Network Optimization: International Inbound Logistics

by

Lipsi Kumari

Bachelor of Engineering in Chemical Engineering

and

Scott Sladecek

Bachelor of Business Administration in Supply Chain Management

SUBMITTED TO THE PROGRAM IN SUPPLY CHAIN MANAGEMENT
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE IN SUPPLY CHAIN MANAGEMENT
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2021

Signature of Author: ____
Lipsi Kumari
Department of Supply Chain Management
May 20, 2021

Signature of Author: ____
Scott Sladecek
Department of Supply Chain Management
May 20, 2021

Certified by: ____
Milena Janjevic
Executive Director, Supply Chain Management Residential Program
Capstone Advisor

Accepted by: ____
Prof. Yossi Sheffi
Director, Center for Transportation and Logistics
Elisha Gray II Professor of Engineering Systems
Professor, Civil and Environmental Engineering

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Submitted to the Program in Supply Chain Management
on May 20, 2021 in Partial Fulfillment of the
Requirements for the Degree of Master of Applied Science in Supply Chain Management

ABSTRACT

Optimizing the flow of goods across the globe is incentivized by logistics savings, amplified by an enterprise's economies of scale. Waters' international shipments are majorly carried out via air freight and are exclusively performed by three main carriers: Expeditors, FedEx, and UPS. The specific problem addressed in this capstone is finding the best solution to systemically reduce the overall inbound international logistics costs for Waters Corporation, which have been flagged as higher than necessary over the last two years. The project methodology followed three main steps: receiving raw data, analyzing the excel spreadsheets, and finally providing outputs of findings. The different sets of raw data were bucketed into two main categories: historical shipment level detail (SLD) and Waters negotiated rates (rates). The carrier-selection cost savings are estimated at 13% of Water's total international logistics costs into their three DCs. There is a growing opportunity to expand that savings target by reducing the number of annual shipments. The estimated 13% savings can be materialized through a decision-making tool allowing automatic selection of a carrier that ensures lowest shipping costs.

Capstone Advisor: Milena Janjevic
Title: Executive Director, Supply Chain Management Residential Program

ACKNOWLEDGMENTS

This capstone is the result of the efforts and contributions of various people to whom we would like to express our sincerest gratitude:

- Li-Chung Pan, Mitch Fonda, and Lindsay Flynn, our supervisors at Waters who provided various kinds of support to us, ranging from the company data to personal advice; thank you for making this project a great learning experience
- Milena Janjevic, our capstone advisor who provided a steady hand through the entire capstone process and who led us well by example
- Scott Sladecek
    - To my family, especially my mother, Susie Sladecek, who never got to see her youngest child experience what her life-long sacrifices afforded to him
    - To my best friend, Lindsay Irwin, whose partnership has exemplified the strongest source of comfort and support throughout my studies
- Lipsi Kumari
    - To the CTL family (faculty, advisors, alums, and students) for providing consistent support in refining my work and providing direction throughout my time at MIT
    - To my friends and family for supporting me in my vision of higher education and learning; their support and guidance has been the catalyst for me to constantly learn, evolve, and achieve ambitious goals in life
    - To the supreme power (god) for a consistent source of unlimited power and wisdom to help me become who I am today

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Chapter 1. INTRODUCTION

1.1 Overview

Waters Corporation (NYSE: WAT), the world's leading specialty measurement company, has pioneered chromatography, mass spectrometry and thermal analysis innovations serving the life, materials, and food sciences for 60 years. With approximately 7,000 employees worldwide (as of 2020), Waters operates directly in 31 countries.

The overall objective of this project is to optimize, improve, and develop an inbound distribution network that balances costs and service while considering capacity and operational constraints, risk, growth, inventory, and corporate objectives. The scope will include any material from an international origin into one of the three distribution centers operated by Waters.

We derive this overall objective into three specific objectives:

1. Objective 1: Analyze the current company practices regarding their inbound logistics network and identify main levers for cost reduction
2. Objective 2: Analyze historical data to quantify potential improvements on performance with regard to levers previously identified
3. Objective 3: Provide a company with a decision-making tool allowing automatic selection of a carrier that ensures lowest shipping costs

This study is important to supply chain management because of the value brought to the shareholders of Waters Corporation by a reduction of logistics costs, providing more capital to fund core business operations for laboratory equipment. The carrier-based analysis adds to the overall body of literature, which is geared towards intracompany operations rather than outside company processes.

1.2 Problem Statement

The specific problem addressed in this capstone is finding the best solution to systemically reduce the overall inbound international logistics costs for Waters Corporation, which have been flagged as higher than necessary over the last two years. Within Waters' complex global supply chain, major nodes and lanes support the organization as it continues to grow in the specialized laboratory equipment market. Figure 1 shows Waters' overall supply chain including distribution centers (DCs), suppliers, manufacturing plants, and the connections between.

Waters' network includes 7 manufacturing facilities, over 3,000 vendors, and 3 DCs, which allows their products to be accessible in more than 100 countries. Waters operates three distribution centers (DCs) located in the USA (GDC), Europe (EDC), and Asia (ADC), and transports raw material, work in progress (WIP) inventory, and finished goods (FG) into the three DCs.

A distribution network is composed of two main types of components. The first component is nodes (e.g., facilities, customers, origins and destinations of flows). The second component is flows (e.g., the path of goods that move between nodes). Within the project scope are the destination nodes of any of the 3 DCs and origins of international (rather than domestic) suppliers with respect to the DC. The flows are physical movement, via the mode of air, of the goods between the nodes. Executed by third party carriers, the flows create the cost that constitutes Objective 3 noted in section 1.1.

The flow of goods is broken into two further distinctions. Material coming into DCs is deemed as inbound and goods flowing out of the DCs is deemed as outbound. Distribution costs are absorbed by the entity that is receiving the goods. Therefore, because the project focus is on the three DCs, the scope entails only inbound material.

Waters' network includes three strategic carriers to perform the shipping of goods from all of Waters' nodes. Expeditors, FedEx, and UPS dominate a large portion of business and have negotiated rates with all three of the carriers. Waters leverages all different modes of shipping (i.e., ocean, air, rail, trucking) however the scope of this project is concerned exclusively with air shipments as it is the highest cost mode and thus offers the largest opportunity for cost reduction against their over-inflated annual logistics costs.

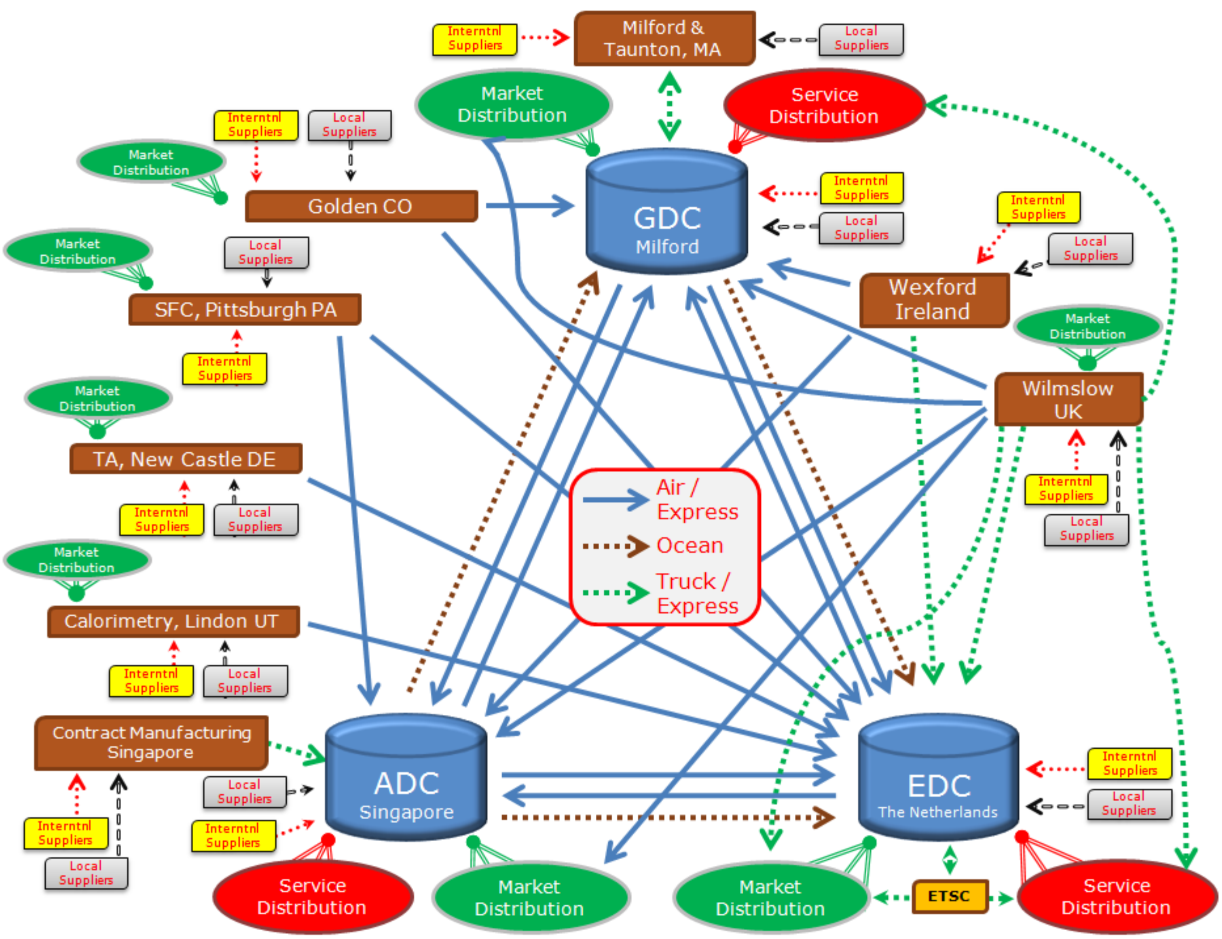

Figure 1: Waters' global inbound logistics nodes and lanes structure (source: Waters Corporation)

