Angeles	60	60	LA includes Phoenix
5	Portland	30	30	
6	Seattle	14	14	<-shipping hub
7	Denver	30	30	
8	Salt Lake	35	35	
9	Sacramento	40	40	
10	Fresno	25	25	
11	San Fran	50	50	
12	Billings	26	26	
13	Boise	25	25	
14	Puyallup	30	30	
15	Spokane	10	10	
16	Calgary	15	15	
17	Vancouver	20	20	

410

Total Transportation Cost **$1,102,125**

	Departure Port	GUAYAQUIL	PUERTO QUETZAL	GUAYAQUIL	
	Arrival Port	SAN DIEGO	SAN DIEGO	PUERTO QUETZAL	
	Distance(nautical miles)	2972	1762	1290	
	# of days travel	8.0	4.7	3.5	
	Bunker Fuel Cost/tonnes	$ 456.00	$ 456.00	$ 456.00	
Model 1 Low Fuel cost	*Bunker Tonnes Burned/day*	127.00	127.00	127.00	
	Cost/day	$ 57,912.00	$ 57,912.00	$ 57,912.00	
	Fuel Cost/trip	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**	$ 475,127.48
	Net	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**	

Table A.6: Shipping Extremes

Bunker fuel	MPH	Miles/day	Truck rate/mile
$ 456.00	15.5	372	$ 2.94

Houston ISO380

Ship	From	Port	To	Market	Unit Cost
0	1	GUAYAQUIL	2	PUERTO QUETZAL	$ 489.81
266	1	GUAYAQUIL	3	San Diego	$ 1,128.47
0	2	PUERTO QUETZAL	3	San Diego	$ 669.03
144	2	PUERTO QUETZAL	6	Seattle	$ 3,500.00
60	3	San Diego	4	Los Angeles	$ 352.80
0	3	San Diego	5	Portland	$ 3,184.02
0	3	San Diego	6	Seattle	$ 3,689.70
30	3	San Diego	7	Denver	$ 3,234.00
35	3	San Diego	8	Salt Lake	$ 2,205.00
40	3	San Diego	9	Sacramento	$ 1,470.00
25	3	San Diego	10	Fresno	$ 987.84
50	3	San Diego	11	San Fran	$ 1,470.00
26	3	San Diego	12	Billings	$ 3,813.18
0	3	San Diego	13	Boise	$ 3,863.16
0	3	San Diego	14	Puyallup	$ 3,610.32
0	3	San Diego	15	Spokane	$ 3,830.82
0	3	San Diego	16	Calgary	$ 4,721.64
0	3	San Diego	17	Vancouver	$ 4,101.30
30	6	Seattle	5	Portland	$ 485.10
0	6	Seattle	12	Billings	$ 2,387.28
25	6	Seattle	13	Boise	$ 1,484.70
30	6	Seattle	14	Puyallup	$ 200.00
10	6	Seattle	15	Spokane	$ 823.20
15	6	Seattle	16	Calgary	$ 2,075.64
20	6	Seattle	17	Vancouver	$ 411.60

Run using data solver

Nodes	Market	Net Flow	Supply/Demand	
1	GUAYAQUIL	-266	-700	
2	PUERTO QUETZAL	-144	-200	
3	San Diego	0	0	<-shipping hub
4	Los Angeles	60	60	LA includes Phoenix
5	Portland	30	30	
6	Seattle	14	14	<-shipping hub
7	Denver	30	30	
8	Salt Lake	35	35	
9	Sacramento	40	40	
10	Fresno	25	25	
11	San Fran	50	50	
12	Billings	26	26	
13	Boise	25	25	
14	Puyallup	30	30	
15	Spokane	10	10	
16	Calgary	15	15	
17	Vancouver	20	20	

410

Total Transportation Cost **$1,360,944**

	Departure Port	GUAYAQUIL	PUERTO QUETZAL	GUAYAQUIL	
	Arrival Port	SAN DIEGO	SAN DIEGO	PUERTO QUETZAL	
	Distance(nautical miles)	2972	1762	1290	
	# of days travel	8.0	4.7	3.5	
	Bunker Fuel Cost/tonnes	$ 456.00	$ 456.00	$ 456.00	
Model 1	*Bunker Tonnes Burned/day*	127.00	127.00	127.00	
Low Fuel cost	*Cost/day*	$ 57,912.00	$ 57,912.00	$ 57,912.00	
	Fuel Cost/trip	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**	$ 475,127.48
	Net	**$ 462,673.29**	**$ 274,303.61**	**$ 200,823.87**	