Alternate Pricing Model for Transportation Contracts

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ABSTRACT

Transportation spend is an increasingly relevant topic of concern for all manufacturing companies. Along with the money spent on transporting goods, service betterment has become an everyday expectation. In a tight market, when contract carriers are unable to fulfill the shipper's demands, the shipments are tendered to the spot market, where the costs are higher and service levels are lower. Through our study, we developed a dynamic index-based pricing which updates the contract rates on a monthly basis. This not only reduces the auction ratio (percentage of shipments going to the spot market), but also quantifies the incremental line haul savings/costs. We developed an optimization model based on national average line haul rates for contract carriers and spot market published by DAT to maximize the number of shipments moved from spot market to contract carriers, while satisfying various constraints such as cost and monthly variation. Our model shows that 8% of the shipments that had gone to auction would stay with contract carriers for a few, but not all, locations without any additional spend. Shippers can use our model to gather insights and reduce the auction ratio to drive better service levels and reduced costs even in tight markets.

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1. Introduction

The U.S. trucking market is estimated to be around $700 Billion, with full truckload accounting for almost 30% of it (AT Kearney, 2018). The US trucking industry volume was projected to grow by 4.2% in 2018 (Baertlein, 2018). Truckload shipments involve a carrier picking up goods from a single location and delivering to the destination with no intermediate stops. In today's environment of constrained transportation capacity, the importance of shipper-carrier relationships is of utmost importance, making these carriers an important part of logistics strategy (Zsidisin & Schlosser, 2007).

The North American Full Truck Load industry tends to operate on fixed lane-by-lane price contracts that are set either once per year or once every two years (CSCMP, 2018). However, demand outpaced supply in 2017 through early 2018 in every sector in the trucking industry, leading to carriers rejecting the shippers' loads and forcing shippers to move to the spot market at a higher rate than normal (Ashe, 2018; Cassidy, 2018). Spot market refers to the auction mechanism where shippers issue loads and carriers offer bids to fulfill the loads on a near real-time basis. The DAT national average index reported that spot rates increased by 42% in 2017 in response to tightened capacity. As the spot market rate increased, the shippers incurred higher transportation costs. Along with the costs, there was a negative impact in terms of service levels (State of Logistics CSCMP,2018).

Our sponsor, like most other shippers, experienced a high level of rejected loads by primary carriers. These shipments ended up being fulfilled by carriers in the spot market. This led to higher costs and reduced service performance as defined by internal metrics tracked by the sponsor company such as Customer Service On Time (CSOT).

Our sponsor company wanted to reduce the number of shipments which go to the spot market by improving the acceptance of loads by contract carriers. One potential approach to increase the acceptance ratio is to incorporate alternate pricing models to make these tenders more attractive to the contract carriers. To evaluate the impact of such pricing models, we developed a contract rate index which is linked to the market conditions using a monthly line haul cost index. The underlying concept behind the index is that line haul rates offered to contract carriers would increase or decrease based on whether an independent index increased or decreased.

After discussions with our sponsor company and contract carriers, we decided on using a monthly index which is linked to the DAT line haul index. We optimized the index to maximize the acceptance by the carriers over a 12-month period and evaluated the performance of the index over an additional 12-month period. Additionally, we conducted interviews with carriers to understand the technological, process, and financial impacts and risks of using such an index.

1.1 Motivation

Shippers typically observe that in a trucking market where supply is insufficient to meet demand, carriers often reject the loads issued by the shipper. Figure 1 shows the acceptance ratio (% of shipments accepted by contract carriers) for our sponsor company over a two-year period which covered both tight and soft market conditions. The acceptance ratio of carriers went down from around 75% in a soft market to around 55% in a tight market.

This forces the shipper to access the spot market to fulfill these loads. A spot market is a mechanism where the loads issued by a shipper are matched with any carrier who has trucking capacity available to fulfill the demand. The price for fulfilling the shipment is determined dynamically. Our sponsor company has observed that shipments which are fulfilled through the spot market often have higher costs and a lower service level associated with them. An understanding of why the contract carriers reject the shipments issued to them will give insights that can improve the acceptance ratio. This will in turn drive cost savings and service level improvements.

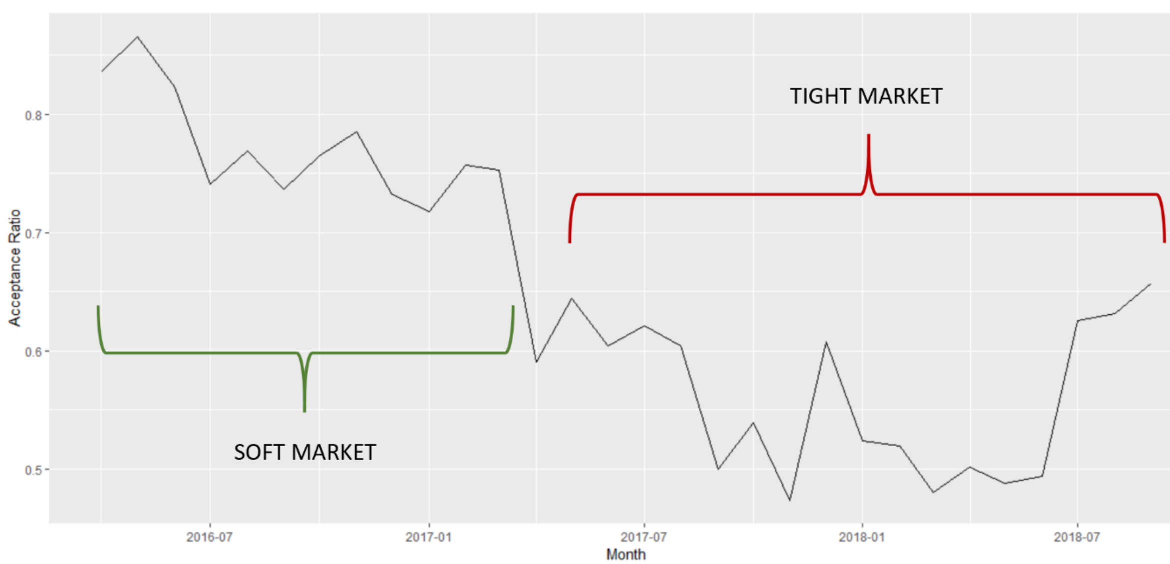

Figure 1. Acceptance ratio from May 2016 to September 2018.

1.2 Problem statement

The sponsor company was facing increased rejections by carriers during tight market conditions. Our Capstone intends to address the research question of whether a dynamically updated line haul rate for contract carriers results in lower rejections by the carriers. We evaluated whether an independent index can be used to update the line haul rates which are indicative of the prevailing market conditions.

1.3 Sponsor company

We partnered with a leading consumer packaged goods company that manufactures and delivers finished goods to more than 6000 customer locations in North America. It primarily utilizes contract carriers, but also uses the spot market to fulfill shipments to its customers if required.

1.3.1 Lane categorization

There are three types of shipments managed by our sponsor company:

- Outbound(Customer) - Finished goods shipments from plants and distribution centers that they own to customer locations that they don’t
- Inbound(Raw Material) - Shipments of raw materials from third-party suppliers to plants of sponsor company
- Interplant(Transfer) - Shipments of finished goods from plants to distribution centers

Outbound shipments can be fulfilled either through customer pick-up or for hire shipments. The sponsor company has segmented the outbound lanes into four categories: Tail, Pay for Performance, High Volume Interplant, Base/Others. Table 1 provides a percentage summary of the lane counts and shipment volumes by these categories.

