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Supply Chain Network Analysis for Outboard Motors at Motor Boaters USA

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Supply Chain Network Analysis for Outboard Motors at Motor Boaters USA – Seeking to Reduce Costs and Improve Efficiency

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Executive Summary

Motor Boaters USA has received shipments of outboard motors, from Japan, through Tacoma, Washington. The organization wants to evaluate the current distribution network and explore different avenues of distribution. The organization assigned the task of evaluating their motor distribution network to a team of Industrial and Systems Engineering (ISyE) students at Kennesaw State University, Marietta campus. The task is broken into three scenarios. For the first scenario, the team must evaluate the feasibility of shipping motors throughout the U.S. from Atlanta, Georgia, as opposed to Tacoma. For the second scenario, the team must evaluate the feasibility of shipping motors throughout the U.S. from both Tacoma and Atlanta. For the third scenario, the team must evaluate the feasibility of shipping motors through the U.S. from Tacoma, Atlanta, and Chicago.

Through data cleaning, data analyses, clustering methods and network calculations, the YACD analysts were able to find optimized solutions to their network in order to present an option moving forward. The YACD team examined three alternatives. The first alternative included moving the port-of-entry from Tacoma, Washington to Savannah, Georgia. The second alternative included adding a port-of-entry to Savannah, Georgia to compliment the port-of-entry in Tacoma, thereby creating two separate distribution regions, the east and the west. The third alternative included a third regional distribution center in Chicago, Illinois, along with the already installed second port-of-entry at Savannah.

After calculations were carried out, the YACD analysts found that with the inclusion of a distribution warehouse in Chicago, the most efficient network distribution can be utilized. Due to the large savings, it would be feasible to purchase or lease a warehouse in Chicago for distribution. Because MBUSA does not express interest in purchasing or leasing a warehouse in Chicago, the second alternative is the most feasible. Finally, although the first alternative reduced the trucking mileage greatly, the costs did not reduce but increase slightly.

Through these findings, the YACD recommends that MBUSA pursue having a port-of-entry at both Tacoma and Savannah, thereby splitting the nation into two trucking divisions, east and west.

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Chapter 1: Introduction

1.1 Company History and Team

<u>Motor Boaters USA</u>

Motor Boaters USA (MBUSA), is a recognized leader in the power sports industry. MBUSA has grown to $3.3 billion dollars in sales while employing around 4,000 people for the consolidated 2016 year. MBUSA products include a strong marine line including outboard motors, speedboats, and other aquatic recreation craft along with a formidable land-side line including all-terrain vehicles, golf carts, snowmobiles, motorcycles, and utility vehicles. MBUSA products are distributed through a nationwide network of dealers and original equipment manufacturers (OEMs) in the United States. The brand is bolstered with offices distributed across the country

<u>Yesenia Ali Chase Djanene (Y.A.C.D.) Network Analysts Team</u>

The Y.A.C.D. Network Analysts team members include Yesenia Pérez, Djanene Manuel, Ali Ghiasi, and Chase Griffith. Yesenia is an ISYE program major with an emphasis in Industrial Engineering and will be the Project Manager. She will work to develop and maintain timeline and goals. Ali, an ISYE major with an emphasis in Systems Engineering and will be the Team Leader/Logistics and Supply Chain Manager. Ali will evaluate improvements to logistics and transportation methods. Chase, an ISYE program major with an emphasis in Systems Engineering, will be the Business Analyst and Project Optimization Specialist. He will be defining, analyzing and documenting requirements as the project progresses. Djanene, an ISYE program major with an emphasis in Industrial Engineering, will be the Video Director and a Technical Writer. In addition, she will provide software expertise. The project term will be supported by members of the MBUSA Logistics and Sales Division.

1.2 Overview

As part of the international supply chain for finished goods, MBUSA has multiple manufacturing facilities located on both Asian and South American continents. The manufacturing facilities located in Asia ship finished goods to the United States, where they arrive at ports-of-entry in Tacoma, Washington and Los Angeles, California. Finished goods shipped from South America arrive at the Los Angeles port-of-entry (POE) and are then moved via rail to Lithia Springs in Atlanta, Georgia. While many types of products come from these locations, the focus of this project will be on the outboard motors product group, arriving at the POE in Tacoma, Washington and the shipping distribution network.

The main goal of this project is to optimize the large and small outboard motor shipping distribution network by becoming as cost effective as possible. This will be accomplished through the reduction of transportation costs and distances. To achieve this goal, there are multiple factors to take into consideration, including the quantity of import containers and their units, customer sales data, warehouse rates, volume growth assumptions, transit distances by mode and transit costs by mode.

1.3 Objective

The objective of this project focuses on helping MBUSA investigate potential improvement in US distribution network, to reduce the total cost and improve the service performance.

The Scope of Work includes:

- Creating a historical baseline model
- Comparing model baseline to "What-If Scenarios"
- Inclusive Product: Outboard Motor Product Group
- Product sourcing: Only Consider Domestic Distribution Facilities
- Product Flow
  - Import to Regional Distribution Center (RDC), with product transferring by Light Truck Load (LTL) and Full Truck Load (FTL)
  - RDC to dealer distribution (LTL and FTL)
- Consider current and future volume growth: 2019-2021

1.4 Justification

Optimizing a distribution network presents multiple primary and secondary improvements. The primary improvements include reducing shipping costs and developing efficient intermodal transportations. The secondary improvements include emboldening a higher quality of life, encouraging a healthier planet through a sustainable method of operations and creating a replicable system for future review and improvement.

As with any successful business, profit is key. Logistics and supply chain analysis can lend immensely to increasing profit and one of the most effective ways to increase profit is to reduce costs. An efficient transportation system carries with it low costs but they will rarely be static and almost always be dynamic. Focusing on the changing aspect of the network and rates will help keep costs low and profit high. These changing shipping rates can be broken into individual entities of cost. These individual entities include topics such as vehicle maintenance costs, hourly rates, handling costs, and insurance costs, to name a few. By developing efficient intermodal transportation, time on the ocean and roadways can be reduced. Reduction in transportation time lowers these costs, which can, therefore, have a positive impact on profit. Outside of the obvious, profit-driven, reasons to improve a distribution network, there are other, humanity-driven, reasons to improve a distribution network.

As the modern era of business has progressed, it has become more common for companies to focus on valuing the individuals and surrounding environment affected, directly and indirectly, by its products or services. Businesses have focused on individuals and the environment through promoting a higher quality of life as well as a consideration for nature and the environment. An efficient distribution network is no different regarding these concerns. Through the use of an efficient network, trucking routes can be shortened in order to effectively decrease the time spent on the road, fuel usage, and transportation waste. These reductions will have a positive impact on quality of life and the health of the environment.

1.5 Project Background

Currently, MBUSA imports small and large outboard motors into Tacoma from an Asian supplier. From Tacoma, the motors may be moved inland to RDC, via truck, in Tacoma to be shipped, via truck, to dealers and OEMs around the nation. The motors may also be moved, via rail, from Tacoma to an RDC in Lithia Springs, Georgia where the motors are shipped, via truck, to dealers and OEMs around the nation. MBUSA has been working with third-party logistics organizations to regularly analyze and change their distribution network. The Y.A.C.D. Network Analysts team will be working primarily with MBUSA's logistics and supply chain group.

1.6 Problem Statement

MBUSA currently has one RDC in Tacoma and one RDC in Atlanta. The MBUSA logistics and supply chain team want to analyze last previous year shipping data along with the next three years' projections in order to predict what should be done regarding a more effective outboard motor shipping network and reduction of transportation costs.

Chapter 2: Literature Review

2.1 Data Analysis

To analyze the data and to create the historical and the model baseline, a specific and an efficient analysis and decision models was developed. According to the article from Jivanah Venugopalan et. al. entitled, *Analysis of Decision Models in Supply Chain Management,* "In today's scenario, supply chain processes have been greatly influencing businesses and trades globally. Customer needs are sought to be met reducing lead times thereby leading to enhanced delivery with quality standards and reasonable prices kept in mind. Considering the historical as well as interpreted data and analyzing all factors involved, firms/organizations can forecast what the trade scenario in the future. Nowadays, computerized mechanisms and technology has taken over a crucial role in the field of supply chain. This has led the models, which were designed and developed from the existing models, to be implemented in terms of software or 'optimization tools' in order to acquire a rapid and more precise result. A platform for developing such tools is provided by Math Works in the form of MATLAB programming [5]."