1.3 Structure of the report

This capstone is organized in the following manner:

1. Chapter 2, 'Literature Review' provides a review of relevant academic literature relevant to our problem. Results of our literature review are used to inform possible solutions and viable levers to solve Waters' problem of inflated inbound international logistics costs.
2. Chapter 3, 'Data and Methodology' describes the adopted approach towards syndicating and cleansing raw shipment data in conjunction with negotiated carrier rates
3. Chapter 4, 'Results and Conclusion' explains the development of the carrier selection tool and how it will help Waters create a more data-driven procurement function and also summarizes key savings opportunities

Chapter 4, 'Results and Conclusion' explains the development of the carrier selection tool and how it will help Waters create a more data-driven procurement function and summarizes key findings

Chapter 2. LITERATURE REVIEW

The network optimization literature constitutes a prolific and robust body of work. This chapter synthesizes the learnings and applications that are most applicable to this project.

2.1 Overview of network optimization approaches

The proposition of optimizing an organization supply chain network has several directions to be explored. Supply chain optimization projects can entail facility location optimization, mode optimization, and network flow optimization.

Facility location optimization is concerned with the geographic locations of different node (production/manufacturing facilities, distribution centers, customers, suppliers, or warehouses). For example, one of the world's largest carriers, FedEx, has their world "super-hub" in Memphis, Tennessee, U.S.A. because of the central location and rare weather-induced facility closures (FedEx History, n.d.). By locating the super-hub in Memphis, TN, FedEx accounted for the center of the national population density to optimize their routes that move shipments across the country.

Mode optimization is concerned with striking the best mix of modes (air, ocean, truck, and rail) for transporting goods. The consideration of the lead time spectrum is imperative as ocean is on the "slowest" side and air is on the "fastest" side. Mode optimization can be leveraged for several objectives (e.g., lead time, service level, inventory in transit, environmental impact, etc.) but is typically used to minimize cost.

Network flow models optimize costs to the lowest aggregation of fees an organization would incur when shipping goods across arcs (transportation flows between facilities). This kind of model considers seasonality of shipments to take advantage of low demand times to ship goods, vertically integrating the logistics to reduce long-term costs, or bundling shipments together to reduce the frequency of shipments needed to move goods across arcs. A network flow model is the focus of this project since the scope dictates a fixed location of nodes and an air-only mode. The new flow of goods proposed by the network model will decrease the overall cost incurred by Waters while allowing Waters to continue to meet service level requirements.

There is an abundant body of literature focusing on this network flow problems. For example, Google Scholar search results in over 2,000,000 hits for “supply chain network flow model.” A major input for this category of models is the transportation cost estimation.

For a comprehensive review of different approaches for network flow optimization, we refer the reader to Network Optimization in Supply Chain Management by Geunes, et al (2003). The rest of this literature review focuses on the two most relevant aspects of network optimization for our problem setting: (1) identification of the main levers for network flow optimization and (2) transportation cost estimation.

2.2 Network Flow Optimization and Transportation Cost Estimation

Main levers for Network Flow Optimization

When focusing on cost optimization and network flow for global inbound logistics, we find three main levers in the reviewed literature: mode selection, carrier selection, and frequency rationalization. Table 1 presents a summary of the reviewed literature according to these levers. These variables are also further presented in the following sections.

Reference	Modal selection	Carrier selection	Frequency rationalization	Other characteristics
Erengüç, Ş. S., Simpson, N. C., & Vakharia, A. J. (1999)			X	upstream SCM connection
Ma, C., & Shao, Y. (2007)	X	X		
Benjamin, J. (1990).	X			JIT inventory applications
Thomas, D., Griffin, P. (1996)	X			integrative supply chain
Allen, W. B., Mahmoud, M. M., & McNeil, D. (1985)	X	X		
Eskigun, E., Uzsoy, R., Preckel, P. V., Beaujon, G., Krishnan, S., & Tew, J. D. (2007)	X			lead time model
Waller, M., Meixell, M. J., & Norbis, M. (2008)	X	X	X	environmental impact

Table 1: Consolidation of literary review on main levers for network flow optimization

Provided below is a synopsis of each main lever that summarizes the findings of the comprehensive literature review. These are not mutually exclusive nor collectively exhaustive of any and all levers to optimize network flow, but they are the main criteria found to be applicable to Waters' supply chain.

Modal selection: Global supply chains require multiple modes of transportation, all of which are named intuitively. Ocean freight is moved via the ocean and typically have much higher total value of goods on board and lower cost per mile. This mode is also the slowest mode to choose from which requires a finely tuned logistics coordinator to give ample lead time downstream. The mode of air freight is the fastest but most costly form of transportation. Changing between modes can have an impact on the company's overall logistics cost, which can be when multimodal transportation is leveraged which allows the transportation operator to carry out the logistics with multiple modes throughout the freight journey (Ma et al 2007).

Carrier selection: Depending on the location(s) of the organization's supply chain, certain third-party carriers can be leveraged to transport goods from one node to the next. Not all carriers serve all nodes which is imperative to consider when developing the organizations transportation approach and selecting strategic suppliers for shipping services. Beyond the feasible service area, impact to lead time must be considered when choosing a carrier (Allen et al 1985). The shipper, in this case Waters, will also need to communicate their needs to the carrier, who in turn will need to calculate the costs of those requirements. Those business needs may demand infrastructural improvements which will be passed on to the shipper; if those improvements are applicable to an arc, then those costs can be offset to multiple shippers (Allen et al 1985).

Frequency rationalization: The frequency with which a carrier conducts shipment on a particular lane can impact the carrier's attractiveness with respect to the shipper (Waller et al, 2008). However, the carrier must be conscious of the shipment frequency because the more shipments made, the higher the annual shipper's transportation costs.

Modelling approaches

The reviewed literature suggests that most of the models are formulated as mixed integer linear programs (MILP). These are composed of the following elements:

Decision variables: specifies the amount that each variable should be leveraged to obtain the optimal objective. For example, this could be the amount of flow on each lane with each carrier that minimizes the objective of cost. With an increasing number of suppliers and nodes in the supply chain, the number of decision variables can easily become immense and convolute the optimal objective (Cochran et al., 2006)

Objectives: the goal of the model, typically set as "minimum" (e.g., cost) or "maximum" (e.g., profit) (Chen et al, 2014). However, other objectives can be applied such as minimum environmental impact, minimum organizational risks, and maximize supply chain resources (Geoffrion et al, 1995 and Waller et al, 2008).

Constraints: The bounds and limitations that the model cannot go beyond. Considerations include the overall shipment capacity for each mode selected. All shipment modes are susceptible to external constraints, such as government regulation, fuel prices, operator shortages (e.g., drivers, captains, pilots), and overall operating costs, which can then suppress overall network capacity if demand falls below carrier break-even points (Waller, M., Meixell, M. J., & Norbis, M., 2008).

To optimize global inbound logistics of this complexity, using network design and rationalized shipment frequency is a valid approach as suggested by Felicio et al. (2018). Network optimization is performed via linear/ mixed integer programming in which an objective function, decision variables, and constraints are all identified and computed to suggest an optimized goal. Formulation of mixed integer linear programming with an objective function includes not only operations cost but also cost due to lead time in the network (Jeong et al. 2007). The model can be applied to additional manufacturing plants or changes in international suppliers by amending the decision and constraint variables.