Table 1
Lane categorization based on volume and lane count

Lane Type	Percentage of Lanes	Percentage of Shipments
Tail	29%	10%
Pay for Performance	19%	26%
High Volume Interplant	3%	39%
Base/Others	49%	25%

Tail lanes are categorized by few, intermittent, or sporadic demand. Tail lanes comprise 29% of the lanes but contribute to only 10% of the total shipments. We observed that these lanes have more shipments that are tendered by spot market as compared to the other lanes. Tail lanes are listed as point to point and grouped as a ship from location and a 3-digit destination zip code.

Pay for Performance lanes typically involve shipments to the three top customers of the sponsor company. They comprise 19% of the total lanes and contribute to 26% of the total shipments. Carriers provide rates for both base and premium service for these lanes.

High volume interplant lanes are the lanes between the distribution centers having a large number of shipments. They comprise 3% of the total lanes, but contribute to 39% of the total shipments. Loads issues in these lanes are either same-day or next-day tenders. The lead time between tender issue and goods pick-up for such lanes vary from 3-11 hours.

All other lanes are grouped as Base/Other lane type. They comprise 49% of the total lanes, but contribute to 25% of the total shipments.

Since tail lanes experience higher number of shipments getting fulfilled in the spot market (33%) , the scope of our Capstone involves for hire shipments for outbound customers for tail lanes. Shipments in other lane categories are usually accepted by the contract carriers, resulting in an auction ratio of 12% for High Volume interplant, 23% for Pay for Performance, and 24% for Base/Others.

1.3.2 Contracting process

The contracting process begins every year with the sponsor company sending a bid letter for all the lanes to a group of selected carriers. With the forecasted annual volumes available, the carriers decide the price they want to bid on a particular lane. Along with the forecasted volumes, the sponsor company also provides details about accessorial charges like driver detention, empty miles etc. The sponsor company selects one or more primary carriers for each lane depending upon price, performance, and available capacity.

1.3.3 Tendering process

After selecting the carriers, the sponsor company populates the routing guide with the carrier, contracted rate, and weekly volume for each lane in the Transportation Management System (TMS). Once the delivery date and quantity has been generated for a particular destination location, our sponsor company issues load tenders to the contract carriers of that particular lane via their transportation management system. contract carriers are expected to accept or reject load tenders within 2 hours of receiving them. If a carrier accepts a load, then delivery appointments are set up at the origin and destination. Carriers who cannot accept a load are expected to provide an appropriate rejection reasons such as more than 20% volatility in the forecasted volume, insufficient lead time between tendering and goods issue etc.

If the primary and all the contracted back-up carriers reject the tendered load, then the shipment goes to a freight auction, which is accessible to a larger group of carriers.

Carriers who wish to participate in these auctions log in to a portal where they can view the list of loads that they are eligible to bid on. The carriers can submit bids for these shipments through the auction portal. Carriers are expected to separate freight charges into line haul and accessorial charges. Based on various bids submitted by all the carriers, the sponsor company selects the carrier with the winning bid within twenty-four hours, and the load is tendered to the carrier at the agreed upon rate.

1.4 Chapter summary

Shippers have contracts with carriers to service their lanes. However, when demand outpaces supply, carriers often tend to reject the loads issued to them. This results in shippers resorting to spot market to fulfill such loads, driving up costs and reducing service levels. Our sponsor company also faces these issues in the USA market, especially for shipments in the tail lanes. Our proposed approach to increase the acceptance ratio is to develop an alternate pricing model to offer market relevant line haul rates to the contract carriers.

The remainder of this report is organized as follows. Chapter 2 discusses the truckload industry, shipper-carrier relationships in USA, dynamics of procurement of full truckloads, and existing index-based pricing mechanism for accessorial in trucking industry. This chapter also provides a summary of our discussions with multiple carriers of our sponsor company. Chapter 3 describes our approach in developing a relationship between national level index and rejections by carriers, which is used to develop an optimization model to reduce carrier rejections by adjusting the contract price with a market relevant index. Chapter 4 analyzes the results showing the impact of index-based pricing at a warehouse level. Chapter 5 summarizes our conclusion and explores areas of future research.

2. Literature Review

The literature review is grouped into four thematic sections: transportation procurement process, shipper-carrier relationship, tender acceptance/rejection by carriers, existing index-based pricing models in trucking industry, and discussions with the carriers of our sponsor company. The study helped us to analyze the feasibility of implementing an alternate pricing model in long-term contracts between carriers and shippers.

2.1 Transportation procurement: Contract vs spot market

Shippers procure transportation predominantly using contracts developed through reverse auctions (Caplice, 2009). The objective of this process is to allocate carriers optimally to individual lanes. This typically involves three stages (Caplice & Sheffi, 2003):

- Bid preparation - This involves classification of lanes and generating expected demand for each of the lanes by the shippers. Lanes are classified on the basis of source and destination location. This is followed by shortlisting of carriers by various criteria like financial health, past performance and technical capabilities. This stage enables shippers to develop stronger strategic partnerships with a fewer number of carriers (Vos, 1999).
- Bid execution - The shipper conveys the information and the carriers respond with their quotes. The bids are typically provided as a rate per mile with a minimum charge, if applicable or flat rates (Vos, 1999). A carrier can offer bids on a lane by lane basis or provide a conditional bid. A conditional bid involves a rate which is applicable only if certain conditions such as minimum volume, number of lanes awarded etc. are met (Caplice & Sheffi, 2003).

- Bid analysis and assignment - Allocation of a specific lane to a carrier involves deciding on cost factors, performance metrics and other qualitative factors. Certain shippers select carriers with the lowest bids who meet their minimum service levels. Another approach involves selecting carriers who provide the highest benefit as calculated by a weighted sum of individual metrics such as cost, on-time delivery (Vos, 1999). This utilizes a carrier assignment model with an objective the total cost of expected shipments during a period of time. The model ensures that individual lanes are allocated sufficient trucking capacity to meet the expected demand.

Although this results in a contract between the shipper and the carrier, the carrier has an opportunity to reject a tendered load. When the primary rejects a load, it gets offered to any backup carriers for that lane. If the back-up carriers also reject the load, a shipper can access spot markets to post these loads (Nandiraju & Regan, 2008). Spot rates are defined as the price quoted for immediate settlement on a commodity or a service.

2.2 Shipper-Carrier Relationship

A critical factor in the efficient management of transportation is the relationship between carriers and shippers. One logistics executive quoted in an article in *Inbound Logistics* stated, "Shippers now have to think about helping their carriers, rather than just dictating to them. The big potential for change rests on collaboration [with carriers]" (Douglas 2006, 162).

Supplier partnerships can provide a purchasing organization with many of the benefits of vertical integration, such as greater coordination, better asset utilization, and faster response to market changes. A study on Hershey’s, the U.S.-based candy company, and its carriers established trust as an important precursor to effective relationships. It also clearly exhibits that carriers who had a partnership with the firm rejected loads the least (Zsidisin & Schlosser, 2007).

2.3 Rejection by Carriers

Carriers who are contracted with our sponsor company are expected to accept 100% of their committed volume plus an additional 20% surge volume every week. However, sometimes the carriers are unable to pick up the loads even if they had committed to them earlier. Even if carriers have a contract with a shipper, these acceptance commitments are not strictly enforced. Similarly, a shipper is not penalized financially if the forecasted volume does not materialize. The key incentive for a carrier to accept a load is potential future business from the shipper due to high service levels in metrics like On-Time Delivery (Scott,2017).