2.2 Transportation Models

In the article *The Role of Transportation in Logistics Chain,* the authors emphasize the importance of an efficient transportation systems, *"*Transport system makes goods and products movable and provides timely and regional efficacy to promote value-added under the least cost principle. Transport affects the results of logistics activities and, of course, it influences production and sale. In the logistics system, transportation cost could be regarded as a restriction of the objective market. Value of transportation varies with different industries. For those products with small volume, low weight and high value, transportation cost simply occupies a very small part of sale and is less regarded; for those big, heavy and low-valued products, transportation occupies a very big part of sale and affects profits more, and therefore it is more regarded [6]."

"Many buyer and supplier contract negotiations ignore the impact of transportation charges on supply chain costs and order sizes. What the field of purchasing has traditionally considered a cooperative relationship between a buyer and supplier cannot possibly optimize supply chain costs without involvement of the transportation carrier in the process. Trilateral optimality refers to a supply chain where seller, buyer, and carrier costs are explicitly considered in establishing optimal lot sizes. It is proposed that comprises by the buyer, the seller, and the carrier can serve to improve profitability for all parties [7]."

2.3 Clustering Algorithms

An effective way to study and analyze large sets of data is by dividing the data points into groups with the same similarities. This can be done using the cluster analysis. "Cluster analysis is the formal study of methods and algorithms for grouping, or clustering, objects according to measured or perceived intrinsic characteristics or similarities. The aim of clustering is to find structure in data and is therefore exploratory. One of the most popular and simple clustering algorithms, K-means, was published over 50 years ago and thousands of clustering algorithms have been published since then, K-means is still widely used [8]."

In *An efficient enhanced k-means clustering algorithm*, present a modified clustering algorithm and discuss the advantages of using the algorithm as opposed to other, more traditional clustering algorithms. K-means clustering utilizes a “prototype,” which is described as a center that is the mean value of all objects belonging to a cluster. In the improved algorithm, clustering is more efficient based on the search method involved. While the traditional k-means method included data points already included within a specified distance to the established cluster centroid, the new method ignores these data points and searches for points that are further away. This method drastically reduces the burden on software and hardware as well as time taken for calculations [9]. The improved method is important to our study because of the massive amount of data points involved. In order to secure a solution faster and quicker, the Y.A.C.D. team will manipulate and collapse data, which will lead to an acceptable solution faster and easier.

2.4 Simulation

Conceptual models are valid descriptions of reality, therefore, using simulation as a supply chain optimization tool is a great way to create and test models without costly real-world experiments. “Simulation refers to a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software [10].” “Computer simulation refers to methods for studying a wide variety of models of real-world systems by numerical evaluation using software design to imitate the system’s operations or characteristics, often over time [10].” In this project, we used the Arena simulation software to carry out our computer simulation studies.

Chapter 3: Problem Solving and Project Management

3.1 Problem Solving Approach

To solve this problem, historical shipping information will be analyzed, a model baseline will be created, multiple what-if scenarios will be tested, and one or more optimal alternatives will be selected.

MBUSA has provided historical shipping data from 2018 as well as projected shipping predictions for 2019, 2020 and 2021 years. The shipping data from 2018 will be analyzed as a historical baseline and, through interpretation, a model will be created. The model will represent the status of the shipping distribution network at the end of the 2018 year. Once the historical shipping information has been analyzed and the model has been created, multiple scenarios will be explored.

The scenarios to be explored include:

- Moving the POE
- Adding an additional POE
- Adding a POE and an RDC

Each of the scenarios include a different supply method for the RDCs, which receive, hold and ship products to dealers and OEMs. First, we will consider moving the POE location from Tacoma to Savannah, Georgia, placing primary distribution responsibilities on the Atlanta RDC. Second, we will consider adding a POE to Savannah, Georgia. This added POE will complement the POE in Tacoma, creating two distribution areas. Third, while using the two POEs from scenario 2, we will add an RDC in Chicago and use it as a distribution point, which will allow distribution to be divided into three areas.

Once the different scenarios have been explored, we will consult with the MBUSA logistics team and discuss the feasible options. Feasible options will be approved by MBUSA for continued inspection and calculation. Having options available to us will allow for the processing of data and creation of equations to be used in calculations and simulations. After multiple simulations have been completed and one or more options have been found to be optimal, the MBUSA logistics team shall begin a course of action if desired. The process activity diagram for the steps mentioned above are shown in figure 1.

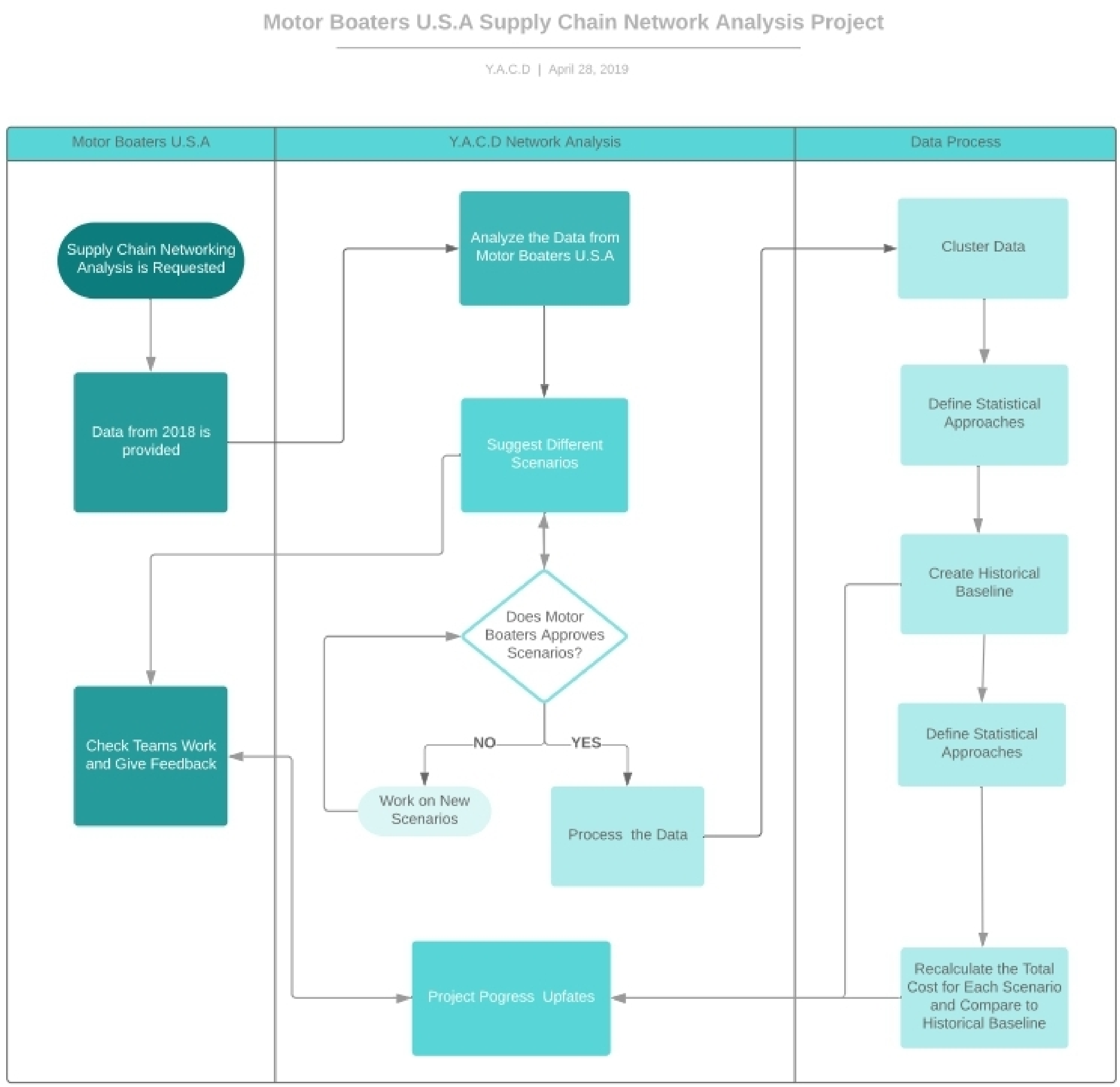


Figure 1 – Problem Solving Process Activity Diagram

3.2 Minimum Success Criteria and Requirements

In order to be considered minimally successful, the Y.A.C.D. team must improve the efficiency of the outboard motor distribution network currently in place within the United States. Improving efficiency will be defined in two parts, decreasing the cost of transportation and decreasing the distance of shipment travel, which will improve service performance.