As part of network optimization, the costs of distribution and transportation between different modes of transportation – air, ocean, rail, and truck freight between DCs, manufacturing plants and suppliers can be compared, as suggested by Weisel et al. (2020). The model minimizes the time spent on distribution and the cost of shipping simultaneously, hypothesizing that the rationalizing shipment with linear programming were the most profitable at low rates of returned product (Xuefang et al., 2013). The different scenarios of operating freight volumes at Waters' 3 DCs while looking at the financial and operational viabilities and special product handling like cold chain and hazmat could be optimized by MILP/LP, as suggested by Seung et al. (2007) in their project. The DCs and freight options will be decided based on the input of characteristics (number of DCs, shipments per day, containers, etc.) and then allotted specific transportation trips based on the total costs. The financial cost optimization modeling helps visualize the organization's overall impact.

We note a variety of solution methods employed in the analyzed literature. Select contributions, however, with massive, complex, and multi-echelon supply chains, use both broad heuristics and detailed computations used to calculate costs.

Transportation Cost Estimation

Regardless of sophistication, we find that all these models have one common underlying component, which is transportation cost estimation. The sources do not directly specify the method in which the input costs are computed, but nevertheless still have cost as an input. Transportation cost estimation is used as an input parameter to all models analyzed and consists of defining the costs associated with different flows in the network. In the following, we review various approaches relevant to this aspect.

According to Caplice et al (2018), multiple types of data can be employed to estimate the cost of different flows which are then integrated into the model. These include:

- Company-specific historical charges
- Company-specific negotiated rates
- Industry-wide benchmark data

Caplice et al (2018) also notes that supply chain design models assume linear costs. The real-life costs are however not linear, so these need to be approximated and reformulated for a linear model. To accomplish this, several approaches can be employed. For example, when estimating costs based on company-specific historical charges, transportation costs can be estimated by simply taking an average transport cost. A more sophisticated approach is to use regression to uncover the cost functions. Here, linear regression analysis is a compelling application. Linear regression is used to understand two primary characteristics: if a specific set of variables accurately predicts an outcome (in this case, cost) and which variables best predict that outcome (Statistics Solutions, 2013). Therefore, leveraging the existing data to via a linear regression will reveal the mathematical expression to forecast carrier costs that impact the network flow for Waters.

2.3 Summary

Upon reviewing the literature in Table 1 enabled us to articulate the levers, modelling approaches, and transportation cost estimation methods commonly used to optimize the flow of a network.

We identified three main levers to optimize cost and network flow for global inbound logistics: mode selection, carrier selection, and frequency rationalization. Mode selection determines the method in which goods are transported across arcs and can be air, ocean, or truck. Carrier selection refers to the company that the shipper chooses to execute the shipment of goods from node to node. Frequency rationalization is how often the shipper decides to ship goods and directly impacts the overall cost of transportation.

We also found that the most common way of estimating the transportation cost MILP modeling, which accounts for decision variables, objectives, and constraints. Decision variables in Waters' case would be the volume moved across each arc of their supply chain network. The objective for Waters would be to minimize cost across all shipping lanes. The constraints for Waters would be the service level, which is the elapsed time between the movement of goods between nodes.

The final aspect of the reviewed literature provided insight to the transportation cost estimation used in network flow optimization. They can fall into three categories: company-specific historical charges, company-specific negotiated rates, and industry-wide benchmark data. For Waters, we use all but industry-wide benchmark data.

Chapter 3. DATA AND METHODOLOGY

As mentioned previously, this capstone has three objectives:

1. Objective 1: Analyze the current company practices regarding their inbound logistics network and identify main opportunities for improvement
2. Objective 2: Analyze historical data to identify potential improvements on performance with regard to levers identified
3. Objective 3: Provide a company with a decision-making tool allowing automatic selection of a carrier that ensures lowest shipping costs

The problem to be solved was to optimize Waters' inbound distribution network. Among the different network optimization models (facility location, mode, and network flow), the elected appropriate choice for this project is network flow, which emphasizes efficient means of movement between different nodes along arcs. Furthermore, of the three levers of flow optimization: modal shift, carrier selection, and frequency rationalization – carrier selection was the focus.

Given the data provided by Waters (company-specific historical charges and company-specific negotiated rates) the method used to achieve lower international inbound logistics costs is to perform linear regression upon the workable data sets.

3.1 Objective 1: Analyze Current Company Practices

The literature review enabled the identification of three main levers of network flow optimization: mode selection, carrier selection, and frequency/capacity rationalization. To determine the most relevant one(s), Waters stakeholder interviews were conducted to understand the baseline operations of the inbound distribution network. The results of those discussions revealed that the commodity managers make the decision on which mode is selected due to the time constraint of the material needed. Therefore, mode will be out of scope due to Waters' hands-on approach when selecting mode. The underlying assumption, due to data and scope considerations, is that air freight is the sole mode leveraged and will therefore be the only mode incorporated into the final model.

Due to a lack of a centralized procurement function, Waters has little control over the frequency of the inbound shipments. However, the analysis of company data shows that the shipment size (directly related to the frequency) is a major determinant of cost. This is exemplified by the fact that the main hubs for the inbound logistics are centered around only 3 DCs. While this project will not seek to optimize the frequency of the shipment, the cost computation will explicitly account for shipment size.

The volume of shipments that Waters annually ships allow them to have a strategic relationship with their preferred carriers and has instilled a logistics infrastructure of moving goods to and from different nodes. However, their current practices do not consider each carrier during time of selection. Therefore, carrier selection is the only lever to be used in the network flow model.

As mentioned in Chapter 2, network flow models are often manifested as MILP models. Due to the lack of constraints, there is no mathematical impetus to formulate the carrier selection model as a MILP model. Therefore, the minimum cost of operations can be calculated by taking the minimum cost of each lane.

Figure 2 depicts the high-level tandem approach used for both the stakeholder discussions and the literature review to finalize the most relevant and practical solution for Waters.

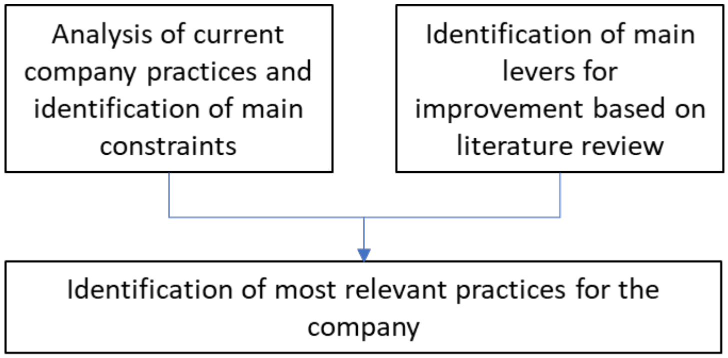

Figure 2 Analysis of current company practices and identification of main constraints

Currently, Waters leverages an oversimplified routing guide, exemplified in Figure 3, to dictate the carrier to be selected when shipping products to their 3 DCs. This tool is outdated and remains static without incorporating everchanging parameters of shipping costs, lanes, and volume, among other variables.

ROUTING INSTRUCTIONS

USE TABLE BELOW TO DETERMINE CARRIER

***NOTE* Consolidate shipments whenever possible**

Freight should be combined into one shipment instead of several per week.
FedEx packages should be combined to determine total weight.

WEIGHT	CARRIER	ACCOUNT #	ADDRESSED AS:
< [x] lbs	*FedEx*	***Example 1*** ***Example 2*** ***Example 3*** ***Example 4***	***Waters Corporation*** ***Waters Corporation*** ***Vicam, A Waters Business*** ***Waters SFC***
≥ [x] lbs	*Expeditors*	***Collect***	

Please be advised if any issues arise with above carriers, The Waters Corporation Import Department needs to be notified. Waters will then attempt to resolve the issue with the carrier in question.

Do not choose another carrier without approval from the Import Department.

Consign shipments to:

Waters Corporation
C/O Expeditors
Delivery address per purchase order

Figure 3 International routing guide on Word format (source: Waters Corporation)

The choice of shipment method and carrier is delegated to different geographical business units, causing a myriad of shipping practices and resulting in loose control of logistics costs. This decentralized approach has created a culture that lacks accountability and ingenuity regarding best shipping practices and does not allow effective leverage of Waters' economies of scale. Counterproductive to forming a more centralized logistics team is Waters' negotiated rates with the three carriers (UPS, FedEx, and Expeditors), which creates the illusion of centralized shipment decisions and methods, when in fact the opposite is true. This problem is a unique combination of culture and procedures galvanized by the sense of sophisticated negotiations.

Given the project scope and limited type of information provided, the carrier selection is the foremost lever selected in this capstone to optimize Waters' network flow model to decrease inbound logistics costs.

3.2 Objectives 2 and 3: Analyze Historical Data and Create Decision-Making Tool

The project methodology followed three main steps: receiving raw data, analyzing the excel spreadsheets, and finally providing outputs of findings. Figure 4 depicts the approach to each segment of the project.