Kafarski & Caruso (2012) found that the main factors contributing to the rejection are as follows :

- Not enough lead-time to secure a truck
- Surge in volumes on specific lanes
- New lanes
- Long load times at origin or unload times at destination
- Service in an area of weather impact
- Inconsistent lane activity, and
- Low rate offered previously on the same lane

The above factors were verified through our conversations with several of the carriers of our sponsor company. Additionally, during our conversations with the carriers, we discovered that they have a strong motive to allocate their capacity to spot market rather than their contracted freight in tighter market conditions in order to maximize their revenue.

2.4 Discussions with the carriers of our sponsor company

In addition to the data analysis, we also conducted in-depth discussions with several carriers. These included both asset owners and non-asset firms. Based on the feedback from carriers and existing literature, we concluded that the shipper-carrier relationship is a crucial element for carriers to decide whether to accept or reject loads. Often, carriers that have a long-term partnership with the shipper will accept more loads than the committed volume. We also observed that smaller carriers, in order to establish a stronger relationship with the shipper will accept loads that are not profitable. Other carriers, though, were not willing to accept loads beyond their commitment because it was more profitable for them to accept loads in the spot market than fulfilling shipments at their contracted rate.

Most carriers opined that an index-based contract price would increase their acceptance rate. However, we sensed some reservation from the carriers about the adequacy of indices, like DAT, or Cass Truckload line haul Index, to portray the current market dynamics. Updating the index once a quarter was mostly favored by the carriers. However, a few carriers were keen on having the contract price updated every month to mirror the market reality more closely. Transportation brokers preferred an index that is updated less frequently as they procure their capacity in the beginning of every tear. In contrast, asset owners preferred the rate to be updated as frequently as once a week so as to get a contracted rate which reflects the existing market scenario.

While a few of the carriers were open to the idea of fluctuating prices, even if they are below their contract rates, most revealed that they would be interested only if the contract prices increase in response to the market. Certain asset owners were not willing to accept loads, even with surplus capacity, if the new indexed rate offered is below a threshold value. To summarize, carriers carriers were generally not in favor of a symmetric index, which can result in indexed contract rates going below the original rates they had bid for.

2.5 Existing index-based pricing models in transportation industry

In our literature review, we found that index-based pricing models are not used for line haul rates in the US trucking industry. However, fuel surcharges are commonly used to account for the volatility of fuel costs, which form a major component of the transportation cost. Fuel surcharge accounts for variations of fuel prices in comparison to historical levels and adjust the amount paid to carriers for fuel expenses (Straight, 2017) . It is a form of risk sharing between shipper and carriers. Fuel surcharge details are usually provided in the bidding document shared by the shipper with all the carriers.

Fuel surcharges typically have three components: index, peg and escalator. The fuel surcharge,paid to the carrier in addition to the line haul rate, is calculated as shown below (C.H. Robinson , 2013):

Fuel Surcharge($/mile) $= \frac{Index\ (\$/gallon)\ - Peg\ (\$/gallon)}{Escalator\ (miles/gallon)}$

where Index is an independently determined average price of fuel, typically from the Department Of Energy.

The Peg is the fuel cost level at which the fuel surcharge program gives a zero value for the surcharge, typically set at $1.2 per gallon for historical reasons.

The Escalator is a factor which accounts for the amount of fuel used by a truck. It is essentially a proxy for fuel efficiency.

The Department of Transportation average fuel price is published weekly. Most fuel surcharge programs only move in five cent increments of fuel price in order to minimize short-term fluctuations.

The impact of varying levels of index in comparison to a peg is shown in figure 2.

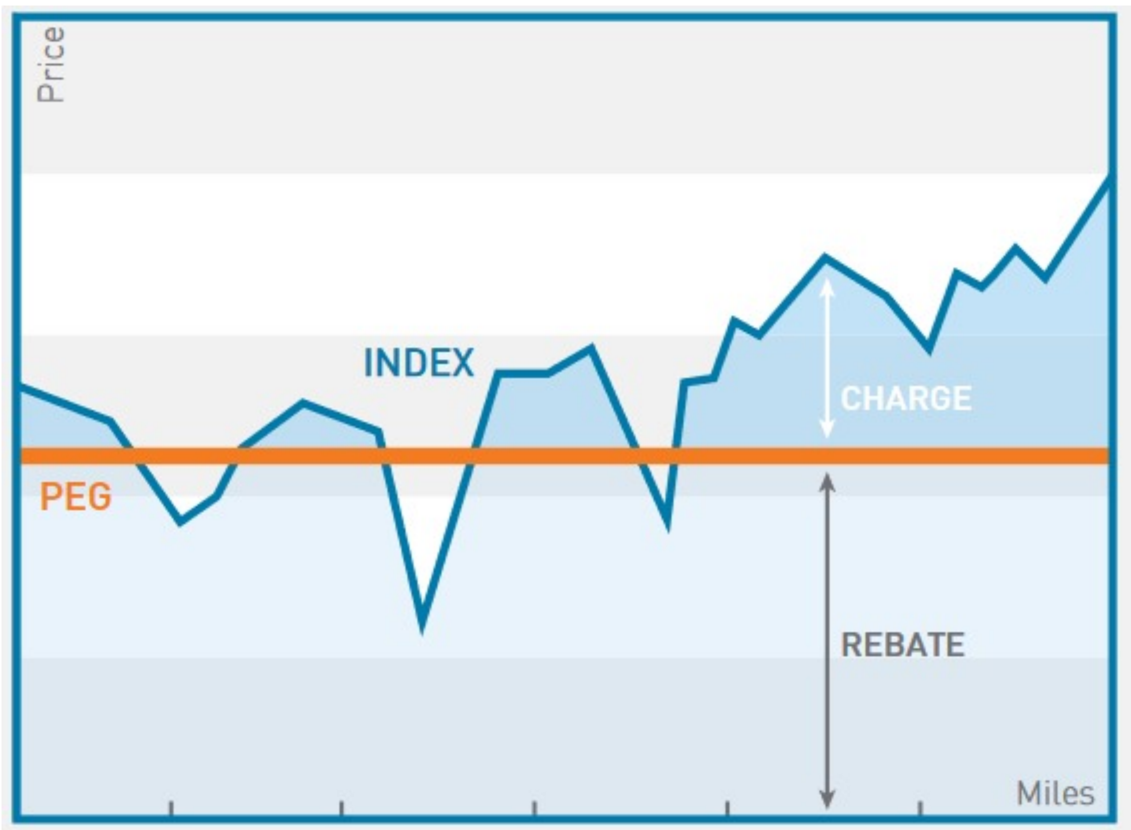

Figure 2. Illustrative example of fuel surcharge calculation. Copyright 2013 by C.H. Robinson.

Another commonly used in the transportation industry is the baltic dry index (BDI), which is a daily indicator of the dry bulk shipping rates. The Baltic Exchange calculates the index by assessing multiple shipping rates across more than 20 routes for the BDI components viz a viz

Baltic Capesize, Panamax, Supramax and Handysize indices. The BDI value can be used to estimate daily charter price of a ship using a conversion factor. A higher BDI is indicative of future economic growth (German & Smith, 2012).

2.6 Chapter Summary

We reviewed various factors such as shipper-carrier relationship, market dynamics, etc. and their impact on the transportation procurement process. From the literature review and discussions with the carriers, we discovered that a market relevant contract price can be used as a lever to meet the objective of increasing the acceptance of loads by contract carriers.