Transportation costs within the scope of this study include those costs associated with moving product over the Pacific and Atlantic Oceans as well as costs associated with moving product through the Panama Canal. Other costs are those associated with moving product by rail and truck.

Distances within the scope of this study include those oceanic distances associated with moving product from Asian sources to Tacoma, Washington or Savannah, Georgia. Distances within the scope of this study include those transnational distances associated with moving product either by rail or by truck to many locations within the U.S.

3.3 Gantt Chart

In order to manage this project efficiently, effectively and in a timely manner, a Gantt chart was created. The chart shows the tasks that need to be performed against time as shown in Figure 2. The project began with the identification of the systems requirements and preliminary meeting with MBUSA.

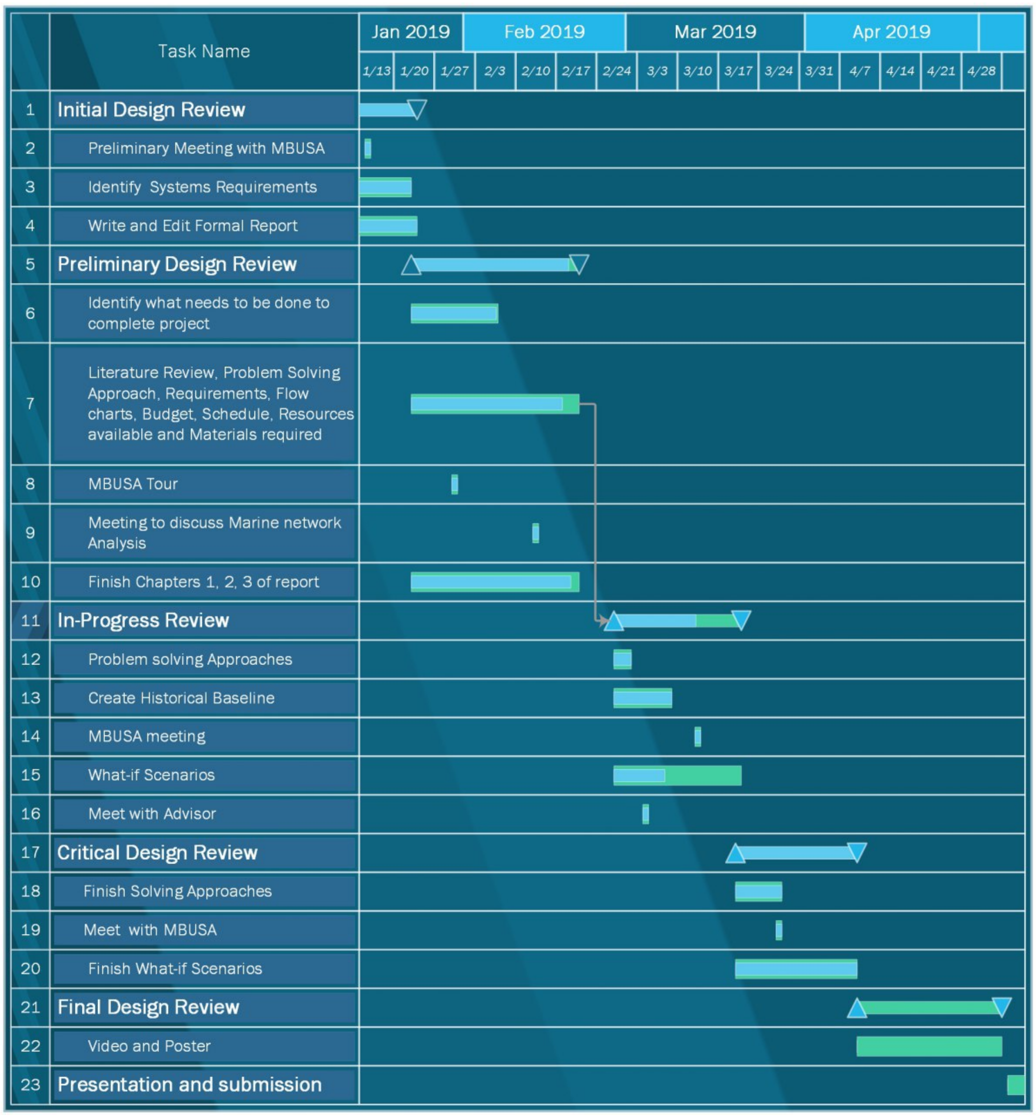


Figure 2 – Gantt Chart

3.4 Schedule

The schedule of the tasks is shown below.

PROJECT TASK				
TEAM TASKS	**START DATE**	**DUE DATE**	**% COMPLETE**	**Duration of Tasks (Days)**
1. Project Definition and Scope	**1/9/19**	**1/23/19**	**100%**	**15**
1.1 Preliminary Meeting with MBUSA	**1/15/19**	**1/15/19**	**100%**	**1**
1.2 Identify Systems Requirements	**1/9/19**	**1/21/19**	**100%**	**13**
2. Problem Solving Approach	**1/23/19**	**3/20/19**	**100%**	**56**
3. Create Historical Baseline	**2/27/19**	**3/8/19**	**100%**	**9**
4. Meet with Advisors	**3/4/19**	**3/4/19**	**100%**	**1**
5. What if Scenarios	**2/27/19**	**4/9/19**	**100%**	**41**
6. Video and Poster	**3/20/19**	**4/25/19**	**100%**	**36**
7. Complete Calculations	**2/20/19**	**4/9/19**	**100%**	**48**
8. Finish Writing Technical Report	**1/9/19**	**4/29/19**	**100%**	**106**

Table 1 – Team Schedule

3.5 Project Management

The project responsibility is divided among four individuals. First, the project manager is responsible for overseeing the achievement of the project objectives and obtaining the necessary software. Second, the team leader is responsible for directing individual objectives and managing the logistics and supply chain issues that arise. Third, the business analyst is responsible for verifying those cost requirements are met as well as overseeing project optimization. Fourth, the technical writer is responsible for moving plans, concepts, ideas, results and discussion into the project document as well as recording and editing video that is applicable to the project.

3.6 Responsibilities

Responsibilities are listed below as well as the individuals who are responsible for the implementation of those responsibilities. The responsibilities are not absolute and it is likely that responsibilities will be shared evenly amongst the group.

- ❏ Yesenia Pérez – Technical Writer/Video Director/Researcher
- ❏ Ali Ghiasi – Team Leader/Data Analyst/Project Optimization Specialist
- ❏ Chase Griffith – Technical Writer/Data Analyst/Project Manager
- ❏ Djanene Manuel – Technical Writer/Project Coordinator/Researcher

3.7 Budget

Currently, there are no costs associated with the project. However, hypothetical costs have been examined and are discussed below.

The hypothetical costs associated with this study include eight broad cost categories. While one category may be derived from another, they are discussed individually for clarity. The cost categories examined are ‘software purchasing’, ‘license renewal’, ‘consulting’, ‘relocation’, ‘warehousing rentals’, ‘warehousing construction’, ‘handling’ and ‘Panama Canal’.

Regarding software purchasing and license renewal, a software package called ‘SAP’, as well as its subsequent license agreement, was purchased some years back and would not be included in the logistics teams’ budget. The depreciation for the software is passed on to sales so, again, logistics would not include it within its budget.

Regarding consultants, MBUSA does not explore outside assistance through consulting. Therefore, consulting is not included within the logistics budget. All work is completed in house by hired employees of MBUSA.

Regarding relocation, there is rarely a relocation cost due to it being included within a contract agreement and handled by the third party requesting the relocation. On the occasion that a relocation cost does fall on MBUSA, it usually amounts to twenty-five thousand dollars. Due to the lack of relocation for this project, its cost will not be considered.

Regarding warehousing rentals, there is a significant portion of this study devoted to adding and removing warehousing as well as changing warehousing location. Due to this large portion, warehousing rental rates were found through a quick internet search. The rates are specified by dollars per square foot per month. For Tacoma, the average rate is $0.9228/Sq. Ft./Month [1,2]. For Chicago, the average rate is $1.0558/Sq. Ft./Month [3]. For Atlanta, the average rate is $0.8034/Sq. Ft./Month [4]. From initial inspection, it can be seen that the ideal location for warehousing is Atlanta for one warehouse location and Atlanta and Tacoma for two warehouse locations.

