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INBOUND TRANSPORTATION COST ANALYSIS WHEN NODE ADDED TO DISTRIBUTION NETWORK

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ABSTRACT

Supply chains are not static beings. Companies change every year and their requirements change with them. As companies look to expand their network to enter a new geographical market, they have placed a great focus on how the additional node will impact transportation costs. A variety of frameworks and tactics exist to identify outbound cost savings potential, but neglect the impact on inbound freight. This thesis will seek to fill that void by demonstrating a methodology on how to understand inbound freight impact and a post hoc cost analysis from the shipment data of a mid-sized grocer. Through the utilization of the methodology presented in this thesis, the mid-sized grocer mentioned above was able to see significant cost savings. The methodology presented is also transferable to other companies and industries. The thesis concludes with recommendation for future research including better supplier information database, incorporation of accessorial charges, and implementation of backhauls to achieve greater economic returns.

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Chapter 1

Introduction

There is a growing expectation placed on current day businesses to have their shelves full and their online deliveries fulfilled quickly. Amazon and Walmart promise two-day shipping on orders, and we as consumers happily accept this without much thought about all the management that takes place in order for that single event to happen. Transportation is the most important and overlooked piece of business logistics in the end to end supply chain. Transportation is responsible for moving goods across business “nodes”. These nodes are any physical touch points from supplier’s raw material warehouses, production facilities, manufacturer’s distribution centers (DCs), retailer’s DCs, retailer’s stores, or even directly to a consumer. As a higher level of service is expected across every node from raw material suppliers, manufactures, and retailers, companies are spending more on transportation. Negative operating cash flows are unsustainable in the long run, so companies need to find a way to ship more profitably and reduce transportation costs.

As larger companies enter into their mature phase and see less growth in sales figures, they are looking towards their supply chains in order to cut costs to increase their bottom line and keep investors happy. Transportation is the single largest variable cost in a supply chain network and continues to rise. United-States logistics costs have risen by 11.4 percent since 2018, and the costs represent the highest share of GDP in the past ten years (Bearth, 2019). Balancing internal pressures of fulfilling on-time delivery requirements to customers as well as cutting costs is a daunting task, and are placing tremendous of focus on outbound transportation costs.

As more nodes are added, outbound transportation costs will decrease, inbound costs will increase, and total transportation costs will be unknown. Many companies focus heavily on the positive impact on outbound transportation to the customer that is gained from adding more nodes to a distribution network. However, companies struggle to identify how their inbound freight will be impacted because of the dynamic nature of suppliers.

There are multiple theories on ways to drive transportation costs down. This thesis will evaluate various approaches to reduce logistics cost through the lens of a grocer (disguised as “Company A” for the entirety of this paper) while keeping in mind company size, industry, nature of shipments, and other differentiating characteristics. This thesis will focus more heavily on inbound freight as it has the greatest opportunity for improvement due to the dynamic nature that changes from company to company. The analysis will showcase one technique and provide a methodology that is transferable to other companies looking to expand their network or rationalize their supplier base. This thesis will conclude with final recommendations on future analyses- to increase cost-saving potential.

Chapter 2

Literature Review

Before discussing methods to mitigate the impacts of inbound transportation costs when the number of nodes in a distribution network increases, it is critical to understand the driving forces behind rising costs and rationale for why a company would look to expand. Examining the underlying causation of these topics will help identify the issues at hand and provide a future outlook for transportation expenses.

History

Researchers from the Smeal College of Business at The Pennsylvania State University and the Coggin College of Business at University of North Florida published an article in early 2014 in the Council of Supply Chain Management Professionals quarterly article (*CSCMP's Supply Chain Quarterly*) on the history of rising transportation costs and the main driving forces behind these increases.(Coyle, et. al., 2014) From the 1990's through the first part of the 21st century, shippers saw high availability and low transportation costs relative to inventory holding costs. These factors encouraged more frequent fast shipments to customers through just-in-time (JIT) deliveries. During the mid-2000's the transportation market has changed dramatically and called the previous strategy of excessive shipments into question. Companies began to see instability in crude oil prices and an imbalance of supply and demand for transportation services.