3. Methodology

The general methodology involved identifying and quantifying the relationship between a trucking industry standard index and the load rejections by carriers for tail lanes. After we modelled this relationship at a warehouse level, we created a contract price model which was dependent on the change in DAT index and a constant α to calculate a dynamic contracted rate, which is updated monthly. The α value for a warehouse can be thought of as a multiplier which translates the change in national market trends (as reflected in the DAT national average rates) to a regional index. If $\alpha > 1$, the changes in the national average rates are amplified in the index for that particular warehouse. Correspondingly, if $\alpha < 1$, the changes in the national average rates are damped. We optimized α for each warehouse to maximize the number of tail lane shipments that move from spot market to contract carriers subject to constraints such as the allowable percentage increase in line haul costs and limits on month to month index variations. Figure 3 provides an illustrative sequence of our methodology.

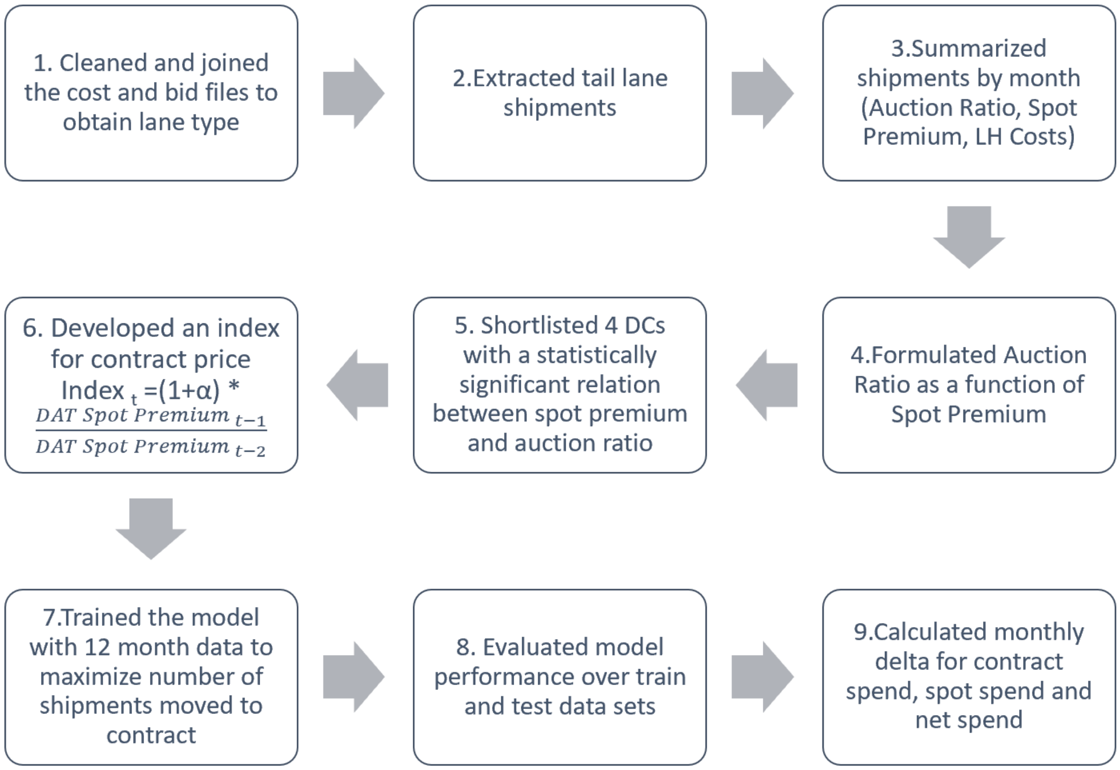

Figure 3.Summary of methodology used.

3.1 Data Mining

In order to evaluate the effectiveness of index-based pricing, we analyzed the transactional shipment data to understand the monthly trends of Line Haul cost Per-Mile (LHPM) on shipments that were fulfilled by contract carriers and shipments that were rejected by the contract carriers. We elected a monthly aggregation because our sponsor company has access to monthly DAT rates. Additionally, we observed that a weekly aggregation results in a much more volatile trend whereas a quarterly aggregation results in too much smoothening of price trends. We realized that this choice of monthly update, although arbitrary, is the most practical time horizon to update the index.

We utilized the following datasets provided by our sponsor company:

- Cost files containing shipment details (origin, destination, costs, distance, whether a shipment went to contract carrier or spot market, etc.) from April 2016 to September 2018.
- Bid files containing the lane details (origin, destination, lane type, the amount bid by carriers for contract shipments, etc.) as per the latest bidding round in 2018.

The first step involved in the analysis was aggregation of the cost files. The cost file was structured in a way that resulted in multiple rows for each unique shipment. As part of the aggregation, we summed up the costs incurred by each business unit for a shipment and created a table where each row corresponded to a unique shipment and its associated costs. After this, we calculated the line haul costs for each shipment by subtracting the fuel and accessorial costs from the total shipment costs. The LHPM was calculated by dividing this line haul cost by the distance of the shipment as provided in the data set.

After this aggregation, we filtered the data set to remove all shipments with missing / "Not a number" value for LHPM. We also removed all intermodal shipments, as the scope of the project involved full truckload shipments only. This was followed by joining the filtered cost data with the bid files to obtain the lane details for each shipment. We observed that there were no variable or pairs of variables which could uniquely match a shipment with a lane. To join the datasets, we cleaned the Bid file by removing:

- Any origin-destination pairs having multiple lane types
- All lanes with a lane type other than Tail, and
- Duplicate tail lanes having the same origin-destination pair

After removing these lanes, we utilized the combination of origin ID and destination postal code of shipments to match the lane types.

To evaluate the feasibility of using a national index rate, we obtained the DAT national spot and contract rates over the same time period of analysis. These rates are monthly average line haul rates of shipments in USA based on actual shipments. Figure 4 depicts the change in market dynamics after mid-2017 when the average DAT spot rates started increasing significantly compared to the DAT contract rates. The sponsor company exhibited a similar directional trend for spot rates, but at a higher magnitude compared to the DAT spot rates. The rates for our sponsor company depicted in the figure is an average value across all regions thus hiding the regional volatilities.