Regarding warehousing construction, there is no plan to construct new warehousing on part of MBUSA so this cost will not be considered.

Regarding handling, there is a $6/per unit cost. This cost includes all handling applications including unloading, storing, picking and shipping. This cost also plays a large role in final calculations so it will be more deeply explored during calculation completion.

Regarding Panama Canal fees, any extra cost associated with transport through the Panama Canal is included in the ocean rates. Since these costs are already included, there is no need to call them out individually throughout the remaining portion of the report.

3.8 Materials Available

This section lists the current materials that are both available for use and likely to be used. It is likely that not all of the materials listed will be used and that we will add materials as the project progresses.

- Arena Simulation
- Lingo Optimization Software
- Microsoft Excel
- Microsoft Word

3.9 Resources Available

This section lists the resources that are available to the Y.A.C.D. team. The resources available are:

- Professors at Kennesaw State University
- MBUSA
- Third-Party Logistics
- KSU Library and Databases
- Previous Senior Design Projects
- Internet

Chapter 4: Data Analysis

4.1 Data Breakdown

Before beginning data analysis, the data received was reviewed and cleaned for ease of reference. The raw data included the following elements:

- Plant/Warehouse: representing starting points
- Bill of Lading (BOL) Number: used solely for LTL shipments
- Master Bill of Lading (MBOL) Number: used solely for FTL shipments
- Ship Date: not referenced during study but included for possible future analysis
- Carrier: not referenced during study but included for possible future analysis
- Means of Transport: different means are ship, rail, and road
- Ship Mode Code: not referenced during study but included for possible future analysis
- The Logistics Division (TLD) Ship-To Party: not referenced during study but included for possible future analysis. "The Logistics Division" is a third-party invoicing company
- TLD Ship-To Party: Postal Code - the postal codes were used to estimate average shipping distance
- TLD Ship-To Party - Region: not referenced during study but included for possible future analysis
- Model-Key Shipment Quantity: not referenced during study but included for possible future analysis
- Quantity on Element: not referenced during study but included for possible future analysis
- Distance: the main factor in each scenario calculation; used to estimate average shipping distance

4.2 Data Cleaning

Once the data received was fully broken down, cleaning of data was necessary in order to better implement calculation and for clear understanding upon reference. First, rows including a hashtag (#), the phrase 'no assigned', and the abbreviations 'CONF' or 'POOL' were deleted because of their insignificance to outcome of the project. Some cells, those using nine-digit zip codes, had to be reduced in value for ease of use. Because other cells only used five digits, the nine-digit zip codes were reduced to five. The shipment method cells were changed from broad categories to detailed categories. The LTL data was transformed into LTL from Tacoma, and LTL from Atlanta. This was done because of the importance of having Tacoma and Atlanta as the only locations of imports in the U.S. and having LTL as the only method of transport within the U.S. The data cleaning was completed in Excel.

4.3 LTL Rate Calculation

After the data had been cleaned, we reviewed it and spoke with a MBUSA representative regarding an explanation on the amount spent by MBUSA for the 2018 year. What was explained is summarized as follows. The rate per mile was applied as LTL.

For an LTL shipment, one must refer to the Bill of Lading (BOL) number and apply the rate to the number of miles included from the starting point to the stop point. Please see table 1, "LTL Data 1," for reference during the explanation of the example below.

A	B	C	D	E	F	G	H	I	J	K	L
0020	20T0002425	L600031459	1/2/2018	SEFL	LTL	BOAT STORE	Missouri	F90JB	1	807.1	807.1000346
0020	20T0002425	L600031459	1/2/2018	SEFL	LTL	BOAT STORE	Missouri	F90JB	1	807.1	807.1000346
0020	20T0002426	L600031459	1/2/2018	SEFL	LTL	BOAT STORE	Missouri	F90JB	1	148.9	148.8997541

Table 2 – LTL Data

Referring to BOL 20T0002425, located under column B, there are two lines including 2 units. Those 2 units traveled a distance of about 807.10 miles. Using this mileage and the LTL rate of $1.68 per mile, a total of $1,355.76 was spend moving these units to Missouri. A third unit was sent separately from the first two to the same location. The LTL rate was again applied to the mileage of the third unit, which was 148.90 miles, and the total came to $250.32. This makes a grand total of $1606.08. Once the LTL mileage and rates were examined, reducing the number of shipping locations from around 51,000 to 50 was the next step.

4.4 Clustering Calculation and Verification

In order to facilitate the project, a massive reduction of shipping locations needed completing. To accomplish this, all mileages for each state were averaged and one single mileage was used as a clustered point.

To find clustered points for each state, all zip codes were organized by their respective state, as shown in figure 4. Next, the mileages paired to the organized zip codes were averaged to create one distance, which was used in conjunction with the state containing the averaged zip codes. This is shown in table 2. The number 2946.5, next to "Connecticut", is the average mileage of the numbers shown below it. This number is the clustered value representing the state of Connecticut.

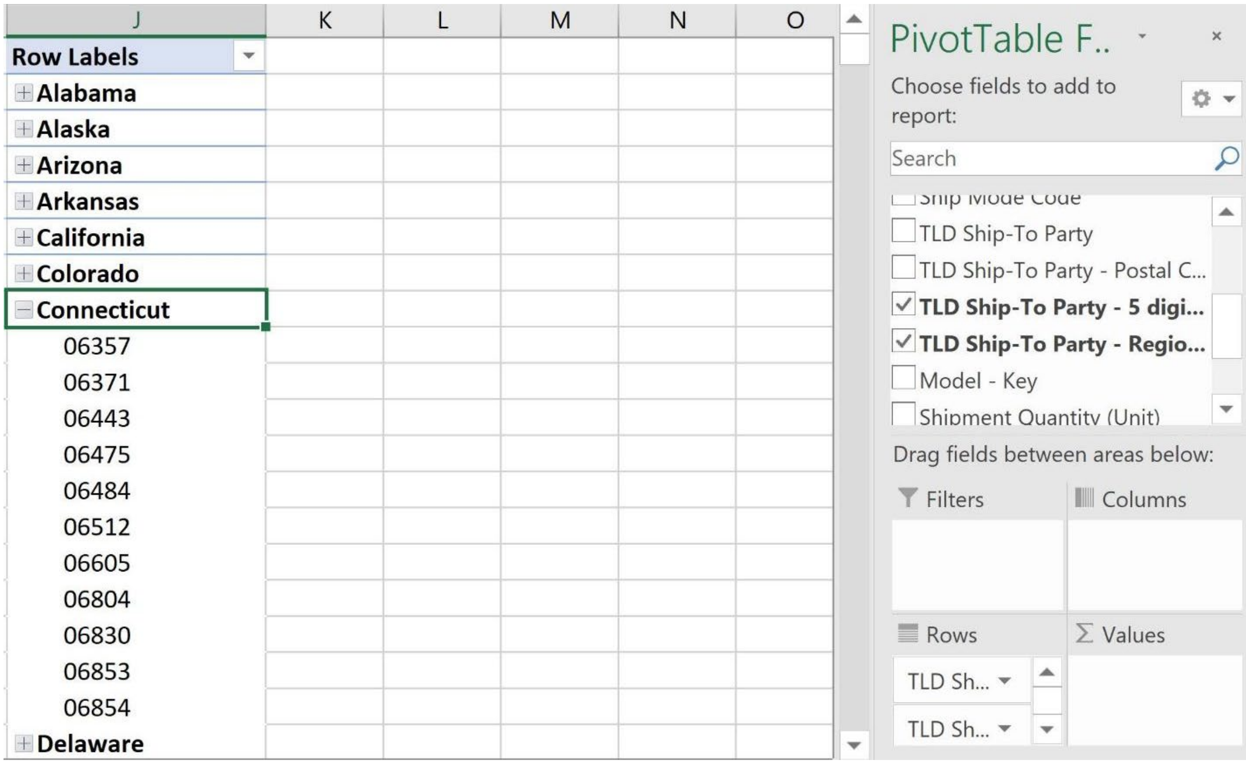


Figure 3 – Zip Codes of Connecticut

Connecticut	**2946.5**
06357	2980.3
06371	2973.1
06443	2956.7
06475	2969.3
06484	2934.5
06512	2943.9
06605	2918.8
06804	2915.0
06830	2895.9
06853	2912.5
06854	2912.7

Figure 4 – Average Mileage of Connecticut

Once the clustered values were calculated, the number of times a truck visited each state was multiplied by the clustered value in order to find the weight each state had on the nation. The weight multiplied by the LTL rate represents the cost of moving a shipment from an RDC to an endpoint. The cost is applied to each scenario calculation affecting the feasibility of taking one route, starting in the same place and ending in the same place, over the other. “A weighted average is extremely useful in that it allows the final average number to reflect the relative importance of each observation and is thus more descriptive than a simple average. It also has the effect of smoothing out data thereby enhancing accuracy [11]”.