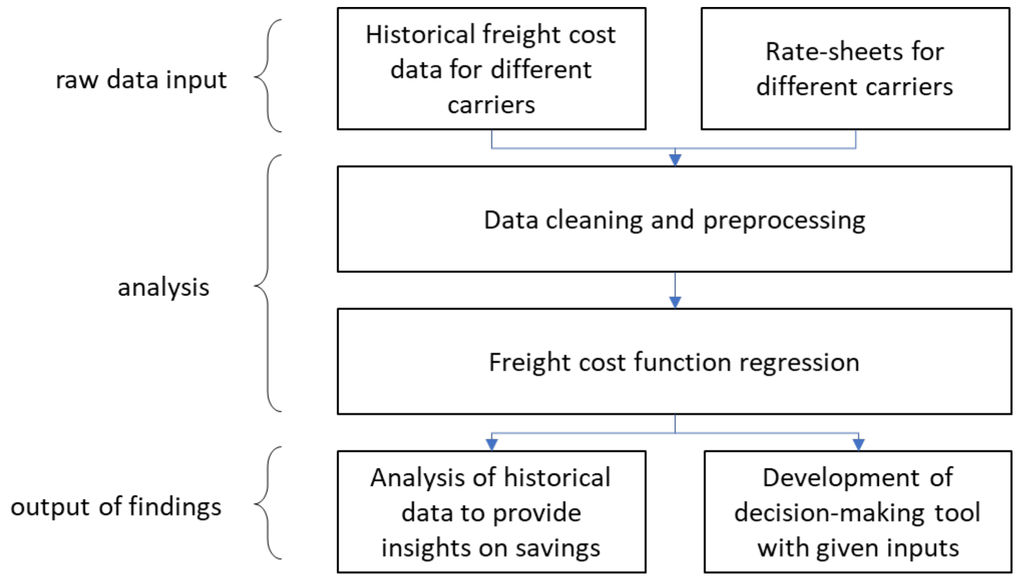

Figure 4 Framework for overall methodology

Evaluation of data received required an extensive deep dive into each column and row among all three carriers. Furthermore, the different sets of data were bucketed into two main categories: historical shipment level detail (SLD) and Waters negotiated rates (rates). Below is a review of what these data offer.

SLD, spanning all of 2019 and 2020, provides previously shipped parcel on between Waters and their respective carrier with information on origin and destination. Upon inspection of the SLD, we conducted an exercise of deciphering the lanes, that is, the airport combination codes associated with the origin and destination, respectively. This required writing formulas in excel to automatically join the two fields so that automation of carrier/lane comparisons could begin. In some datasets (e.g., UPS) zip codes were provided, and these were used to interpret which airports would be appropriate to create each lane. Other data fields such as hazardous material (yes/no), elapsed shipment time, shipper organization, and invoice number were also helpful. As an example, the hazardous material has been leveraged to understand the correlation between the "Y/N" inputs and the overall price. The elapsed shipment time was used to understand the average shipping duration between lanes to ensure timely delivery and that the service level is able to be maintained. Shipper organization was analyzed to find if there were any difference in carrier charges between parcels being sent from inside or outside of Waters' supply chain network. Invoice number fields were used to remove the duplicate charges so that the calculated charge per unit (e.g., dollar spent per kilogram) was not artificially inflated due to redundant records in the raw data.

The rates data provided for each of the carriers was less uniform and more cryptic than the SLD. For example, FedEx rates data reflects FedEx's separation of geographic regions, with different zones, and different charges for each one-pound increment. Zone 2 might refer to a large swath of the continental U.S. but does not specify any specific airport. The rates sheet also has different charges depending on the type of service selected. For example, the Domestic Express Saver option will reflect a higher charge compared to the Ground Shipment option for a seven-pound package. In contrast, Expeditors describes itemized charges per shipment including fuel surcharge, import/export fees, minimum charges (fixed fees), and currency conversion calculations.

The rates data sheets were perplexing due to the inconsistent nature of the data between the three carriers. Often, despite having negotiated rates and contracts in place with carriers, these rates are simply a quote and are contingent upon availability of capacity. The rates are not a promise to *execute* shipments for these rates. For example, in March 2020 when the COVID-19 pandemic permeated through and disrupted every industry, Waters (and the majority of shippers) saw a carrier-centric disregard for adherence to the established rates already negotiated. Similarly, the SLD sheets do not reflect the previously negotiated rates and had many different components added into the final payable amount, including discount rates that were exactly reflected in the rates sheets.

However problematic the datasets are, the goal is to narrow down a basket of consistent variables across all carriers to create a prediction of what future shipments will cost, which will then unveil the cheapest carrier. This was performed differently between each dataset.

For the rates data, the variables accounted for across all the carriers were the explicit freight cost, the fuel surcharge, and a discount factor. This excludes portions of import/export fees and other embedded costs that are unable to be extracted from the total cost provided by the carrier. For the SLD data, linear regression was performed to find the best weights with each cost element to understand which component impacted the final cost the most.

Due to these consistency and dependability considerations, the carrier-selection tool was initially built from the SLD datasheets. However, the challenge with this data set, is that there were limited records that fell inside our project scope resulting in low confidence in our predicted cost model. To address this issue, a two-pronged approach was employed in the model to leverage both SLD and rates data, exemplified in Figure 5:

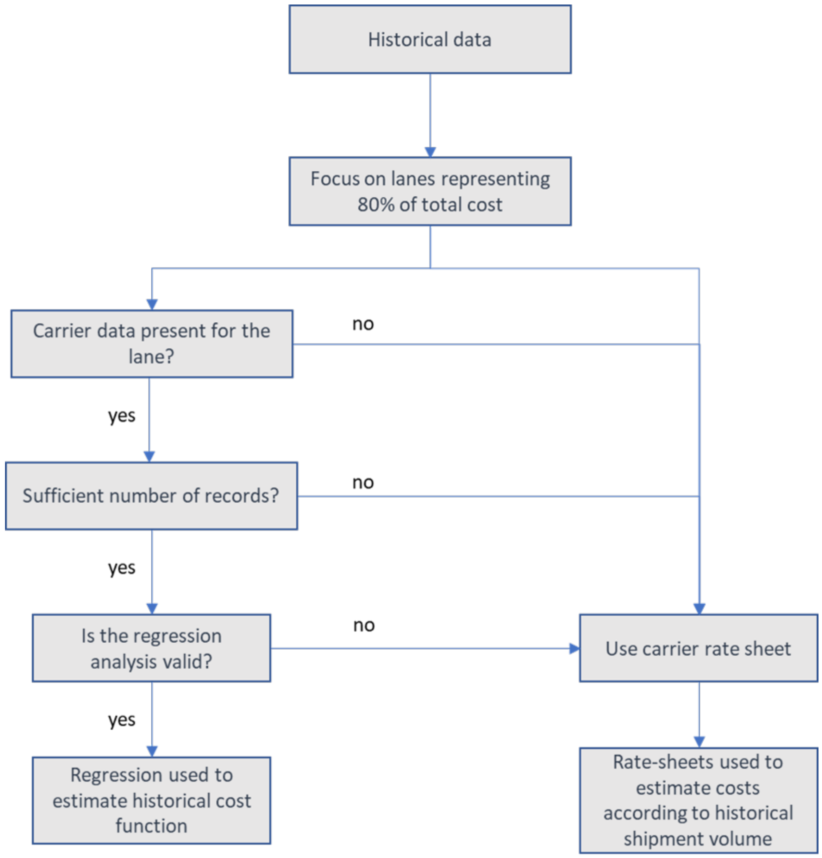

Figure 5 Two-pronged approach for carrier selection based upon both SLD and rates data

This approach allows the carrier selection result to toggle between SLD and Rates data, depending on the strength of the underlying information. As a default, the rates datasheet will be used since there is more managerial oversight into those figures than the SLD data. It also provides an ability to update regularly with new request for information (RFP) results if Waters elects to survey the market for new carrier rates.

The tools used to develop the analysis described in Figure 5 were largely excel and python coding to understand the trends in the data. A significant challenge resided in understanding the cross-section of lanes between carriers, which is the center of decision making for our model. The objective remains to select the lower cost but is only applicable when there is more than once carrier that can meet the shipping criteria. For example, if neither UPS nor FedEx services the lane from Warsaw, Poland to Boston, Massachusetts and only Expeditors services that specific lane, then the model will simply select Expeditors and project what the cost should be based upon the stronger underlying dataset.

The decision-making tool will require certain inputs by the procurement professional in determining the cheapest carrier: the number of shipments required, the total chargeable weight, the origin (where the parcel starts its shipment journey), destination (where the parcel ends its shipment journey), and the service type per carrier (dictating the speed of shipment). These are the inflexible parameters that must be built into the carrier selection model. The output of the model will be the expected total cost of the shipment described in the input criteria, the selection of the cheapest carrier, the estimated lead time, and the service level selected with respect to the selected carrier.