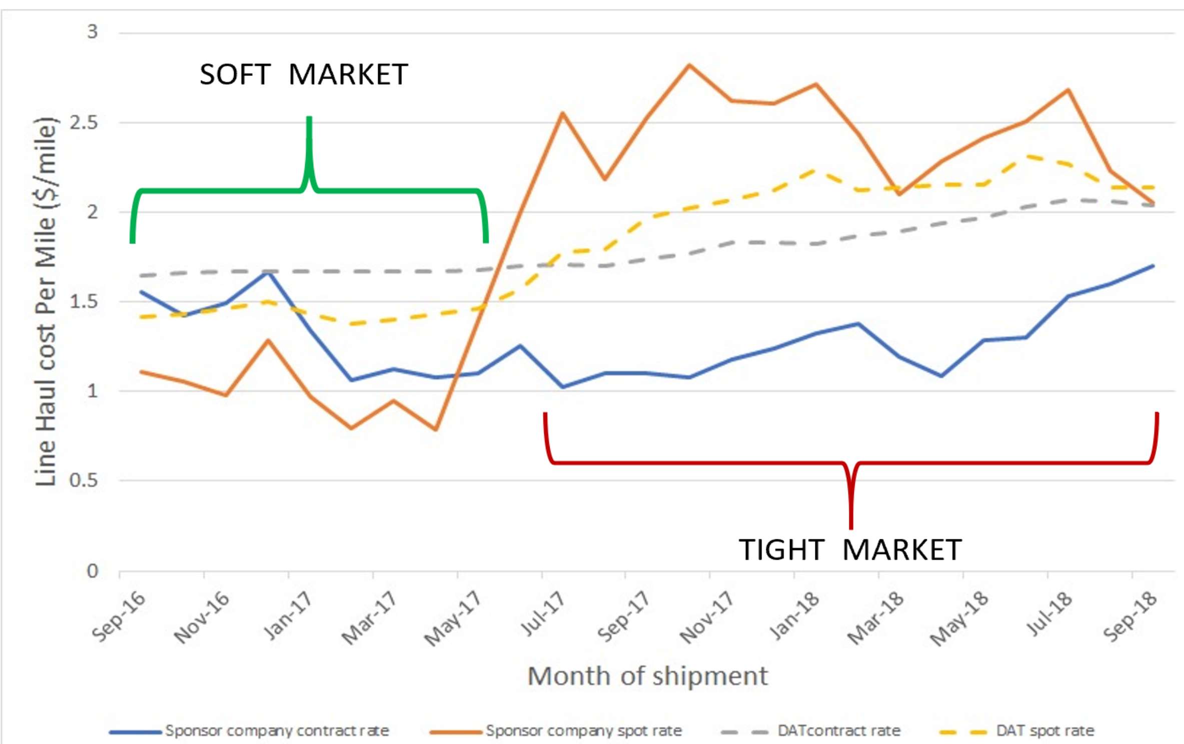

Figure 4. Evolution of DAT and sponsor company's spot and contract rates.

Since the DAT rates are monthly and our sponsor company preferred a monthly horizon for analysis, we aggregated shipments from each warehouse at a monthly level. For each month we calculated the following variables:

Spot Premium= $\frac{Average\ LHPM\ for\ all\ shipments\ from\ the\ warehouse\ which\ went\ to\ spot\ market}{Average\ LHPM\ for\ all\ shipments\ from\ the\ warehouse\ which\ were\ fulfilled\ by\ contract\ carriers}$

Auction Ratio = $\frac{Number\ of\ shipments\ from\ the\ warehouse\ which\ went\ to\ spot\ market}{Total\ number\ of\ shipments\ from\ the\ warehouse\ \ of\ analysis}$

The spot premium is an indicator which shows how expensive shipments sent to spot market are compared to those fulfilled by contract carriers. When the average LHPM are the same for shipments which went to spot market and contract carriers, spot premium will be 1. As the LHPM for auctioned shipments increases in comparison to those of contract carriers, spot premium will increase beyond 1.

Auction Ratio is a variable which varies from 0 to 1. When all the shipments in a month are fulfilled by contract carriers, the auction ratio will be 0. Correspondingly, when all the shipments in a month are fulfilled using the spot market, the auction ratio will be 1.

The monthly behavior of spot premium paid by our sponsor company in tail lanes is shown in Figure 5. The figure indicates a clear increase in the spot premium after mid-2017, indicating that our sponsor company has been paying a higher rate for shipments which went to spot market, compared to those which were fulfilled by contract carriers.

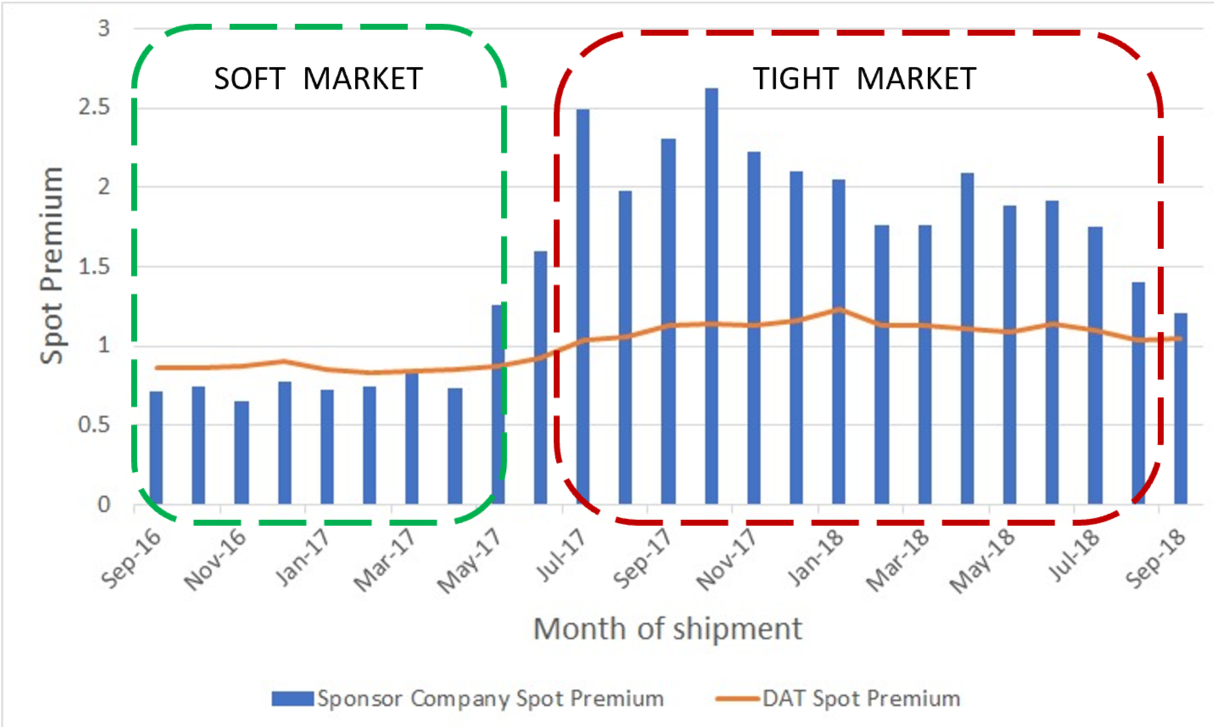

Figure 5. Spot Premium trends for our sponsor company and DAT from September 2017 to September 2019.

We observed that even in a soft market with spot rates lower than the contracted rates, our sponsor company has an approximate auction ratio of 20%. Note that the Auction Ratio = (1 - Primary carrier Acceptance Rate) * (1 - Backup carrier Acceptance Rate). The auction ratio of 20% was attributed to the carriers having insufficient capacity, high volatility in shipment volumes, or a low lead-time between tender and shipment date.

After deriving the monthly spot premium and auction ratios, we analyzed whether there is a correlation between the monthly auction ratio and the spot premium for the sponsor company. We explored the relationship by fitting linear and quadratic models between monthly spot premium and auction ratio for each warehouse. Additionally, we also evaluated the relationship between DAT national spot premium for each month and the corresponding spot premium for each warehouse of the sponsor company.

Since the spot premium and auction ratio dynamics vary widely depending on the geography, we disaggregated the shipments for each of the twelve origin warehouses. We observed that only shipments Wisconsin, Pennsylvania, Missouri, and California warehouses exhibited any significant relationship between these variables, with an R-squared value greater than 0.3. After discussions with our sponsor company, we decided to focus our analysis only on shipments from these four warehouses.

3.2 Optimization Model

The transaction data shared by our sponsor company covered twenty four months of shipments. We aggregated this data for each month and warehouse. Aggregated data was split into two parts. First twelve months of data was used to optimize our decision variable and the next twelve months of data was used to evaluate the performance of optimal model for each warehouse.

We developed a non-linear optimization model for each of the shortlisted four warehouses. We utilized Generalized Reduced Gradient (GRG) engine to solve the optimization model.

The Objective function maximizes the number of shipments that move from spot market to contract carriers. The decision Variable α was found for each warehouse obtained as a multiplier of the monthly change in the DAT index. As α gets larger, the impact of DAT trend on the index increases linearly.