According to an article by Robert Looney of the Center for Contemporary Conflict at the Naval Postgraduate School titled, "Oil Prices and the Iraq War: Market Interpretations of

Military Developments", oil prices were extremely volatile in the mid-2000's due to an increase in demand from the United States war with Iraq and relatively low supply. Low supply of oil can be attributed to four main drivers: 1) the president electing to not utilize oil from the United State's strategic petroleum reserve; 2) lack of spare capacity from the Organization of the Petroleum Exporting Countries (OPEC); 3) Nigerian production problems; and 4) low on hand inventories of oil (Looney, 2003). Mismatch in supply and demand caused the price of oil to rise sporadically that placed a heavy burden on the transportation market as well.

In addition, the lack of availability of transportation services in the United States could not match the rapid pace of international trade growth. The increase in demand has caused freight volumes to rise at an unprecedented rate, resulting in highway congestion and carrier capacity constraints. With congestion and capacity getting worse and the Highway Trust Fund's (HTF) limited budget, the United States was unable to invest properly into the U.S. transportation infrastructure. These conditions crafted the 'perfect storm' to raise and keep transportation costs high. As the researchers from The Pennsylvania State University and University of Northern Florida discovered, the volatility in oil prices, and capacity constraints are raising logistics costs and forcing companies to change their strategy around managing transportation costs in order to preserve profit margins and improve their supply chain performance.

Strategies and Frameworks

The researchers from the Supply Chain Quarterly article denoted three major shifts that are responses to the changing market and are having notable impacts today. The research has also determined that these shifts will aid in improving both supply chain and financial performances driven largely by a reduction in costs and more productive investments.

1. A shift from offshoring to nearshoring

Traditional procurement and manufacturing strategies suggested companies to look for the cheapest option. This philosophy originally meant outsourcing to countries with low costs of labor with little consideration for transportation implications. However, according to this article, companies are shifting from offshoring towards performing manufacturing closer to the point of consumption. Dr. Coyle and his colleagues identified this growing trend in response to heightened oil prices, stating, "Year-to year growth rates of imports from low-cost, long-distance sources in Asia dropped sharply around the time of the oil-price peak in 2008. This is a noticeable contrast to the sharp increase in imports from near-shore sources in North America, Latin America, and the Caribbean during the same period"(Coyle, et. al., 2014). Switching sourcing strategies to focus on nearshoring reduces total miles traveled which ultimately mean less oil consumed and aids in keeping freight costs lower while also allowing the manufacturers to remain flexible in customer service, order fulfillment, and inventory positioning.

2. A shift from product design for marketability and production to design for "Shipability"

Companies are placing a greater importance on packaging/product designs that allow for more economical shipment behaviors. For example, manufacturers of Windex and Method cleaning products have begun selling refills in flexible pouches rather than the rigid plastic bottles. This allows for greater product density and less total shipments needed. The researchers also noted, the Grocery Manufacturers Association surveyed its members and found that the packaging improvements in the consumer product industry has saved one and a half billion pounds of packaging over a five-year period from 2005 to 2010. With the average weight of a full truckload being roughly 42,000 pounds, over the course of five years, manufacturers were able to reduce almost 36,000 full truckloads of unneeded packaging. These alterations to product design allow for savings in freight costs, packaging costs, and space utilization on both a transportation level and at a shelf level at a retailer.

3. A shift from lean inventory strategies to lean inventory-transport hybrid strategies

Lean inventory is a methodology that keeps inventory levels as low as possible in order to keep inventory and warehousing costs low. This method was predicated on frequent, small, just-in-time deliveries that relied on cheap transportation. As oil prices and transportation costs grew in unison, a new transportation strategy began to emerge: companies wanted to have economies of scale. Economies of scale attempts to increase the size of shipments in order to ship more, at a less-frequent rate. In order to take advantage of larger truckloads, companies placed a greater importance on consolidating shipments, capacity utilization, and gauging alternative modes of transportation to offset growing costs. Since the greatest tradeoff in logistics is between inventory and transportation, companies are opting to increase inventory holding costs in order to gain operational efficiencies in shipping. Refer to Figure 1 in the text.