This methodology has been rigorously tested and provides repeatable results that are both coherent and sound. The findings are expected to add efficiency to and subtract costs from Waters' global supply chain network.

Chapter 4. RESULTS AND CONCLUSION

Our resulting model is the effort of several components of the project coming together in concert. To prove the efficacy of the model, reverse-chronological analysis was performed to showcase what Waters' costs would have been if the network optimization tool were leveraged. This analysis required a bifurcation of savings – part due to the natural decline of the Covid19-inflated rates and another part due to the tool modeling a better selection of carriers.

4.1 Data analysis and descriptive statistics

Describing Water's current state is Figure 6 below. Depicted is the overall cost that Waters spent on inbound distribution costs into their 3 DCs of $1.08M USD and the overall number of shipments, 1,865. We drill down into these figures throughout this chapter and begin from this analysis.

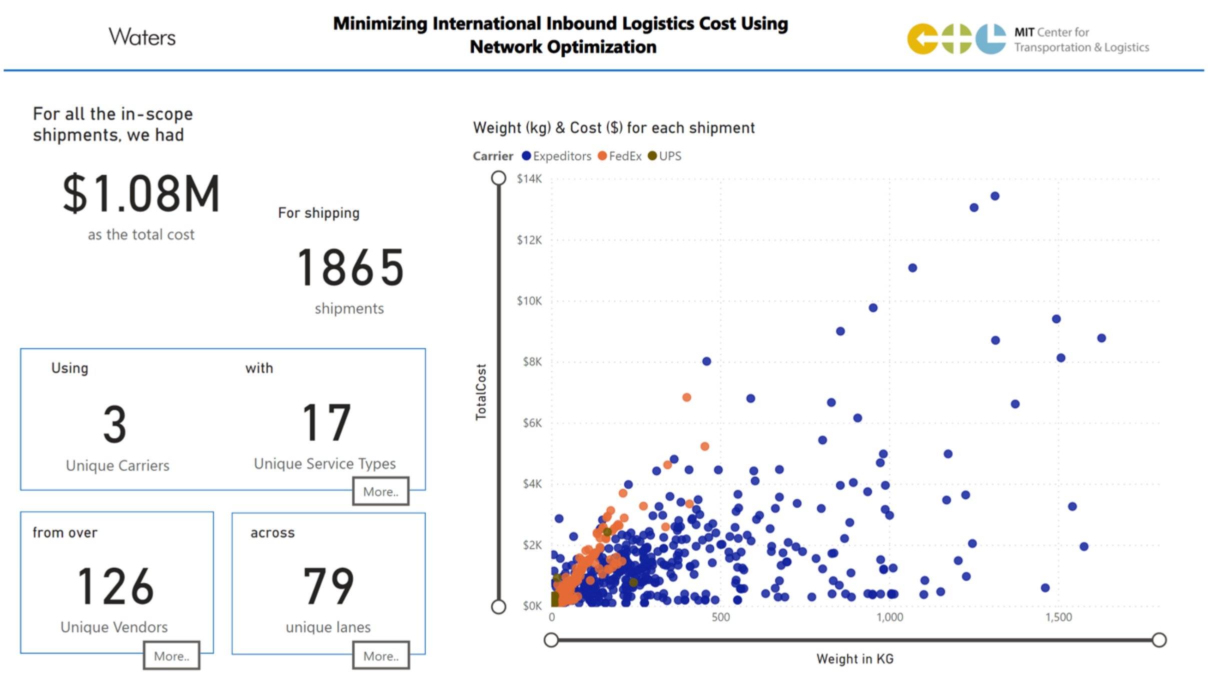

Figure 6 Overall Descriptive Analytics

The highest level of Water's supply chain is identified as the lanes into the three distribution centers. The project scope is the destination nodes of any of the 3 DCs and origins of international (rather than domestic) suppliers with respect to the DC. Figure 7 below expresses the per-lane total cost for any properly scoped lane, which amounts to $1.08 million over a 12-month period.

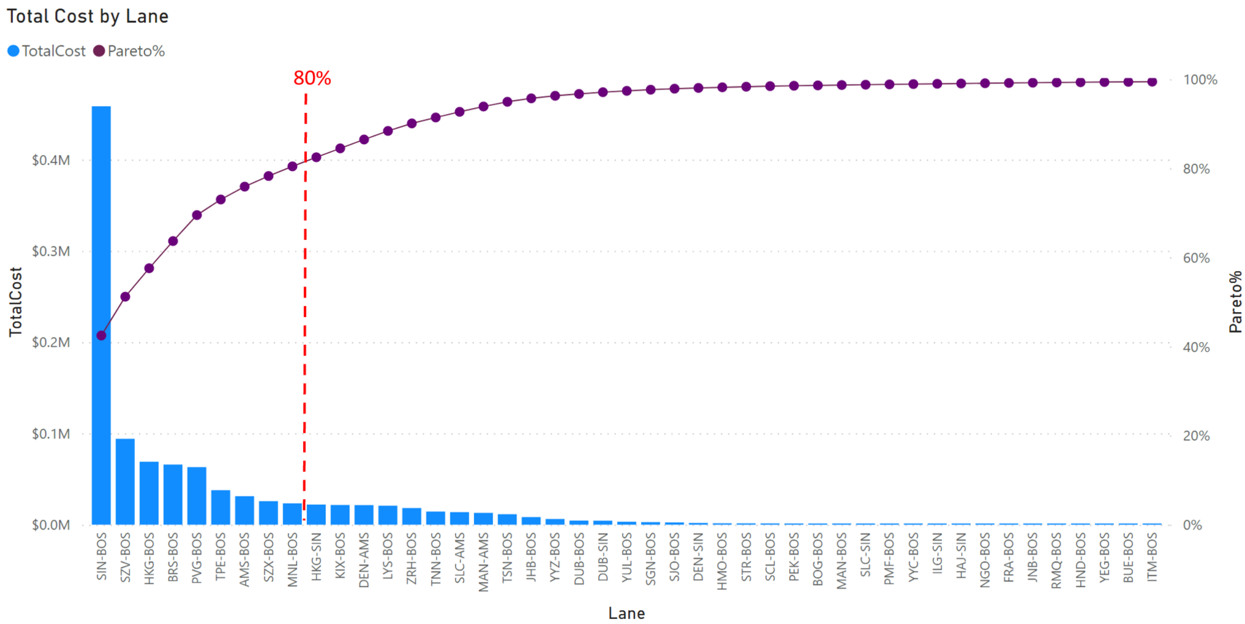

Figure 7 Total cost per lane

By segmenting and rationalizing the lane count, we reduced the focus from nearly 80 lanes to the top 9 lanes, which constitutes 80.45% of the total scoped transportation cost.

Diving further into the top 9 lanes, the mix of carriers were the next focal point to understand which companies absorbed the majority of costs. Figure 7 and Figure 8 show the cost breakdown per lane for Expeditors and FedEx, respectively.