The equation for the index is $\text{Index}_t = (1 + \alpha) * \text{DAT spot premium}_{t-1} / \text{DAT spot premium}_{t-2}$

where DAT Spot Premium$_t$ is the ratio of national DAT line haul rates for spot market and DAT line haul rates for contract carriers in time period t

In order to ensure that the optimization model provides a solution that is viable for the sponsor company, we established several parameterized constraints to the model. The first constraint was that $\alpha >= 0$ to ensure that the index follows the trend of DAT spot premium over the last two months. For example - if the DAT spot premium in February is higher than the DAT spot premium in January, the index in March will be greater than 1. We set an upper bound of 2 for the index after discussing with our sponsor company to ensure that the indexed contract rates will not be excessively high. We set a lower bound of 0.9 for the index to ensure that the indexed contract rate will be not too low and result in increased rejections by the contract carriers. We varied the allowable line haul cost increase after implementing the index from 0% to 20% to evaluate the impact on acceptance ratio. Based on the results of optimization model and inputs from our sponsor company, we set up a constraint for a 10% allowable cost increase.

Table 2

Monthly snapshot of line haul rates and auction ratios of the sponsor company

Month	Sponsor's Average Contract LHPM($/mile)	Sponsor's Average Spot LHPM($/mile)	Sponsor's Spot Premium	Sponsor 'sAuction Ratio	DAT Contract LHPM ($/mile)	DAT Spot LHPM ($/mile)	DAT Spot Premium	DAT Change
Sep-16	2.13	1.95	0.92	30%	1.66	1.43	0.86	
Oct-16	2.93	1.90	0.65	20%	1.67	1.46	0.87	1%

Table 2 shows the actual data of a warehouse located in Wisconsin with the following columns for each month:

Average of LHPM (Contract) was calculated by dividing the sum of line haul cost for shipments fulfilled by contract carriers by the sum of the distance of shipments fulfilled by contract carriers. Average of LHPM (Spot) was calculated by dividing the sum of line haul cost for shipments fulfilled through spot market by the sum of distance of shipments fulfilled through spot market. Sponsor Spot Premium was obtained by dividing average of LHPM for spot market by average of LHPM for contract carriers. Sponsor Auction Ratio was calculated by dividing the total number of shipments fulfilled through spot premium by total number of shipments.

DAT Contract LHPM is the average national line haul cost per mile for contract carriers as per DAT. DAT Spot LHPM represents average national line haul cost per mile for spot market as per DAT. DAT Spot Premium was calculated as a ratio of DAT Spot LHPM and DAT Contract LHPM. DAT change for period t is calculated by dividing the DAT Spot Premium for period t-1 by the DAT Spot premium for period t-2.

Table 3

Calculated fields in the optimization model

1	2	3	4	5	6	7	8	9	10	11	12	13	14
INDEX	Delta Index	Indexed Contract Rate	Indexed Spot Premium	Predicted Auction Ratio	Delta Auction Ratio	Shipments moved	LH Spend (Index)	LH Spend (Index) CONTRACT	LH Spend (Index) SPOT	Cost % (Index / Actual)	LH CONTRACT DELTA	LH SPOT DELTA	TOTAL LH DELTA
1.12		3.29	58%	18%	-2.18%	0	11,610	9,716	1,894	110.04%	1,291	(232)	1,059
1.23	8.4%	3.47	52%	9%	-2.13%	-1	23,516	21,402	2,114	119.74%	4,355	(478)	3,877

Table 3 shows the calculated data of the warehouse in Wisconsin with the following columns for each month. The monthly value of index (column 1) is calculated by multiplying (1 + α) by the DAT change over the last two months. The α value is obtained by maximizing the number of shipments moved from spot market to contract carriers, subject to constraints. This value of the index is multiplied by the average contract LHPM to estimate the monthly indexed contract LHPM (column 3). The spot premium after using an index is calculated as a ratio of the average LHPM of shipments which went to the spot market and the monthly indexed contract LHPM. The new auction ratio after using an index (column 5) is predicted as a function of the auction ratio without index, the original spot premium and the spot premium after indexing (column 4) using the equation below:

Predicted Auction Ratio = Sponsor Auction Ratio * Index Spot Premium / Sponsor Spot Premium

We estimated the number of shipments which will be moved from the contract market to the spot market (column 7) by multiplying the difference of the predicted auction ratio (column 5) and original auction ratio with the number of shipments as illustrated in the equation below.

Shipments moved = Number of shipments fulfilled by spot market * (Predicted Auction Ratio – Sponsor Auction Ratio)

We estimated the monthly line haul costs of shipments going to spot market (column 10) and contract carriers (column 9) by multiplying the indexed line haul rates (column 3) and the number of shipments which were predicted to go to the spot market and contract carriers after indexing using the following equations.

LH Spend (Index) Contract = of contracted shipments * Indexed Contract Rate

LH Spend (Index) Spot = Predicted number of spot shipments * Average of LHPM (Spot)

LH Spend (Index) = LH Spend (Index) Contract + LH Spend (Index) Spot

The change in line haul costs for contracted shipments (column 12) was calculated as a difference between line haul spend when shipments move under contracted rates with the index-based model and actual line haul spend for shipments fulfilled by the contract carriers. The change in line haul costs for spot shipments (column 13) was calculated as a difference between line haul spend when shipments go to the spot market with the index-based model and actual line haul spend for shipments going to the spot market. The incremental line haul costs (column 14) was calculated as a difference between the predicted line haul spend with an index and the actual line haul spend.

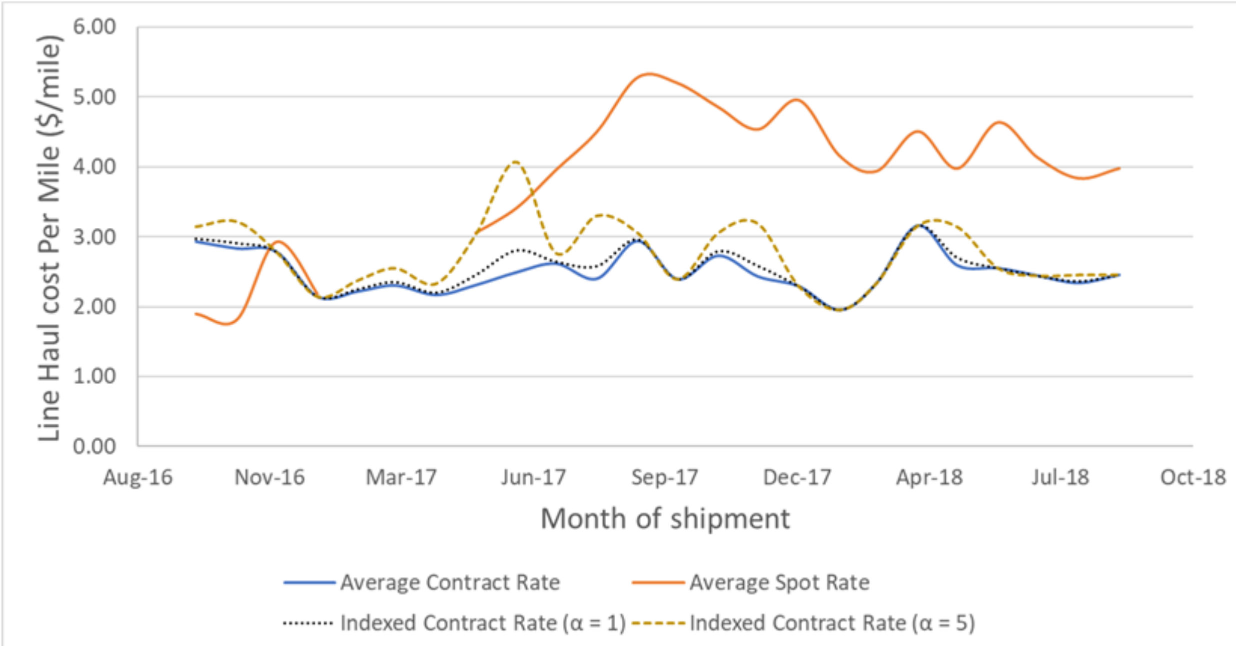

Figure 6. Impact of α on the indexed contract price.