Figure 1. Transport-driven shifts in strategies and their connections to the boardroom

Guiding Transport and Logistics Principle	Transport-Driven Shift in Supply Chain Strategy	Supply Chain Performance Impacts			
		Freight costs	Inventory costs	Customer service responsiveness	Space utilization
Count the miles	**Sourcing:** Shift toward nearshoring	●	●	●	
Don't ship air, don't ship water	**Product and package designs:** Shift toward design for "shipability"	●			●
Consolidate, consolidate, consolidate	**Inventory:** Shift toward lean inventory/transport hybrid	●		●	
		Cost of goods sold (COGS)	Current asset	Sales	Fixed asset
		Return on Capital Employed (ROCE) Impacts			

The research team concluded their essay with highlighting that in order to properly manage transportation costs, greater importance must be placed on the distance a shipment goes, the density of the product, and shipment size. Many companies from retailers to product manufacturers have taken to these concepts over the past decade and have deployed new initiatives to eliminate empty miles and consolidate shipments by locating their distribution centers close to the final customer and working with customer service to smooth ordering patterns. For this reason, reducing transportation costs is an effort that must be supported across the entire supply chain, from having the correct forecast in place, consolidation of loads, and executing on the delivery. However, these initiatives are primarily stressed on outbound shipments and inbound goes largely ignored with few understanding the unstructured nature of receiving product from suppliers.

In 2009 two researchers from the ESC Clermont Business School in France presented an essay during the International Federation of Accountant's 13th annual symposium, titled, "Impact of Inbound Logistics on Design of Production Systems". The research team pointed out the asymmetrical innovations between inbound and outbound transportation. As organizations become more customer-oriented, marketing departments work with the supply chain teams to understand specific customer segments and their needs. A much greater importance is placed on final customer destination in distribution network design than sourcing locations. The team expanded on this concept stating," … one of the most neglected areas of the manufacturing (and retail) supply chain is the inbound logistics segment. Managing outbound logistics has always been the strength of the Supply Chain organization (at manufacturers and retailers). Similar to the Marketing department, the Purchase (Procurement) department has its own unique set of requirements for inbound raw materials/ work-in-progress and other inbound material. In addition, modern JIT manufacturing methods push the Procurement Manager to aim to achieve lowest inventory models, often at the expense of higher inbound transportation costs. There is an inherent conflict in balancing the Just-in-time manufacturing practices (low inventory, shipment sizes, frequency of shipments) with inbound logistics and transportation needs (low cost, visibility of goods)" (Neubert, et. al., 2016). The research team identified that in the past the main focus on logistics optimization was on controlling inventory levels. However, they proposed more collaboration between companies and their partners to ensure appropriate levels of inventory across nodes and fewer unnecessary inbound moves to shift inventory. Two of the more notable methods to increase collaboration between companies and their partners include vendor managed inventory (VMI) and collaborative planning, forecasting, and replenishment (CPFR) (Neubert, et. al., 2016).

Vendor managed inventory. VMI is a model where the buyer of a product shares consumption information with the supplier, and the supplier is responsible for keeping inventory at an agreed upon level. As the buyer utilizes product, the supplier will automatically send them more. This model allows for the passing of information so the supplier is able to make better decision on when to produce by being able to see consumption patterns in real time. VMI aims to reduce inventory, decrease stock outs, minimize variability, and improve customer service. By eliminating the need for excessive safety stock companies are limiting excessive inbound shipments.

Collaborative planning, forecasting, and replenishment. According to the Institute of Business Forecasting and Planning, "CPFR strategies allow aligning of multiple sales and operations planning processes and jointly plan supply chain activities to ensure that the joint business plans between organizations are respected, while minimizing costs and maximizing efficiency from end-to-end of your supply chain" (Laporte-Roy, 2019). CPFR is the process of sharing information develop a unified forecast for the year that both partners execute together. CPFR requires time and resources since every collaboration has to be specially tailored to the customer. When implemented properly, companies can see the benefits through reducing stock-outs, better managed inventory, more visibility, and stronger relationships with their partners.

Network Design

Another strategic means towards reducing logistics costs is through optimizing the network with tactical distribution center placement. As stated above, the three factors that determine a shipments cost are size of the shipment, nature of the commodity, and distance it goes. Through network design companies are able to control the distance the average shipment will go by optimally placing their distribution centers close to their final customers. The impact of strategic network design has resulted in extensive research from scholars and industry experts alike.