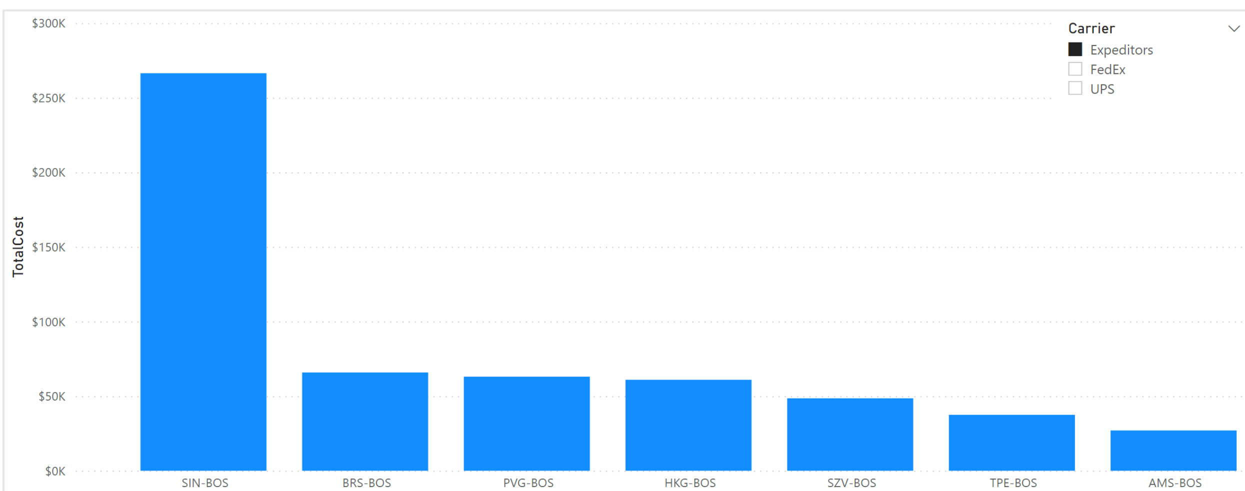

Figure 8 Most costly lanes for Expeditors

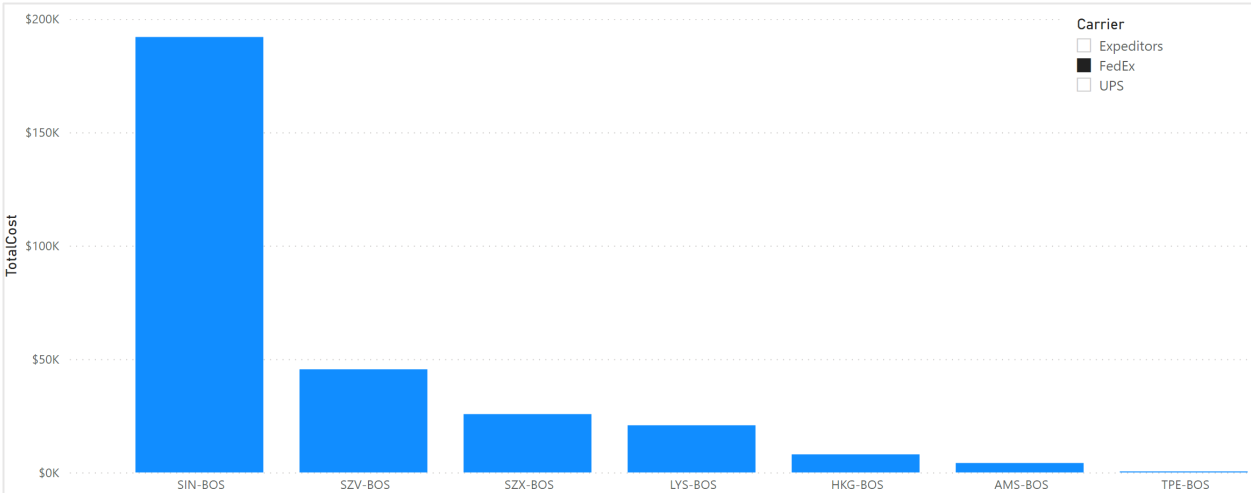

Figure 9 Most costly lanes for FedEx

Notice Figure 7 and 8 refer to Expeditors and FedEx, respectively, because the third carrier, UPS, does not have a viable set of data to confidently depict their costs on their most expensive lanes. Furthermore, 80% of the top-9 most costly lanes originate from Asia and 90% are destined into the North American DC.

Upon diagnosing the patterns between the costs, carriers, and lanes, and service type, we wanted to analyze the seasonality of these carriers, primarily Expeditors and FedEx to stay consistent with the lane distribution analysis. Because of the unique element of a pandemic-induced inflation upon the transportation rates, seasonality is critical to consider, which is outlined in Figure 10 below.

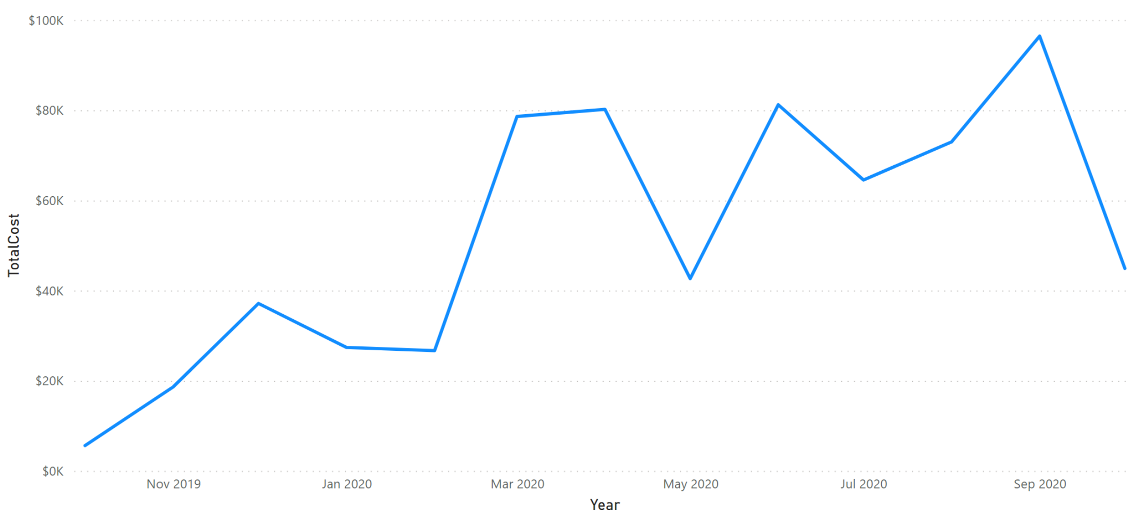

Figure 10 Rolling 12-month seasonality spend for Expeditors

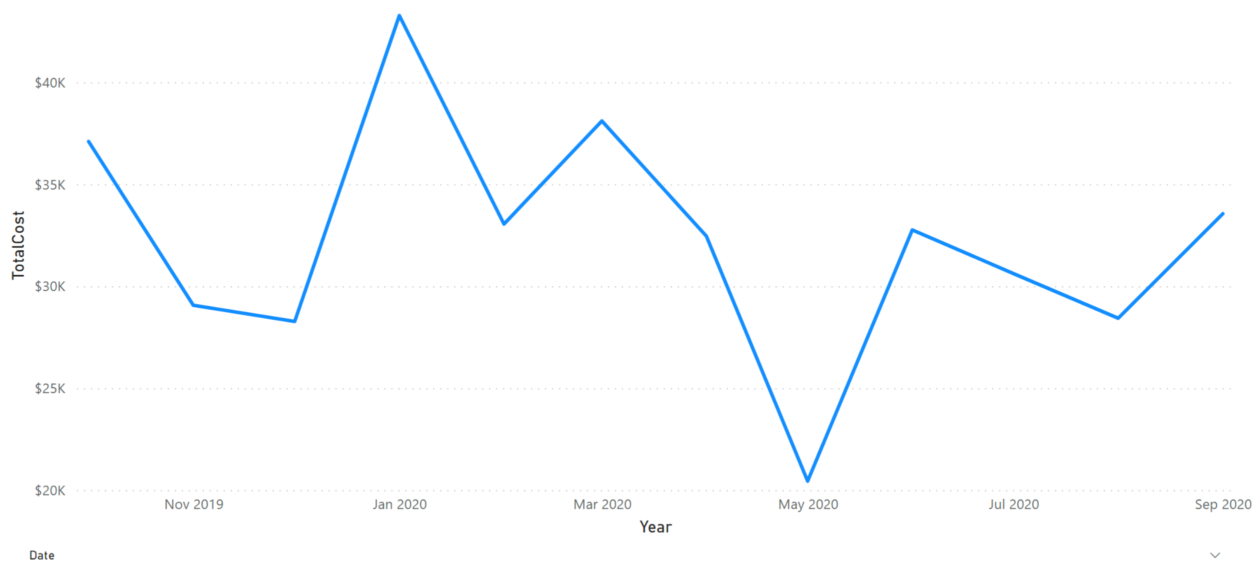

Figure 11 Rolling 12-month seasonality spend for FedEx

The volatility of seasonality is more dramatic with Expeditors, having a spike over 200% of the highest increase for FedEx. Once COVID-19 took full effect, albeit lagging by 2 months from March 2020, the large increases in rates started to follow, showing the shock of the logistics industry.

This data is driven from SLD data which was gathered at the beginning of the project. The rate data would not have been practical as Waters' strategic carriers claimed contractual force majeure and therefore charged spot-rate market prices for shipping services.

4.2 Developing a Cost Model Based on Historical Data

Data reveals that there are significant differences between the negotiated rates and the rates actually charged by different carriers. Therefore, to identify cost functions based on the historical data, we applied linear regression to predict costs for different carriers based on the historical SLD data set. Regression helps to identify the trend and outliers in the data and predict the cost.

Regression was initially performed for each carrier and each lane independently. We also attempted splitting data into multiple sets to account for the COVID-19 impact.

Through trial, we attempted to produce significant results through the following independent variables:

- Chargeable Weight – the value that the carrier uses to determine charge; this number can be the actual weight of the shipment or a calculated weight derived from volume (carrier will select the higher of the two values)
- Lead Time - number of business days between shipment date and receipt date
- Mode- 3 different types of mode (air, ocean, road/truck)
- Hazmat – shipment of hazardous material that should be handled with caution

- COVID – 19 Impact - dummy variables used to understand COVID impact
- Month – the calendar year that the shipment took place
- Service type – five different service types which refer to the elapsed shipment time between each node in the supply chain network

To execute this analysis, python code was leveraged to complete the regression analysis. We used Adjusted R^2 and P-value to find measure the significance of our variable(s).

Upon applying this analysis to the Expeditors SLD data, we were able to derive the following significant regression results found in Figure 13 below.