Figure 6 depicts the impact of α on the monthly indexed contract rate. We observed that in September 2016, October 2016 and June 2017, the indexed contract rate is higher than the actual contract and spot rates paid by the sponsor company. This can be attributed to the increasing trend of DAT rates which was amplified by α. For the remaining months, the index contract rate lies between the sponsor company's contract rate and spot rate.

We trained the model on first 12 months of data and tested over the next 12 months of data. This approach has the advantage of being generalizable i.e. we can evaluate the model performance more realistically over a period of time irrespective of the market conditions.

3.3 Chapter Summary

We formulated an empirical relationship between the auction ratio and spot premium for each warehouse of our sponsor company. We developed a non-linear optimization model that focused on increasing the acceptance ratio by the carriers, through adjusting contract rates in line with an index for each warehouse. We incorporated various constraints to ensure that the monthly line haul spends after implementing the index are viable for our sponsor company. The model provided an output which evaluated the feasibility of index-pricing at each warehouse, which would be discussed in the subsequent section.

4. Results and Analysis

This chapter discusses the results of the model we elaborated in Chapter 3. First, we show the estimated relationship between an index and the auction ratio. Second, we discuss the results of the optimization model.

An increase in acceptance ratio by carriers results in many tangible and intangible benefits for the shippers. There are various drivers available for a shipper to influence the acceptance ratio by carriers, such as offering a contract rate that is aligned with the prevailing spot market rate and developing long-term strategic partnerships with carriers.

Our model evaluated the feasibility of having a contract rate that was aligned to the prevailing market conditions by pegging it to national DAT index. We optimized the value of α, which will be used to multiply change in DAT spot premium to obtain the monthly index.

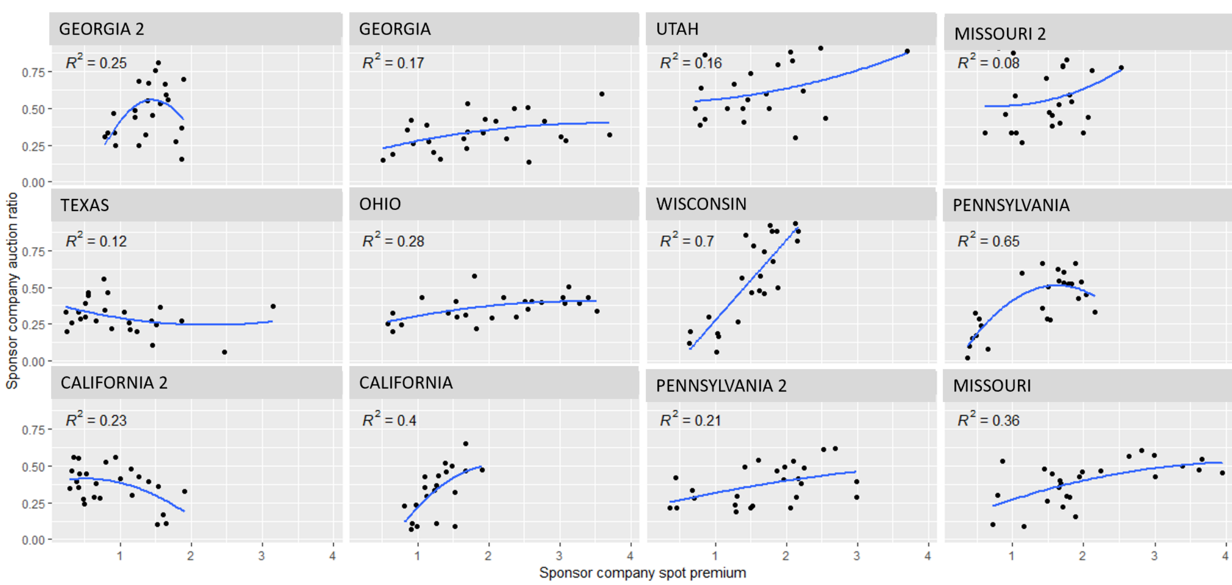

Figure 7. Relationship between sponsor company spot premium and auction ratio.

Figure 7 shows the relationship between the auction ratio and spot premium for shipments from each warehouse. We modelled the auction ratio as a quadratic function of spot premium and observed that eight out of the twelve warehouses do not exhibit a statistically significant correlation between auction ratio and spot premium. This could be because we used national DAT line haul rates which may not reflect the market dynamics of the regions served by these warehouses. Another reason could be that we aggregated shipments on a monthly basis to derive average line haul rates for the sponsor company and also used monthly DAT line haul rates. We also observed that the tail lane shipments from California exhibit a trend where higher spot premiums correspond to lower auction ratios. We shortlisted the warehouses in Wisconsin, Pennsylvania, Missouri and California as relevant candidates for index based pricing because they had a correlation greater than 0.35 between the spot premium and the auction ratio.

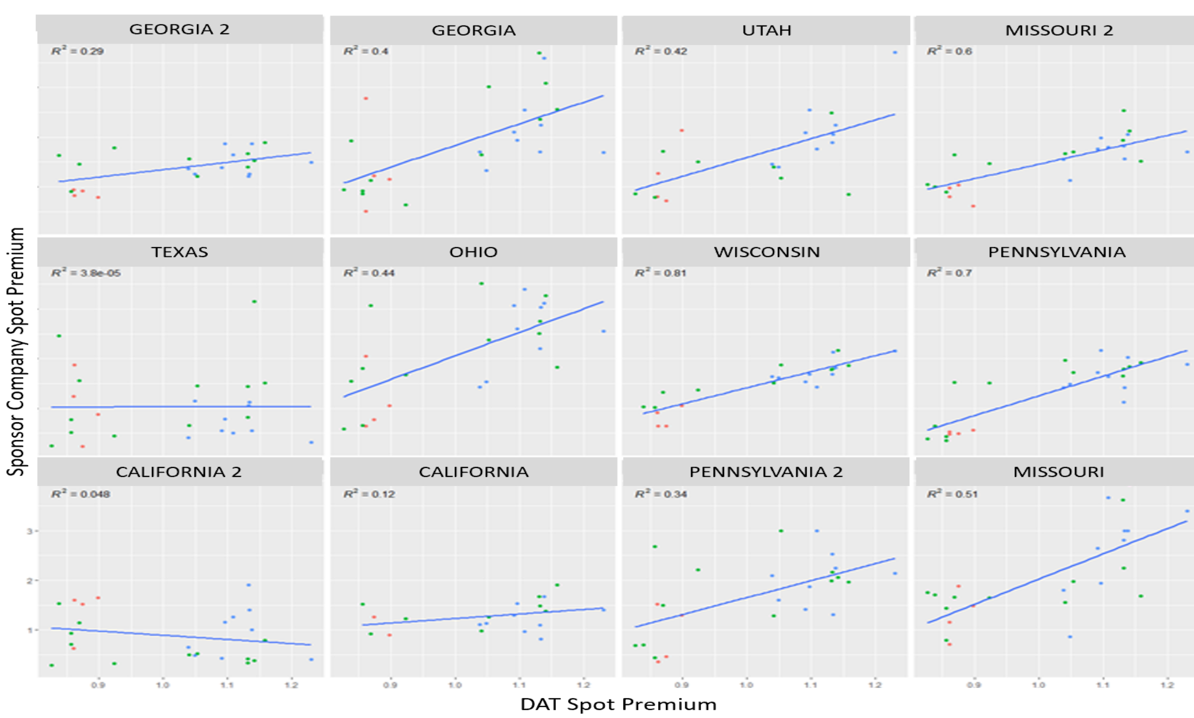

Figure 8. Relationship between DAT spot premium and spot premium for each warehouse.