Researchers from the University of Southern Denmark, Shahrood University of Technology and The University of Michigan published an article in the *European Journal of Operational Research* about network design under uncertainty. The researchers defined supply chain network design as, "…part of the planning process in supply chain management, which determines the infrastructure and physical structure of a supply chain" (Govindan, et. al., 2017). Network design attempts to answer the questions: how many facilities, where they will be located, and capacity/size of the facilities with consideration for final customer and supplier locations.

One consideration for network design the research team alluded to is that typically any changes require large capital investments which make them difficult to alter in the short term and can have long-term effects on the performance of the entire supply chain. The team states that this is one of the most difficult activities involved in the planning process because the parameters, including demand, capacity, and costs, can have such large amounts of fluctuating data that typically result in, "… wrong estimations due to inaccurate forecasts and/or poor measurements in the modeling process" (Govindan, et. al., 2017). One example the researchers gave of a measure that is difficult to estimate but critical to get correct when designing networks is the aggregate demand for products. This measurement shows the total demand for all finished goods, so inaccurate representation of this can have negative implications when determining capacity and size.

Over the last two decades, four main types of facility location models have become common place: continuous, network, analytic, and discrete. According to the research team, there are many differences between the four models, but they all include "… a set of customers with known locations and a set of facilities whose locations should be specified" (Govindan, et. al., 2017). In addition, most models belong to the discrete location model category.

Discrete. This type of facility location model concerns itself with finding the best location for facilities give a set of parameters. Discrete optimization typically aims to minimize total cost and maximize customer demand fulfillment. Similar to most models, discrete places a heavy focus on minimizing outbound transportation costs while believing inbound to be a necessary evil.

Discussion

As evidenced by the insights offered in aforementioned literature, there are many methods to address rising transportation costs. Strategies such as nearshoring, making products more "shippable", and collaborating between shippers and customers are contributing towards a more cost-effective supply chain. Although these methods are valid, typically these strategies are easier to implement in the early design stages of the supply chain. These approaches neglect to provide substantial insight on how shippers can conduct post hoc analyses of their network decisions specifically in reference to inbound transportation. This thesis will seek to fill this void, proceeding with an analysis of one such optimization technique – discrete network analysis when adding nodes to minimize total transportation cost.

Chapter 3

Background

As previously introduced, Company A is a large retail grocery company with an extensive and complex transportation and supplier network. This is due in part to the diversity in product offerings, customer base, and regions serviced. As such, transportation modes are wide ranging, including refrigerated vans (reefer), dry vans, intermodal carriers, dedicated fleets (operating in a concentrated region), and less-than-truckload (LTL). In addition, the responsibility to arrange transportation for the product is split between Company A (Company A arranged) and the suppliers (vendor arranged) for inbound shipments. Company A may have multiple suppliers for the same product category and suppliers that service multiple product categories. Many suppliers have multiple distribution centers that they utilize to ship to Company A, so not all shipments are coming from the same place each time an order is placed with a supplier.

Company A currently operates two distribution centers within the northeastern region of the United States. However, as stated in the introduction, the company is looking to expand into the mid-Atlantic and add a third distribution center to their network. Company A's network is comprised of over one hundred retail stores and is looking to expand further with the addition of the new distribution center over the next few years. Company A is in the top twenty-five grocers by volume and utilizes over three hundred suppliers in order to fill all stores. Most suppliers of Company A have similarly complex networks with a variety of production facilities, distribution centers, and cross docks. The size and complexity of the transportation network is further illustrated through distance and volume statistics, separated by who arranged the freight in Table 1. All these figures are calculated from Company A's shipment data from the transportation team that will be discussed in the next section.