In order to verify the clustering average paired with the rate, a cost verification equation, shown below as equation 1, was used. Its result was compared to a value supplied by MBUSA.

Equation 1: Average Mileage from Tacoma x How Many Times by LTL? x (LTL rate) = LTL Total Cost (LTLTC)

As an example, the state of Alabama is considered. The following values are obtained from table 3. The average mileage to Alabama from Tacoma is 2738.277 miles and a truck transported goods a total of 176 times. When applied to equation 1,

2738.277 miles x 176 visits x $1.68 = $809,653.74

For 2018, MBUSA spent $809,653.74 on shipping from Tacoma to Atlanta. Next, summing each state’s LTL Total Cost produces the LTL Total Cost for the U.S. as shown in equation 2.

Equation 2: $$\sum_{i=1}^{n} LTLTC_i = \text{Total cost for whole country by LTL}$$

Using equation 2 to sum 50 iterations, for each state, of equation 1, the resulting number comes to $82,729,949.48. If this number is compared to the MBUSA-supplied value, it can be verified that this clustering method produces nearly the same value and can be used for this project.

State	Average mileage from Tacoma	How many times by LTL?
Alabama	2738.277	176
Alaska	2514.375	357
Arizona	1441.098	6
Arkansas	2508.119	511
California	1122.411	821
Colorado	1352.322	17
Connecticut	2946.502	101
Delaware	2847.759323	88
District of Columbia	2771.0967	12
Florida	3184.190122	2178
Georgia	2843.062363	817
Hawaii	2657.996242	128
Idaho	453.8122165	106
Illinois	2095.866217	86
Indiana	2361.363101	5396
Iowa	1988.086632	42
Kansas	1912.832599	28
Kentucky	2367.789128	27
Louisiana	2601.360646	514
Maine	3246.262979	281
Maryland	2826.994482	156
Massachusetts	3097.205607	282
Michigan	2405.731088	809
Minnesota	1920.002368	908
Mississippi	2640.1739	246
Missouri	2329.55234	1514
Montana	604.1374602	66
Nebraska	1636.028545	6
Nevada	728.524396	18
New Hampshire	3111.85092	55
New Jersey	2883.885875	200
New Mexico	1273.551701	3
New York	2917.327403	316
North Carolina	2980.045363	542
North Dakota	1251.356092	7
Ohio	2415.888013	88
Oklahoma	2188.440847	158
Oregon	333.8034578	723
Pennsylvania	2679.945269	108
Rhode Island	3029.46971	97
South Carolina	2927.095478	845
South Dakota	1478.880111	15
Tennessee	2568.346195	193
Texas	2333.743373	582
Utah	1752.304277	114
Vermont	2994.987795	11
Virginia	2910.948654	258
Washington	152.7068737	1079
West Virginia	2538.062184	2
Wisconsin	1919.036754	314
Wyoming		0

Table 3 – State Weights

4.4 Scenario Implementation and Results - LTL

Before explaining the results of the calculations below, a recap of the 2018 situation, along with expectations for new situations, will be covered. At the end of 2018, the total cost of shipping units, by ocean, from Japan to Tacoma and then shipping units, by truck, from Tacoma to the retailers amounted to $10,819,727.35. Given that about 50% of the units entering Tacoma will be shipped to the southeast, it was proposed that moving the port-of-entry to Savannah or having a port-of-entry at Savannah would likely yield the optimized solution for the given problem. Please note that ocean, trucking and railway rates were given and no additional rate calculation was needed.

For the first LTL scenario, Savannah was used as the only port-of-entry as opposed to Tacoma with Atlanta representing the regional distribution center. Implications for the use of Savannah include increased ocean miles and costs. The ocean rate changed from $46.04 to $73.17 per unit while the trucking rate stayed at $0.183 per mile. Please see figure 5, “Scenario 1 Map”. Upon completion of the calculations, the result indicated that although the bulk of the shipments ended the southeast, the higher ocean rate pushed the total cost past the 2018 amount of $10,819,727.35 to $10,952,925.85. This new total cost indicates that moving the port-of-entry to Savannah from Tacoma is not worth consideration.

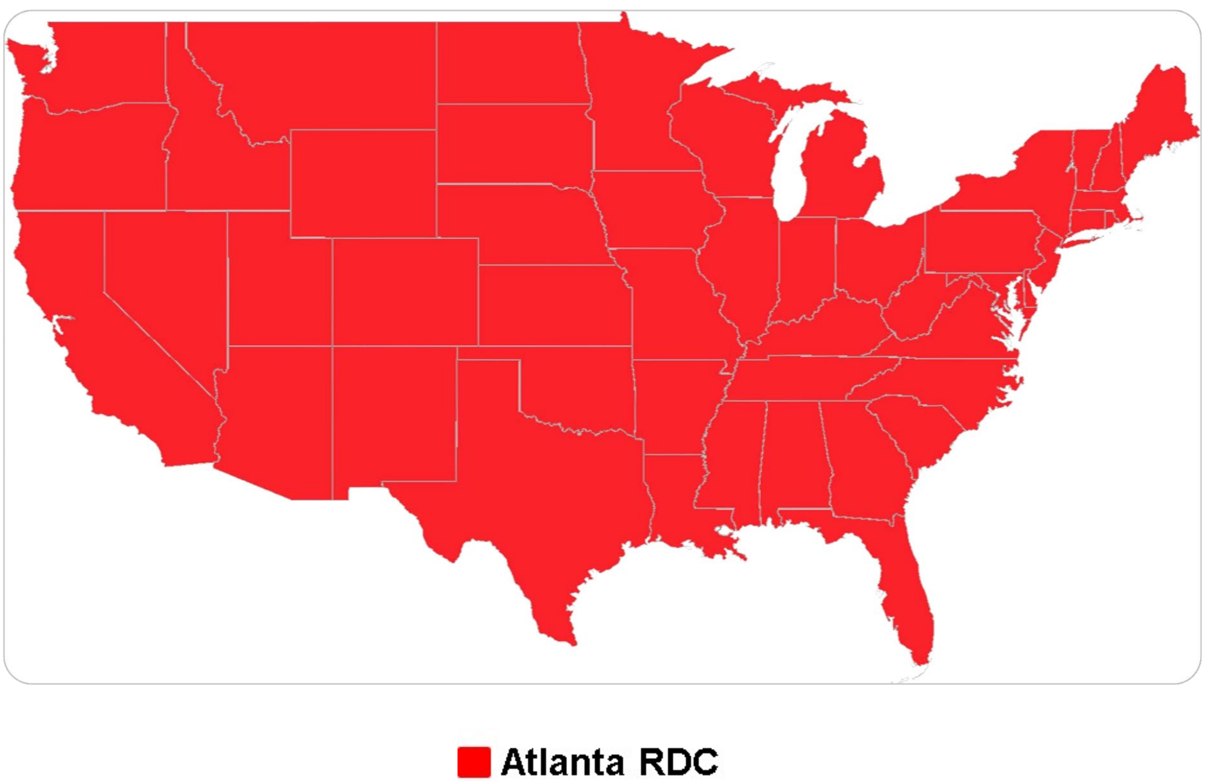


Figure 5 – Scenario 1 Map

For the second LTL scenario, Tacoma and Savannah were used as the only ports-of-entry with Tacoma and Atlanta representing the regional distribution centers for the West and East, respectively. Again, implications for the use of Savannah include increased ocean miles and costs. The ocean rate for Tacoma was $46.04 per unit and the ocean rate for Savannah increased $73.17 per unit with the trucking rate of $0.183 per mile. Upon completion of the calculations, the results indicated that the nation would be split into two portions for optimized shipping. Please see figure 6, "Scenario 2 Map," for an illustration of the nation split into two portions. The new shipping distribution resulted in total cost savings of $2,970,125. This new total savings indicates that having one port-of-entry in Tacoma and one in Savannah is worth consideration.