P_WeightChargeable	P_dummy_covid	P_intercept	carrier	coeff_WeightChargeable	coeff_dummy_covid	intercept	lane	nmodes	nrecords	nservice_type	rsquare
1.34E-40	0.03852039	0.25197169	Expeditor	1.823097	233.0767	123.1292	SIN-BOS	1	0	1	0.778328
0	0.69360513	4.39E-50	FedEx	5.992165	-1.05145	37.61254	SIN-BOS	1	1	2	0.997857

Figure 12 Python derived significant results

Ultimately, we did not decide to leverage this strategy for the remaining carriers and incorporate into the results and findings because the data were not robust enough to produce significant results. We found that only one carrier provided significant results which only included a limited number of lanes, but it was infeasible to scale to the other carriers and lanes. This is likely due to high volatility because of spot market prices in the last year of gathered data. The variability with the seasonality, lanes, and different carriers did not prove to add deeper and relevant insights into a new way that Waters should be conducting their inbound logistics.

4.3 Estimated cost savings

Given the different data sets, there are several ways to break down the overall costs and compare the actuals with a should-cost estimates. However, given the recently inflated costs due to COVID-19, a better anchor to serve as a comparison benchmark is what the shipments would have cost if derived completely from the rate sheets.

To analyze the cost savings, we have computed the following values presented in Figure 13:

- A = Total Cost what Waters paid as given Shipment Level Detail (SLD) or historical
- B = Cost from rate sheet for same carrier and same service level for shipments given in the SLD
- C1 = Minimum cost from rate sheet for any carrier but equivalent service level for shipments given in the SLD; taking three buckets of equivalent service types – 1. Expeditors STD, 2. FedEx Priority & UPS Express, and 3. FedEx Economy & UPS Saver
- C2 = Minimum cost from rate sheet for any carrier but equivalent service level for shipments given in the SLD; taking two buckets of equivalent service types – 1. FedEx Priority & UPS Express, and 2. FedEx Economy, UPS Saver, & Expeditors STD.
- D = Minimum cost from rate sheet for any carrier and any service level for shipments given in the SLD

When analyzing the differences between these values, we can note the following values:

- A-B difference = what did we overpay because of difference in what was charged and the rate sheet of the carrier?
- A-C1 difference = what did we overpay because of picking the carrier we picked over the best alternative carrier we had for a similar service type? Similar service types considered as 1. Expeditors STD, 2. FedEx Priority & UPS Express, and 3. FedEx Economy & UPS Saver
- A-C2 difference = what did we overpay because of picking the carrier we picked over the best alternative carrier we had for a similar service type? Similar service types considered as types – 1. FedEx Priority & UPS Express, and 2. FedEx Economy, UPS Saver, & Expeditors STD.
- A-D difference = what did we overpay because of picking the carrier and service type we picked over the cheapest alternative available to us?
- B-C1 difference = what did we overpay because of picking the carrier we picked over the best alternative carrier we had for a similar service type if we calculate the rate of the carrier we picked from rate sheet (and not from SLD)? Similar service types considered as 1. Expeditors STD, 2. FedEx Priority & UPS Express, and 3. FedEx Economy & UPS Saver
- B-C2 difference = what did we overpay because of picking the carrier we picked over the best alternative carrier we had for a similar service type if we calculate the rate of the carrier we picked from rate sheet (and not from SLD)? Similar service types considered as types – 1. FedEx Priority & UPS Express, and 2. FedEx Economy, UPS Saver, & Expeditors STD.
- B-D difference = what did we overpay because of picking the carrier and service type we picked over the cheapest alternative available to us if we calculate the rate of the carrier we picked from rate sheet (and not from SLD)?

The comparison of these different values allows us to draw several conclusions. These are summarized in the following figure.

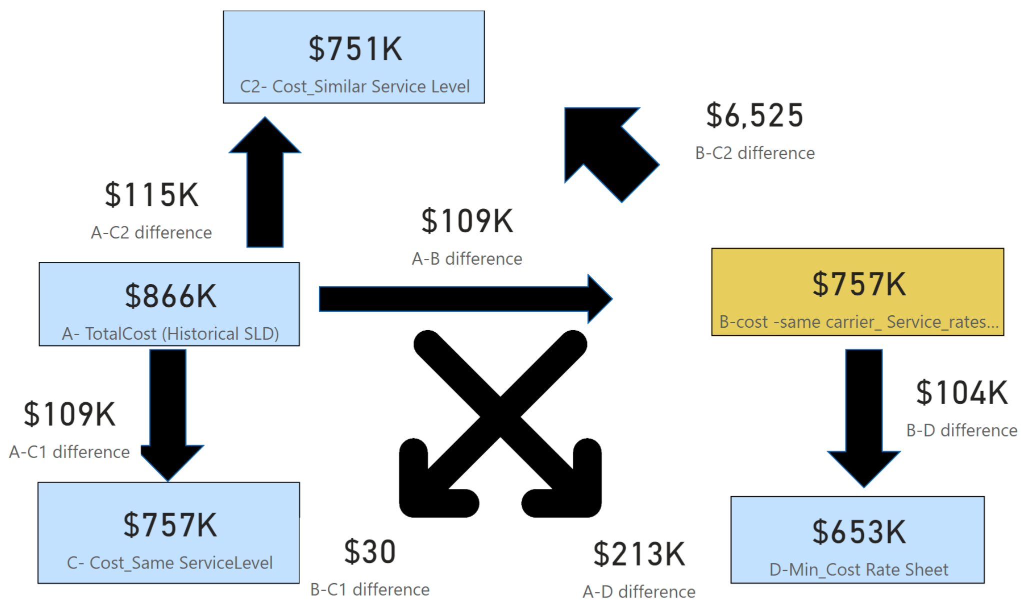

Figure 13 Analysis between carriers, rates, SLD, and service level

Important differences between the negotiated and the charged rates

As mentioned in Chapter 4.1, the overall 12-month spend for all of Waters' lanes equated to $1.08 million USD. However, we narrowed down the lanes from the trivial many to the critical few, resulting in 80% of the accounted cost equaling $866 thousand USD, which allowed for a more focused analysis and is represented in box A in Figure 13 above.

If Waters were to hold to their negotiated rates all throughout the year and keep the exact same carrier and service level, the difference of annual cost would have been $757k USD. This comparison of a cheaper cost of $109k USD is expressed via the relationship arrow between box A and box B in Figure 13 above.

To drill down into the specific differences per month for each Expeditors and FedEx, we consider Figure 14 below describes that cost increases are driven from an increase in the gaps between actuals and rate sheets.

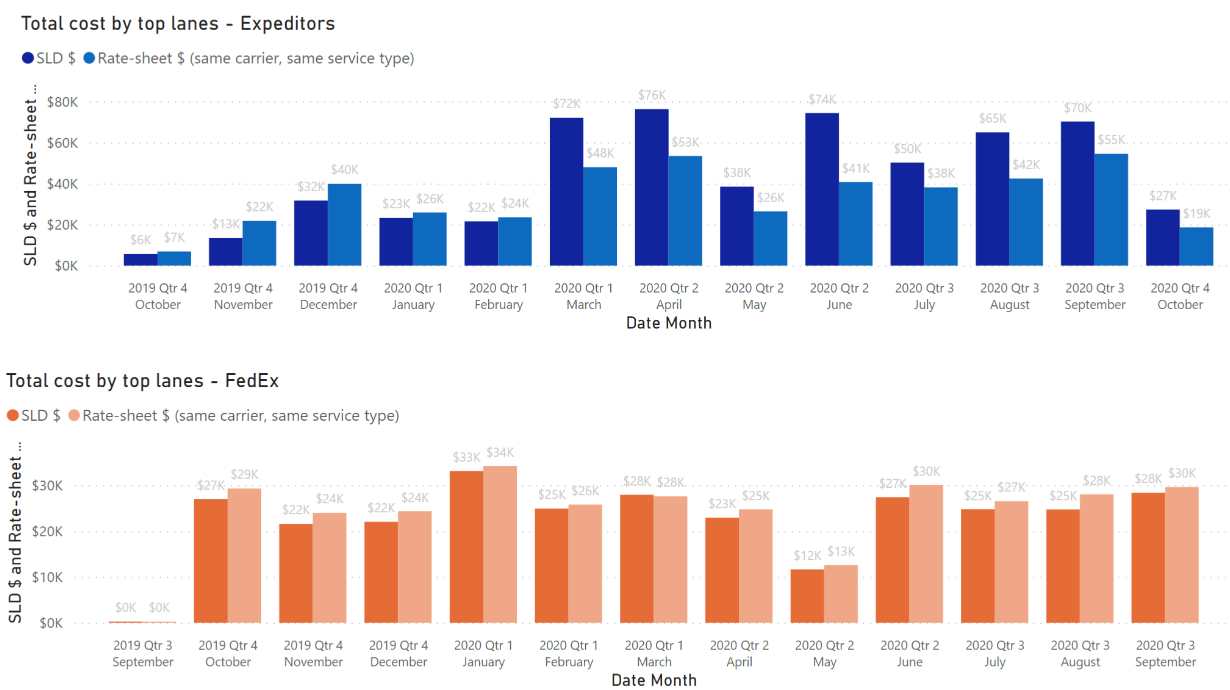

Figure 14 Rate vs SLD differences for Expeditors and FedEx for 12-months

The trend in the data revealed that Expeditors was the most sensitive to the external market shocks (e.g., COVID-19) concluded by the stark differences between the actuals and rate-sheet charges throughout the 12 months.