Table 1. Descriptive Analysis by Freight Arrangement

Vendor or Company A Arranged	Total volume	Volume (%)	Average Miles*	StdDev of Miles*	Min. Miles*	Max. Miles*
Vendor Arranged	284,720,392	56%	527.85	628.99	27.45	2,807.43
Company A Arranged	225,121,035	44%	256.84	368.78	8.32	2,798.90

*values given on a "per move" basis (i.e. from single origin to destination

Objectives and Scope

As highlighted in the conclusion of the Literature Review, companies across industries often experience issues conducting a discrete network analysis and determining inbound transportation cost impact when adding nodes to a distribution network. Since the companies are more focused on outbound shipments, there are opportunities where greater efficiencies or cost savings in inbound shipments could be missed. For this reason, Company A has conducted a survey of all its current suppliers in August-December 2019. This extensive survey was filled out by individual suppliers and sought information on where the suppliers are currently shipping from. The survey additionally asked the suppliers to list any other warehouses in their network that they believe would be closer to southern Virginia in the U.S. than where they are currently servicing Company A's northeastern distribution centers from. The survey received 285 responses from suppliers and represented seventy-two percent of volume. The survey was exported to a Microsoft Excel file where primary analysis was performed. The Excel file has over ninety columns, each corresponding to an individual question asked on the survey and each row represent the responses from one supplier. Columns such as Supplier Name, Distance, Current Cost, and Future Cost are among the twenty columns identified as most useful for this analysis. For a full listing of the relevant columns and their descriptions, see Appendix C. The methodologies and analysis will reference the data through these column names.

Using Company A's data as an example, the following chapter will detail a methodology and corresponding analysis for how shippers can evaluate inbound transportation cost impact and detect savings opportunities. Analyzing supplier recommendations for optimal shipping location will be introduced while keeping the underlying cost savings objectives in mind. Insight from this methodology can be incorporated into the future when companies are looking to expand to obtain the projected benefits.

Chapter 4

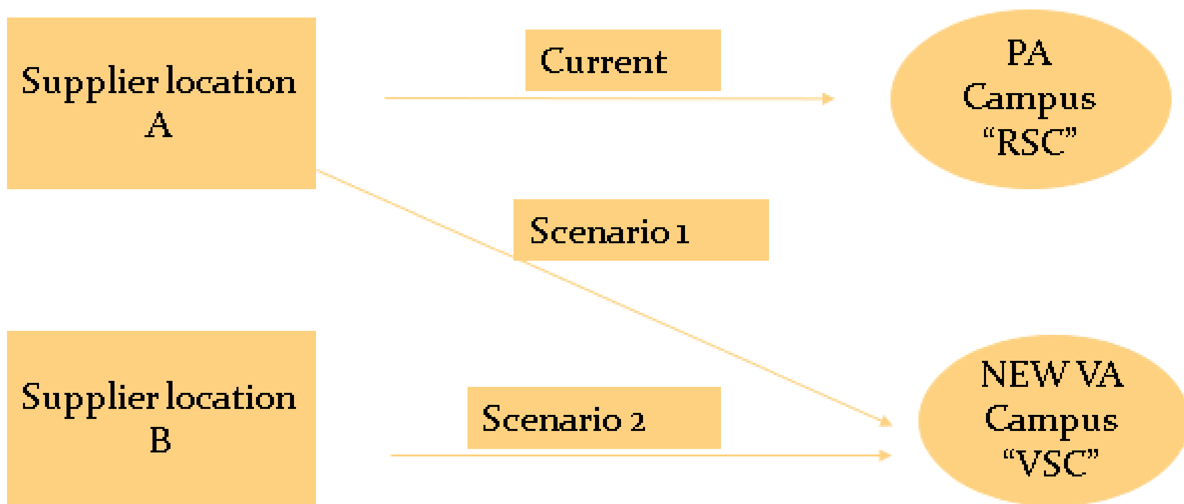
Network Optimization

The goal of this analysis is to identify which locations of a supplier's distribution network should be utilized to service a new distribution center from a cost perspective. The decision to locate Company A's facility in southern Virginia was a strategic choice to expand naturally down the east coast of the United States. Due to Company A's commitment to this area, this approach will discuss methodologies and results from the point of view of inbound transportation, but a similar approach could be used to find an optimal location that reduces total transportation costs.