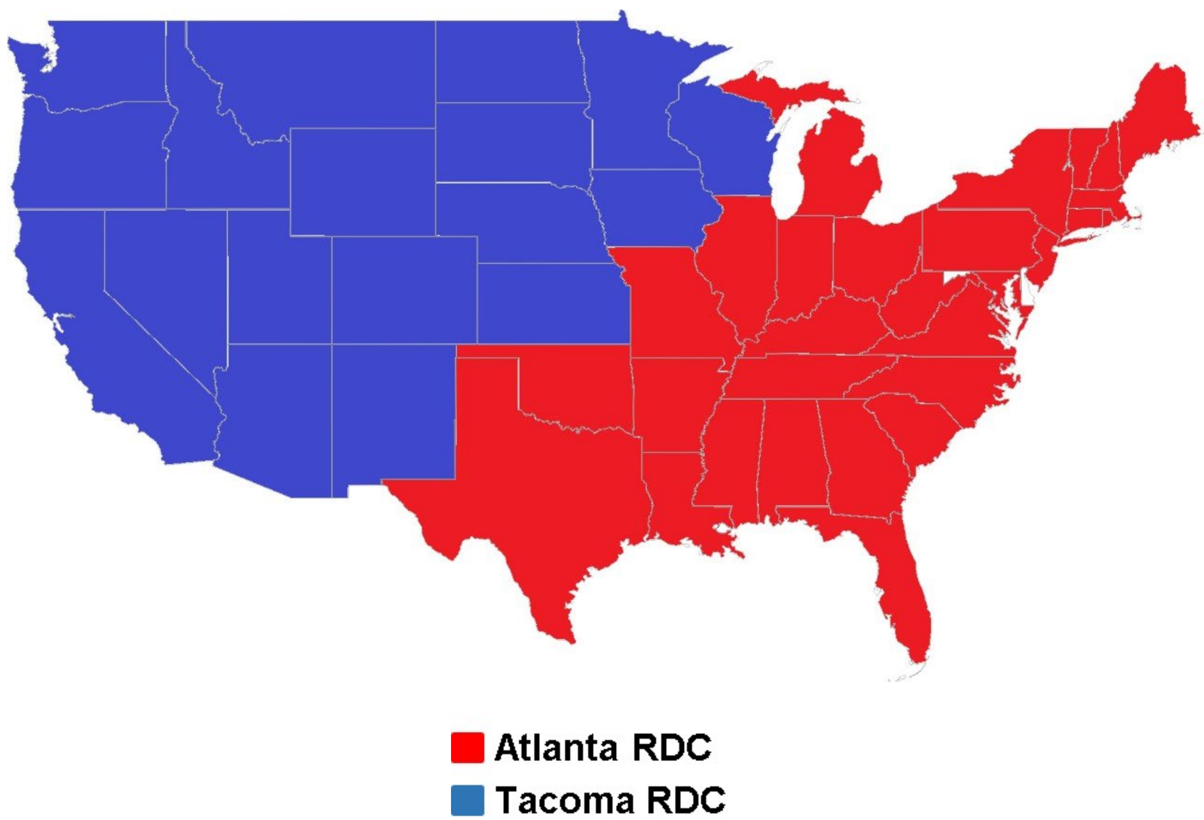


Figure 6 – Scenario 2 Map

For the final LTL scenario, Tacoma and Savannah were used as the only ports-of-entry with Tacoma, Atlanta and Chicago representing the regional distribution centers for the Pacific, Midwest and Southeast, respectively. Please see figure 7, "Scenario 3 Map," shown below. Because Chicago was used as a distribution point, rail was included to move units from either Tacoma or Atlanta. First, a comparison was completed to determine whether units shipping from Chicago should arrive by rail from Tacoma or Atlanta. Because the ocean and railway rates of

$46.04 per unit and $43.05 per unit, respectively, from Tacoma presented a more economical railway option, it was determined that all units shipping from Chicago would arrive by rail from Tacoma. Once the railway source was determined, a trucking rate of $0.183 per mile was used to calculate the costs for each region. These costs were summed to result in a total cost of $6,340,423. This new total savings indicates that having two ports-of-entry in Tacoma and one in Savannah as well as three regional distribution centers in Tacoma, Atlanta and Chicago is worth consideration.

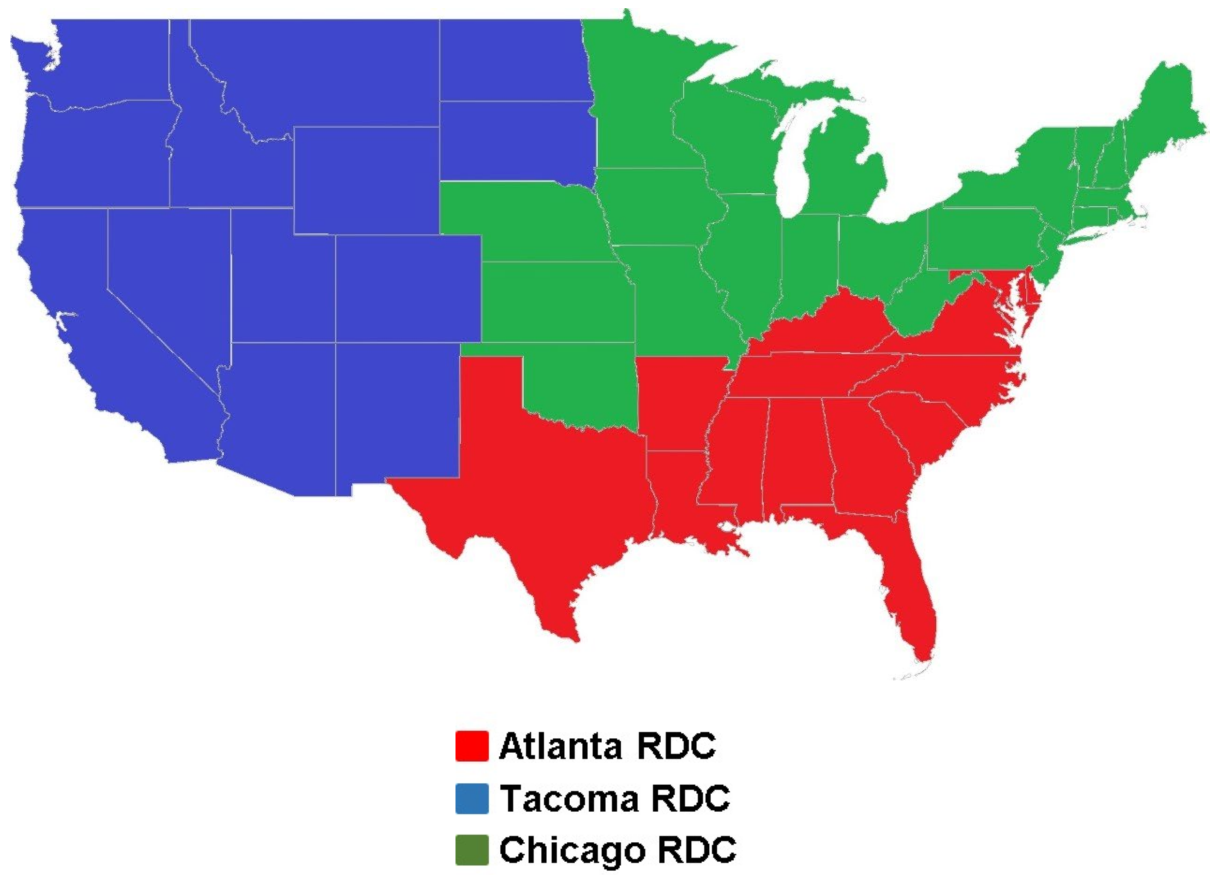


Figure 7 – Scenario 3 Map

4.5 Scenario Implementation and Results - FTL

Before explaining the results of the FTL calculations, a point will be highlighted. Due to the nature of the FTL shipments, a straight forward calculation, such as one similar to LTL, could not be implemented. For instance, a typical FTL shipment can be described as having one starting point and one ending point with one or multiple points in between. Because the start point and the end point could be the same, in terms of the state, calculating weighted averages for each state gets muddled. In order to remedy this issue, a method was carried out in which the "maximum mileage" was used for calculating weighted average. Although this maximum mileage was successfully used to cluster shipping destinations into one location per state, it could not be used to show cost savings. This will be more readily shown in the scenario explanations below. Also, please refer to figures 6 and 7 when visualizing the distribution setup for scenarios 2 and 3, respectively.