Limited cost savings if allowing a change of carrier but considering same or similar service levels

The second analysis conducted in Figure 13 above was to compare the rate sheet-based box B to the equivalent service level but different carrier, represented by boxes C1 and C2. Box C1 is the minimum cost from rate sheet for any carrier but equivalent service level for shipments given from the SLD; taking three buckets of equivalent service types: 1. Expeditors STD, 2. FedEx Priority and UPS Express, and 3. FedEx Economy and UPS Saver. Box C2 is the minimum cost from rate sheet for any carrier but equivalent service level for shipments given in the SLD; taking two buckets of equivalent service types – 1. FedEx Priority and UPS Express, and 2. FedEx Economy, UPS Saver, and Expeditors STD. This relationship expresses the costs that Waters would have incurred if they would have chosen a comparable service-level but with a different carrier. Those costs would have come in at $751k USD for C1 and $757k USD for C2, of which only C1 is lower than the rate-sheet costs in box B, amounting to a $6k USD savings.

Important cost savings if allowing a change of carrier and of service level

Lastly, we look at the cheapest available option, which compares the rate-sheet cost with the same carrier and service level as the historical shipments to the cheapest carrier with the cheapest service level, which is showcased in box D. These savings would be $104k USD from the rate-sheet costs in Box B. The underlying requirement to actualize this opportunity would be to ensure that the lead time with a cheaper service level is not prohibitive with the business needs.

Focusing on the target reduction attributed to carrier and service level selection, we analyzed several slices of data that could help fine-tune an approach to realize the targeted savings of $104k USD per year

4.4 Implementing cost savings

To achieve and capture the savings outlined in chapter 4.3, there are several actions we recommend Waters take.

4.4.1 Roadmap

We recommend focusing on the vendors who compose the largest percentage of the $104k USD savings target represented by the B-D box relationship in Figure 13. Below in Figure 15 is a breakdown of $104k USD savings by vendor

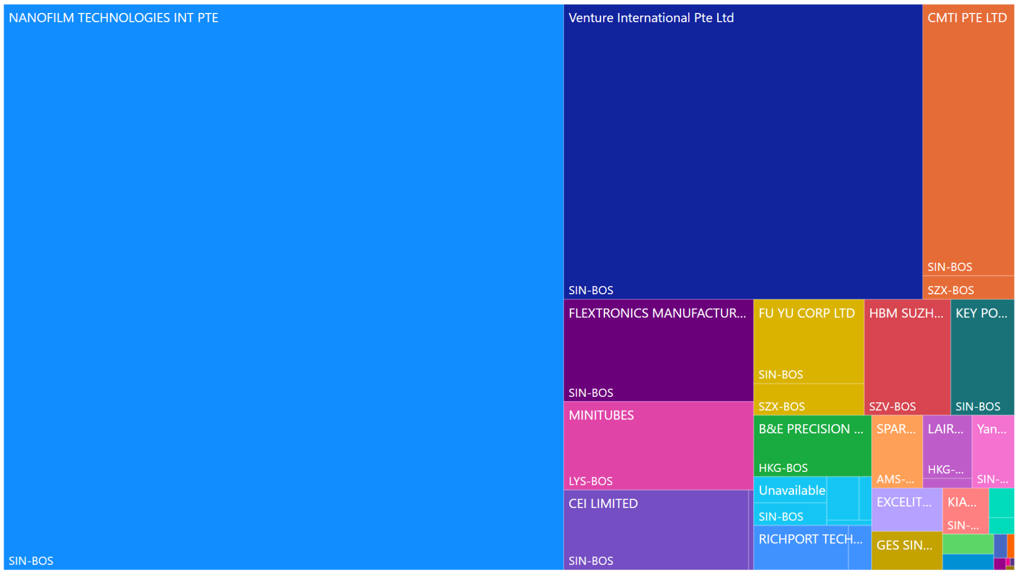

Figure 15 Total cost by vendor for top lanes

The first priority should be the Nanofilm Technologies Int PTE vendor who represents a $68k USD savings potential from the overall $104k USD target. This is the single-most compelling direction in actualizing the savings needed to reduce Waters' overall logistics costs. The second step would be to focus on Venture International PTE Ltd, who represents $22k USD savings potential. With those two vendors alone, 89% of the savings opportunity could be achieved.

In partnering with the top two vendors, we recommend focusing on the 9 lanes that make up 80% of the spend to produce the highest savings on time invested. Narrowing in on the few lanes that matter most will help the team realized quick wins and gain important momentum early in their journey towards transportation-related costs savings.

Furthermore, renegotiate existing carrier rates to maximize the savings opportunity and leverage the knowledge of shipment frequency to focus on the vendor who conducts shipments the most often. Adopting an agnostic view of carrier as long as the best service level for the business requirements is achieved, would prove to yield significant savings over time.

The decision-making tool is designed to allow the procurement function to automatically select the cheapest carrier while allowing selection of the viable service levels that fit the needs of the business.

4.4.2 Decision-making tool

The final model that is intended to be used by Waters' transportation decision makers is an overall excel spreadsheet that is composed of a consolidation of rates data across all three carriers, integrated analysis complete with formulas and color coding, and finally a user interface with Input and Output fields to allow quick decision making of inbound international shipment requirements. This deliverable is in alignment with Objective 3 to "provide the company with a decision-making tool allowing automatic selection of a carrier that ensures lowest shipping costs." This is a manifestation of the relationship between box B and box C2 in Figure 13 above. This instrument, depicted in Figure 16 below, was designed with the intent of

Waters scaling its adoption to the broader procurement function to maximize savings across the entire enterprise.

Inputs

Shipment information

Number of Shipments	1
Total Chargeable Weight	50
Origin	SIN
Destination	BOS

Carriers and service types to be considered

Carrier	Service Type	Include in Model?
	International Priority	yes
FedEx	International Economy	yes
	Express Saver	no
UPS	Express	yes
Expeditors	STD	yes

Outputs

Expected Total cost	234.13
Carrier selection	FedEx
Origin	SIN
Destination	BOS
Estimated Lead Time	4 days
Service Level Selected	International Priority

Figure 16 Decision-making tool for carrier selection

Compared to the initial routing guide depicted in Figure 3, this new decision-making tool is dynamic and able to be updated with new carrier rates once RFP responses are collected and formatted. The current process is to leverage the carrier specific negotiated rates data to estimate the total shipping costs while accounting for service type, lane, and total chargeable weight. This last criterion is dependent on the number of shipments that the shipper wants to send.

Based on the rolling 12-month timeline, there were 1,865 separate shipments made, which is over five separate shipments per day. There is an opportunity to consolidate the number of shipments so that the fixed costs associated with the shipment can be incurred once for the batched shipments.

As described in chapter 4.3, the estimated savings taken out of the logistics costs per year is estimated at $104k USD. This number is not accounting for the opportunity for shipment consolidation, which is also built into the decision-making tool.

4.5 Conclusion

Optimizing the flow of goods across the globe is incentivized by logistics savings, amplified by an enterprise's economies of scale. Waters' international shipments are majorly carried out via air freight and are exclusively performed by three main carriers: Expeditors, FedEx, and UPS. The specific problem addressed in this capstone is finding the best solution to systemically reduce the overall inbound international logistics costs for Waters Corporation, which have been flagged as higher than necessary over the last two years. The project methodology followed three main steps: receiving raw data, analyzing the excel spreadsheets, and finally providing outputs of findings. The different sets of raw data were bucketed into two main categories: historical shipment level detail (SLD) and Waters negotiated rates (rates).

Upon testing different methods, we used the historical SLD volume and applied the negotiated rates to understand the different opportunities present to Waters to reduce their overall inbound distribution costs. We uncovered three main areas that offered savings potential: differences between the negotiated and the charged rates, cost savings if allowing a change of carrier but considering same or similar service levels, and cost savings if allowing a change of carrier and of service level.

We recommend that Waters target the important cost savings by changing carrier and of service level and targeting the most impactful vendors first. We then also suggest leveraging the decision-making tool which automates the selection of both the carrier and service level, resulting in a target of 13% reduction in Waters' overall inbound distribution costs.

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