Methodology

The methodology commenced with the collection of the supplier survey Company A sent two weeks prior. The survey data asked for the addresses of distribution center locations the supplier had in their network. Specifically, Company A was asking each supplier to provide location data for distribution centers in their network that would best service the following states: New York, Pennsylvania, and Virginia. These three states are where Company A has their distribution centers and became the destination point in this analysis. Concatenating the supplier's distribution origin and Company A's destination, created a single lane for identification purposes. Currently, suppliers are shipping from their closest distribution center to Company A's Pennsylvania distribution center, but two new scenarios emerge when a new distribution center opens in southern Virginia: 1) suppliers have a single distribution center and supply both PA and VA Distribution centers from it, or 2) suppliers have multiple distribution centers and determine which is more mutually beneficial to source from. Refer to figure 2 in the text to see multiple inbound scenarios companies face when adding a new distribution center to network.

Figure 2. Inbound Transportation Scenarios When New Distribution Center is Added to Network



Since the methodology is inapplicable in a single sourcing environment, the scope of the first analysis was performed on the second scenario: determining an optimal sourcing location for Company A in the presence of multiple sourcing options. Filtering to only include suppliers with multiple shipping locations revealed thirty-six suppliers that would become the focus of this analysis.

Cost implications for these thirty-six suppliers were calculated through a series of steps. Code written in the computer language R was utilized to access Google API and return the distance between origin/destination pairs. Freight rates were then determined based on a per mile rate table provided by DAT, a tool commonly used in industry to gauge potential freight charges. Volume data of these suppliers was supplied by Company A and utilized to help determine average load weight, transportation mode, and annual cost impact once a per-move cost impact has been established. The analysis took into account different cost structures for different transportation modes including refrigerated versus dry-van and full truckload versus less-than-truckload through various tables to add cost multipliers when applicable. The analysis calculated costs for all three scenarios listed above, including the current shipping scenario to provide an accurate baseline to compare to later.

Findings

Narrowing the data to only include the suppliers with multiple potential sourcing locations leaves thirty-six out of the original 263 suppliers. These thirty-six suppliers are the focus of this analysis and provide the greatest opportunity to identify cost savings. Many sourcing location decisions proposed by suppliers were in closer proximity to the new distribution center than the original sourcing location that services Company A's Pennsylvania distribution center, but the analysis identified as more costly overall. These thirty-six suppliers underwent the cost savings analysis whereby total inbound transportation costs were calculated for each potential supplier location and the lowest cost was calculated. Results of the analysis are reported in Table 2, where all thirty-six supplier locations were found to have potential savings. It is not surprising to see inbound transportation costs increase with the addition of a new distribution center in the network. However, this methodology was able to limit expenses and deliver cost savings potential of up to $498,779, as summarized by Table 2.

Table 2. Summary Pivot of Findings

Alternative Source Locations?	Number of Suppliers	Supplier Proposed Sourcing Location Impact*	Methodology Proposed Sourcing Location Impact*
YES	36	(578,000.54)	(79,288.43)
NO	227	(2,253,735.37)	(2,253,668.46)
Grand Total	**263**	**$(2,831,735.91)**	**$ (2,332,956.89)**

Total Annual Savings	**$ 498,779.01**

*Cost Impacts given on an annual basis and negative numbers represent negative cash flows

Since network changes are major capital investments for many companies, this analysis does not have to be completed on a regular basis. After analyzing potential improvements initially, this analysis will only be needed if a supplier is changing their network. This point leads to one of the main conclusions of this research: do not underestimate simple solutions. Many companies are looking for supply chain revelations that will thrust themselves years ahead of competition as far as cost reduction and efficiency goes, but they overlook daily operations that could lead to significant savings, like making sure suppliers are shipping from the most cost-efficient site.

Further analysis could be performed on all supplier lanes in order to determine cost saving potential via backhauls on outbound freight. As discussed in previous chapters, Company A has an extensive distribution network that includes retail locations all across the North East region of the United States. When drivers are returning to the distribution center, Company A can potentially have them pickup shipments from nearby suppliers to reduce empty miles and increase their fleets efficiency. Although not a part of the scope of this research, potential savings could increase drastically and should be considered moving forward.

In addition to cost saving potential, vendors with multiple sourcing locations could prove more reliable in the face of unforeseen events. Risk management and avoidance should be kept in mind when developing supply chain networks. Low volume, high impact events like natural disasters or medical outbreaks have the ability to cripple supply chains and cause volatility in demand. These demand spikes are a symptom of the bull whip effect that produces greater variability as it travels upstream from consumers to suppliers. Thus, a more strategic buying strategy for Company A is to incorporate the insights brought forth in this chapter, and optimize their supplier's extensive distribution networks to create savings on inbound transportation costs and cost avoidance in the face of a high impact event. Nevertheless, it is important to note that some suppliers simply do not have the volume to warrant additional distribution centers across the United States at this time, and hence, why they utilize a single warehouse.