For the first FTL scenario, Savannah was used as the only port-of-entry as opposed to Tacoma with Atlanta representing the regional distribution center. Implications for the use of Savannah include increased ocean miles and costs. The ocean rate changed from $46.04 to $73.17 per unit while the trucking rate was $1.51 per mile. Upon completion of the calculations, the result indicated that due to the massive cost savings of $9,76,887.80 (84%) was reached, shipping most units from Atlanta is a worthwhile consideration. *This savings amount is not accurate due to the sensitive nature of the calculation.*

For the second FTL scenario, Tacoma and Savannah were used as the only ports-of-entry with Tacoma and Atlanta representing the regional distribution centers for the West and East, respectively. Again, implications for the use of Savannah include increased ocean miles and costs. The ocean rate for Tacoma was $46.04 per unit and the ocean rate for Savannah increased $73.17 per unit with the trucking rate of $1.51 per mile. Upon completion of the calculations, the results indicated another massive savings of $9,176,887.80 (84%), which indicates shipping units from Tacoma and Atlanta is a worthwhile consideration. *This savings amount is not accurate due to the sensitive nature of the calculation.*

For the final FTL scenario, Tacoma and Savannah were used as the only ports-of-entry with Tacoma, Atlanta and Chicago representing the regional distribution centers for the Pacific, Midwest and Southeast, respectively. Because Chicago was used as a distribution point, rail was included to move units from either Tacoma or Atlanta. First, a comparison was completed to determine whether units shipping from Chicago should arrive by rail from Tacoma or Atlanta. Because the ocean and railway rates of $46.04 per unit and $43.05 per unit, respectively, from Tacoma presented a more economical railway option, it was determined that all units shipping from Chicago would arrive by rail from Tacoma. Once the railway source was determined, a trucking rate of $1.51 per mile was used to calculate the costs for each region. These costs were summed to result in a total cost savings of $9,188,761.70. This new total savings indicates that having two ports-of-entry in Tacoma and one in Savannah as well as three regional distribution centers in Tacoma, Atlanta and Chicago is a worthwhile consideration. *This savings amount is not accurate due to the sensitive nature of the calculation.*

Chapter 5: Simulation with Arena and Lingo Optimization

When the project began, a plan was made to involve Arena software. Arena is a simulation software that allows the user to build real-world models in order to test and optimize transportation routes. It is in this testing and optimization of transportation routes that made Arena appealing. However, it was overlooked that, given the training ISyE students encounter with the software, an interarrival time was required. Because the project consisted only of receiving goods at Tacoma and Atlanta and did not include time between receiving of goods, Arena was not applicable to the project. Because an attempt was made to incorporate Arena in the optimization of this project, the results were included in this paper.

5.1 Scenario 1 – LTL Arena Results

The data in the table below shows the LTL data analysis of the total mileage for the 2018 year. While the total mileage is accurate, the total cost is not and should show, instead, a value of $10,819,717.35.

	Historical- Tacoma	
Mean		1000128.378
Standard Error		303238.342
Median		295727.632
Mode	#N/A	
Standard Deviation		2100896.861
Sample Variance		4.41377E+12
Kurtosis		22.00950666
Skewness		4.385978117
Range		12738094.64
Minimum		3820.655103
Maximum		12741915.29
Sum		48006162.16
Count		48

Total Cost	$ 60,751,898.10
Total Mileage	48,006,162

Table 4 – LTL Arena Values

5.2 Scenario 2 – LTL Arena Results

The data in the table below shows the data analysis of the total mileages from each distribution center at Tacoma and Atlanta. The simulation results in figure 5 below show the distribution of weight between units shipped from Tacoma and those shipped from Atlanta.

tacoma		*atlanta*	
Mean	175662.4401	Mean	334594.6657
Standard Error	74806.32636	Standard Error	112009.5823
Median	31585.925	Median	136562.5043
Mode	#N/A	Mode	#N/A
Standard Deviation	317376.3639	Standard Deviation	613501.7489
Sample Variance	1.00728E+11	Sample Variance	3.76384E+11
Kurtosis	4.922673699	Kurtosis	18.1760516
Skewness	2.379398165	Skewness	4.004596409
Range	1091775.508	Range	3237575.28
Minimum	3820.655103	Minimum	996
Maximum	1095596.163	Maximum	3238571.28
Sum	3161923.922	Sum	10037839.97
Count	18	Count	30
Total Cost	1,233,648.67	Total Cost	6,615,952.80
Total mileages	3,161,924	Total mileages	10,037,840

Figure 5 – LTL Arena Comparison

5.3 Scenario 2 – LTL Arena Model

Figure 8 shows the Arena model setup for LTL scenario 2. There are two assignments for ocean rates, two entry points representing Tacoma and Savannah, two assignments for trucking costs and two destinations representing the distribution routes out of Tacoma and Atlanta.

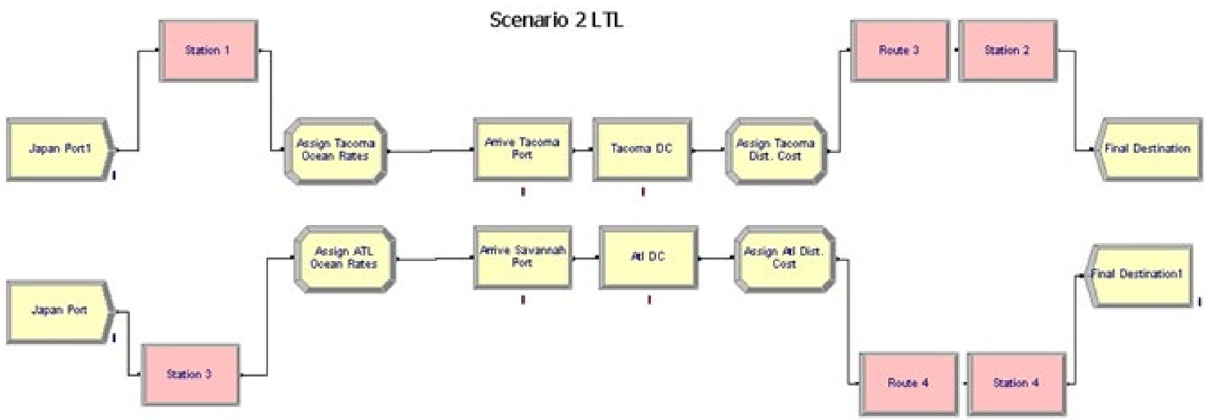


Figure 8 – Arena Model

5.4 Scenario 3 – Lingo

Lingo is optimization software that calculates the optimal alternative, given multiple alternatives, through many iterations of scenarios. Using Lingo, the team wanted to find the optimal percentage of units to ship to Chicago from Atlanta and Tacoma. Figure 9 shows the Lingo optimization equation and constraints. In the figure, the equation aims to minimize the combination of X1, Atlanta, and X2, Tacoma, given their attached costs, $41,712.83 and $39,370.65 respectively. Through a very quick computation, it can be seen in figure 10 that 100% of units shipped to Chicago should go through Tacoma.