Chapter 5

Conclusion and Recommendations

The analysis conducted through this thesis is a small sampling of the many post hoc studies that can contribute to a shippers' competitive advantage and drive overall cost savings. Through a more thorough evaluation of their suppliers' network, Company A could potentially save five-hundred-thousand dollars annually. Although the subject of this research is a grocer with a large network, the methodology is able to be transferred to many other distribution networks. With this thought in mind, the following recommendations will be applicable for any shipper who is looking to reevaluate inbound transportation costs in their network.

Do not underestimate simple solutions. Far too often supply chain managers face internal pressures to reduce costs while improving service, and they overlook ongoing issues. Complacency plagues many industries. Individuals can quickly slip into the mentality that someone must have already fixed the simple things and all new problems require complex solutions. In the case of Company A, ensuring suppliers ship to Company A's new distribution center from the closest point of origin is the simple solution that yielded significant savings. Shippers should identify things that have been done the same way forever and question if there is a better way to drive efficiencies semi-annually.

Aligning internal priorities. Company A made the decision to locate their newest DC in southern VA without conducting any analysis on the total transportation cost impact. Company A chose the location strictly on outbound consideration to improve service to its stores and allow for additional expansion down the eastern coast of the United States. In Company A's case, outbound transportation costs and servicing their retail stores was more valuable to them than potential inbound effects. However, this may not be the case for every company. Companies need to evaluate internally what their goals are and align programs/incentives to motivate internal and external partners. According to Harvard researchers, Narayanan and Raman, "A supply chain works well if its companies' incentives are aligned—that is, if the risks, costs, and rewards of doing business are distributed fairly across the network" (Narayanan, 2004). The research team goes on to discuss how supply chains are interlinked, and if all parties are not working together, they will suffer from incorrect forecasting, poor customer service, and reduced sales. Narayanan and Raman identified three reasons companies have misaligned incentives: 1) companies cannot observe other firms' "hidden actions "; 2) companies not sharing data and information; and 3) incentive schemes are designed poorly. Company A is retroactively attempting to align their network design decision with the companywide goal of reducing supply chain costs through this analysis. Firms should strive for more effective communication and alignment earlier in the decision process.

Identifying cost savings potential on inbound transportation can be difficult due to the dynamic nature of suppliers. Every supplier is different in terms of size, location, and requirements which makes optimal sourcing decisions more difficult. However, the aforementioned methodology provides a framework for identifying savings potential on inbound transportation when nodes are added to distribution network. In order to maximize utility of this methodology, companies should refer to the prior paragraph on aligning incentives and more specifically on sharing data between buyer and supplier. Recognizing optimal shipping locations has many variables such as geographic locations of supplier facilities, shipping requirements, etc. that must be shared by the supplier to create a mutual benefit. Company A was able to obtain critical decision-making information through the usage of a supplier survey, which can easily be replicated by other shippers interested in running a similar analysis. Ultimately, aligning priorities between suppliers and buyers helps to increase total supply chain profits for all involved and can lead to better decision making in the scope of inbound transportation costs.

Chapter 6

Limitations and Future Research

When evaluating the outcomes of this thesis and incorporating the findings into future network decisions, one must be aware of some limitations. Many of these limitations serve as suggestions for future research.

At the forefront of these limitations is the shipper's lack of visibility into their suppliers' actual network. Since suppliers' networks are dynamic, it is difficult for shippers to keep accurate data on every supplier location. This results in the data needing to be aggregated from supplier surveys. Company A had to entrust that each response was thoroughly filled out by the suppliers with limited errors. Humans are prone to error and results in many additional exchanges with the supplier to obtain the correct information in the best case and incomplete/wrong information in the worst. Future research should include strategies for how to better collect and store data on suppliers.