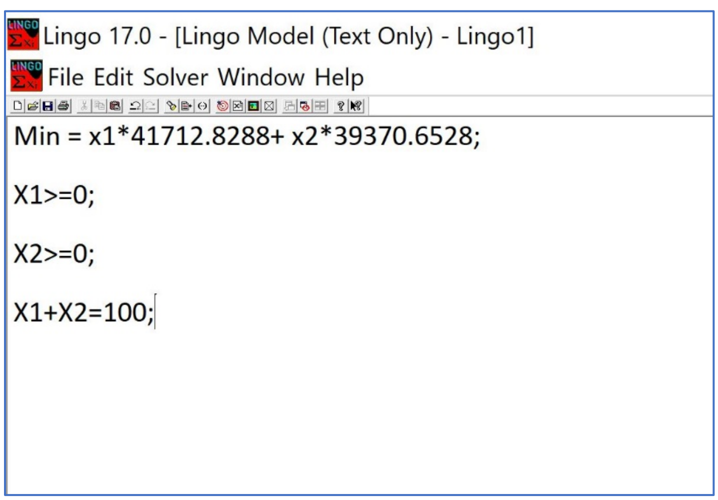
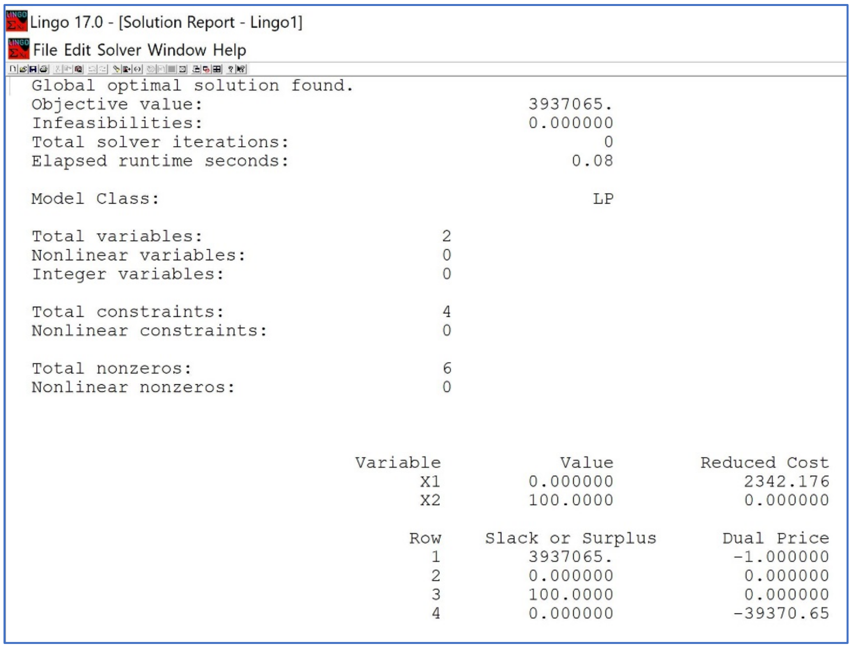


Figure 9 – Scenario 3 Lingo Equation and Constraints




```
Global optimal solution found.
Objective value:                              3937065.
Infeasibilities:                              0.000000
Total solver iterations:                             0
Elapsed runtime seconds:                          0.08

Model Class:                                        LP

Total variables:                      2
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                    4
Nonlinear constraints:                0

Total nonzeros:                       6
Nonlinear nonzeros:                   0


                              Variable           Value        Reduced Cost
                                    X1        0.000000            2342.176
                                    X2        100.0000            0.000000

                                   Row    Slack or Surplus      Dual Price
                                     1        3937065.           -1.000000
                                     2        0.000000            0.000000
                                     3        100.0000            0.000000
                                     4        0.000000           -39370.65
```

Figure 10 – Scenario 3 Lingo Results

Chapter 6: Results and Discussions

From the results of the LTL and FTL calculations, the YACD team found improvements on network optimization when checked against the 2018 data. As mentioned earlier, the FTL calculations did not give any reliable information regarding network improvement and, therefore, will not be mentioned in this section. For scenario1, moving the port-of-entry from Tacoma, Washington to Atlanta, Georgia improved on mileage, with a savings of 61%, but did not improve on costs, with an increase of 1%. For scenario 2, adding a port-of-entry at Savannah, Georgia to compliment Tacoma, improved both metrics, with costs reducing by 27% and mileage reducing by 73%. Scenario 3 gave the best results, with a reduction in cost by 41% and a reduction in mileage by 82%. Disregarding scenario 1 as an option, due to its increased cost by 1%, and considering the decision to not purchase or lease a warehouse in Chicago, Motor Boaters USA should move forward with scenario 2. If, in the future, Motor Boaters USA decides it is feasible to purchase or lease a warehouse in Chicago, shipping by ocean to both Tacoma and Atlanta and then by rail to Chicago would present the optimized solution to their network distribution issues.

Chapter 7: Conclusions

Motor Boaters USA requested that the YACD team improve their distribution network for their outboard motors. Through data cleaning, data analyses, clustering methods and network calculations, the YACD team was able to find optimized solutions to their network in order to present an option moving forward. The YACD team examined three alternatives. The first alternative included moving the port-of-entry from Tacoma, Washington to Savannah, Georgia. The first alternative presented the least desired result, which included increasing costs by 1%. The second alternative included adding a port-of-entry to Savannah, Georgia to compliment the port-of-entry in Tacoma, thereby creating two separate distribution regions, the east and the west. The second alternative presented a feasible solution, with a decrease in costs by 27% and a decrease in mileage by 73%. The third alternative included a third regional distribution center in Chicago, Illinois, along with the already installed second port-of-entry at Savannah. With the distribution center in Chicago, which is supplied by Tacoma and Atlanta via rail, the costs improved to its best, with a savings of 41%, and the mileage improved to its best, with a reduction by 82%. While the third scenario is the most optimized, it is unlikely that Moto Boaters USA will pursue such a situation due to its disinterest in purchasing or leasing a warehouse in Chicago.

Chapter 8: Challenges Faced

Data acquisition and interpretation were main factors in creating delays for the team. In order to counteract this issue, the team pushed MBUSA for the data and explanations needed, researched missing or omitted data, and estimated data that was not clear.

Outside of missing or omitted data, there were multiple discrepancies with the data itself. Initially there were mileage rates that were not correct such as charging $10.22 per mile. These inaccuracies were found through a combination of skepticism and web research. Again, the team had to motivate MBUSA to provide corrections to the data in order to stay on schedule. Within the data cleaning mentioned earlier in the paper, the inaccuracies were also corrected along with reducing data size for analyzation and calculation.

Using the data to reach conclusions was difficult without proper methods or applications. Consultation with faculty within the ISYE department greatly helped us in handling our methodology issues and propelled us forward through the project. Speaking with the faculty also gave us some insight into which applications that were available.

References

[1] https://www.loopnet.com/washington/tacoma_warehouses-for-lease/

[2] https://www.cityfeet.com/cont/tacoma-wa/industrial-space-for-lease

[3] https://www.loopnet.com/illinois/chicago_warehouses-for-lease/

[4] https://www.loopnet.com/georgia/atlanta_warehouses-for-lease/

[5] Jivanath Venugopalan, V.S. Sarath, Roshan Jayaraj Pillai, S. Anantha Krishnan, S.P. Anbuudayasankar, *Analysis of Decision Models in Supply Chain Management, Procedia Engineering*, Volume 97, 2014, Pages 2259-2268. [Online]. Available: https://doi.org/10.1016/j.proeng.2014.12.470. [Accessed March 17, 2019]

[6] Tseng, Y.Y., Wen L.Y. and Michael AP.T. (2005) "The role of transportation in logistics chain." *Eastern Asia Society for Transportation Studies*.

[7] Carter, J.R. and Ferrin, B.G. (1995) "The impact of transportation costs on supply chain management", *Journal of Business Logistics*.

[8] Anil K. Jain, *Data clustering: 50 years beyond K-means, Pattern Recognition Letters*, Volume 31, Issue 8, 2010, Pages 651-666. [Online]. Available: https://doi.org/10.1016/j.patrec.2009.09.011. [Accessed April 5, 2019].

[9] Fahim, A.M., Salim, A.M., Torkey, F.A. and Ramadan, M.A. (2006) "An efficient enhanced k-means clustering algorithm", *Journal of Zhejiang University SCIENCE A.*

[10] W. D. Kelton, R. P. Sadowski, and N. B. Swets, *Simulation with Arena*. New York: Mc Graw-Hill, 2015.

[11] A. Ganti, "Weighted Average Definition," *Investopedia*, 31-Mar-2019. [Online]. Available: https://www.investopedia.com/terms/w/weightedaverage.asp. [Accessed: 09-Apr-2019].

****Any similarites or correlations between locations, organizations or people in this paper are not intended and purely coincidental.*

Appendix A: Acknowledgements

The YACD team would like to acknowledge the following individuals and organizations for their support in completing the project.

The professional logistics team at Motor Boaters USA. These individuals will remain anonymous but should know they provide great feedback and experience within this endeavor.

Dr. Amin Esmaeili, Dr. Lin Li, and Dr. Robert Keyser who offered their experience regarding concepts, methods and software. These individuals were integral to the success of this project.

Dariush Moein, Industrial and Systems Engineer, who offered his experience and service in assisting the team with data analysis and manipulation.

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Appendix C: Reflections

Throughout this project, multiple lessons have been learned including the importance of communication, directions of objectives and following of schedules. Everything seems clear when looking back on the project. A clarified and more useable solution could have been reached if every method and step were defined. The team will use the knowledge they have gained from completing this project in different situations in the future.

Appendix D: Link to Project Video

Please follow the link below to view the project summary video.

https://youtu.be/gxCizzC75Jc