The second limitation is the absence of accessorial charges on freight costs in the line haul rate. Accessorial freight charges are fees logistics companies charge for services that are beyond standard pick-up, linehaul, and delivery operations. Common accessorial fees include detention, truck ordered not used (TONU), pallet charges, etc. These fees are often varying among logistics companies and makes them difficult to forecast their impacts on final costs. The optimal solution provided following the methodology in Chapter 4 might no longer be optimal in the face of these hidden fees. Future research should include strategies to mitigate the impacts of the accessorial charges on the analysis or a strategy on how to incorporate them into the planning process.

Finally, future research topics should include economic costs and benefits provided by the introduction of backhauls. As noted at the end of Chapter 4, shippers can reduce transportation costs further by minimizing empty miles via backhauls. Backhauls can be set up between the shipper and supplier to have the shipper pick up an inbound load on their return trip from an outbound delivery. Limiting the amount of time/distance a tractor- trailer is traveling without freight will undoubtedly lead to significant savings over a period of time if executed properly. Future research should include strategies on how to incorporate backhauls into the plan and the economic return companies could expect.

As outlined through this thesis, shippers can decrease inbound transportation costs through a variety of methods. Future research should entail strategies on keeping up to date supplier data, impact of accessorial charges on final costs, and economic benefits companies could expect through the utilization of backhaul lanes. Doing so will provide a more accurate picture of incurred inbound transportation costs.

Appendix A

List of Acronyms

CPG	Consumer packaged goods
DC	Distribution center
DV	Dry van
IM	Intermodal
LTL	Less than truckload
TL	Truck load

Appendix B

Data File Column Descriptions

Of the 85 columns provided in the initial data file, the following 12 columns are most essential toward the analysis. Descriptions of these columns are as follows:

Column Name	Description	Calculation
Lane	Origin and Destination to identify single lane	=CONCAT(Origin, Destination)
Supplier Name	Name of carrier associated with the bid	
Quantity Available	Total annual loads (truckload) on the lane	
Origin Name	Name of lane's start location	
Origin State	State of lane's start location	
Destination Name	Name of lane's destination	
Destination State	State of lane's destination	
Miles	Mileage from origin to destination for the lane	
Multiple Sourcing Locations?	Does the Supplier offer multiple sourcing locations	
Linehaul Charge Location 1/Linehaul Charge Location 2	Carrier's price per shipment, less fuel and accessorial charges	=Price per mile * Miles
Move Type	"Dry" = non-refrigerated shipment "Reefer" = Refrigerated shipment	
Cost Savings	Difference in cost between the multiple sourcing locations	=LCL1-LCL2

Appendix C

Google API Source Code Written in R

```
rm(list = ls())

library(gmapsdistance)

library(data.table)

MY_PATH <- 'C:/Users/Josep/Documents/Fall 2019/Wegmans Thesis/'

DISTANCE_FILE_IN <- 'Distances.csv'

DistanceFileIn <- paste0(MY_PATH,DISTANCE_FILE_IN)

DistanceFileOut <- paste0(MY_PATH,'DistancesFinal.csv')

DistanceFile<- fread(DistanceFileIn)

DistanceFile

origin <-
c(paste0(DistanceFile$`Origin+VA+City`,'+',DistanceFile$`Origin+VA+Stat
e`))

destination <-
c(paste0(DistanceFile$`Destination+VA+City`,'+',DistanceFile$`Destination
+VA+State`))

Key <- 'AIzaSyDRSgh-sxDij7dXb_1a85dUQTiCvntVzCo'

results_long <-
    gmapsdistance(
        origin = origin,
```

```
        destination = destination,
        combinations = 'pairwise',
        mode = 'driving',
        shape = 'wide',
        key = Key
        )
results_long
 (distance_matrix_meters <- results_long$Distance)
write.csv(distance_matrix_meters,DistanceFileOut, row.names = FALSE)
```

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ACADEMIC VITA

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Related Experience

Mondelez International – Tatamy, PA
Customer Service and Logistics Intern
May 2019-August 2019

Reckitt Benckiser – Parsippany, NJ
Transportation Analyst Co-op
May 2018 – May 2019

Honors and Awards

The Evan Pugh Scholar Award (2019, 2020)
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Memberships/Activities

Council of Supply Chain Management Professionals (CSCMP)
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