Figure 8 illustrates the relationship between the monthly national spot premium (calculated as the ratio of DAT rates of spot shipments and contract shipments) and the monthly spot premium for individual markets served by each of the warehouses of our sponsor company. We observed that the spot premium for shipments from the warehouses located in Wisconsin, Pennsylvania, and Missouri tend to correlate with the national averages. However, shipments from warehouses in Texas and California often exhibit spot premiums which are distinct from national averages. Shipments from Texas warehouse exhibited a spot premium, which was relatively constant even when the national DAT spot premiums varied significantly. We observed that shipments from one of the warehouses in California exhibited a slight inverse relationship between regional spot premium and DAT spot premium. A low r squared value for these two warehouses indicate that DAT spot premium might not be an ideal variable to peg the monthly index on. Subsequent sections cover the model results for each of the four warehouses we have shortlisted and optimized.

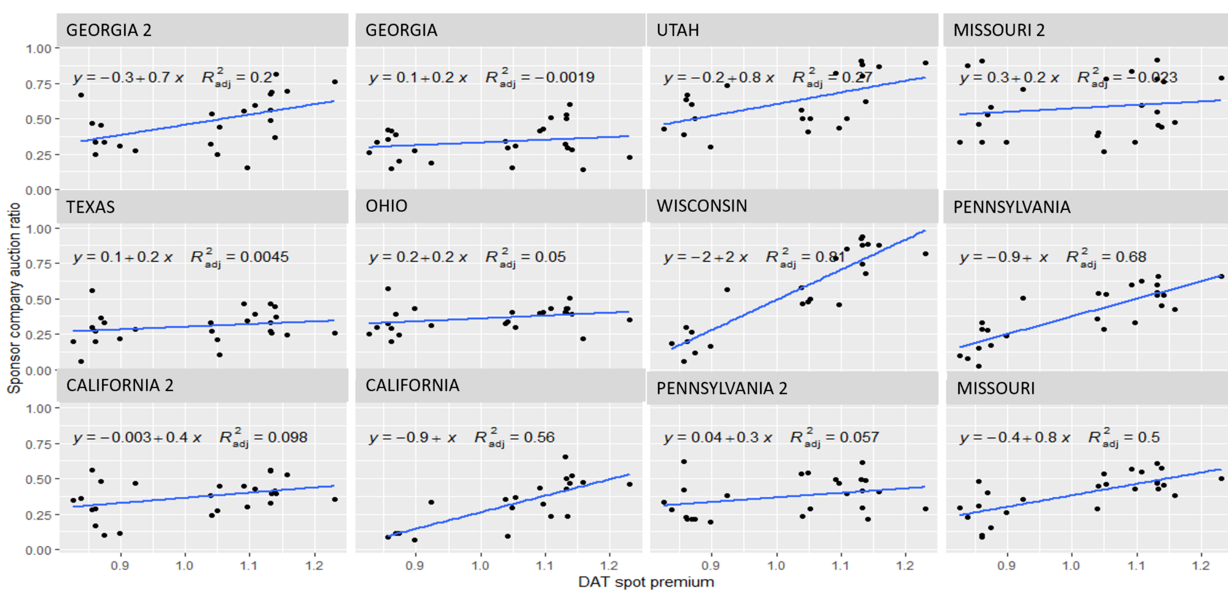

Figure 9. Relationship between sponsor company auction ratio and DAT spot premium.

Figure 9 depicts the relationship between sponsor company auction ratio and DAT spot premium. We explored this relationship to ensure that the sponsor company's auction ratio is correlated with the national transportation market market dynamics as indicated by DAT spot premium. The short-listed warehouses in Pennsylvania, Missouri, California and Wisconsin exhibit an r squared value greater than 0.5. This justifies the use of DAT spot premium to derive the monthly index for these warehouses.

4.1 Model results for Pennsylvania

Pennsylvania has one of the biggest manufacturing sites and distribution centers for our sponsor company. Our sponsor company spent around $ 3 Million in line haul costs for approximately 3700 shipments in tail lanes originating from Pennsylvania during our analysis horizon. We observed that the average line haul cost per mile for shipments from Pennsylvania are relatively higher compared to the other warehouses. The carrier acceptance ratio was 64%, which was close to the average for tail lane shipments.

From our optimization model, we obtained an α value of 6 as a multiplier to maximize shipments moving from spot market to contract carriers.

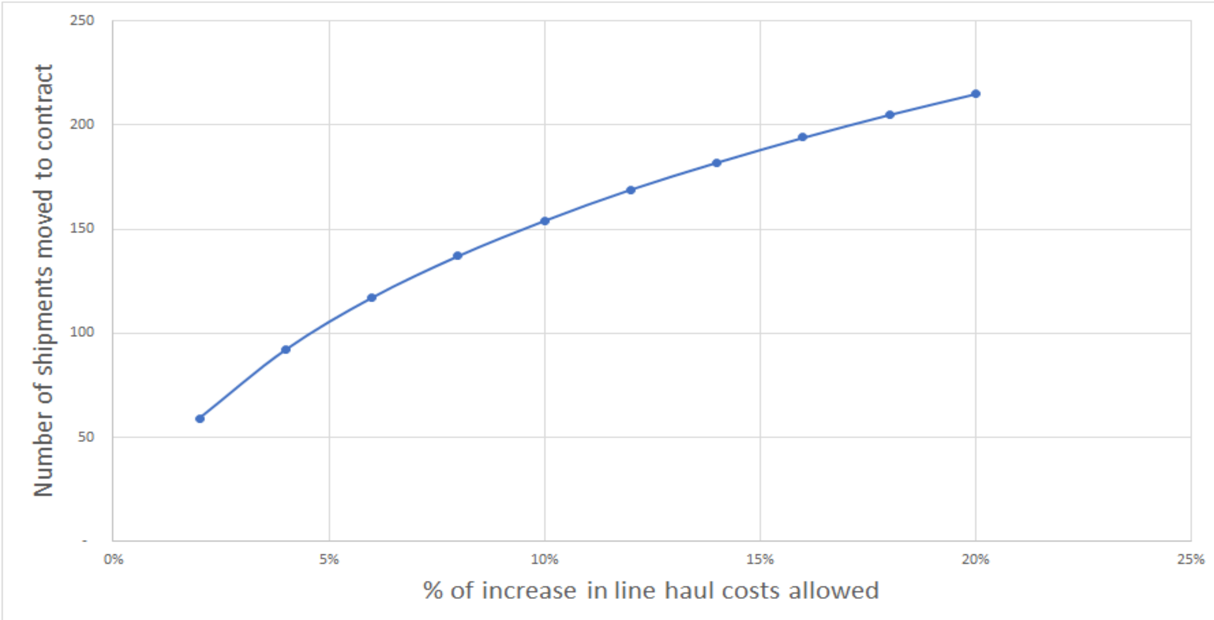

Figure 10. Change in acceptance ratio with varying line haul cost increase for Pennsylvania.

Figure 10 depicts the trade-off between the number of shipments moving to contract carriers and the incremental cost incurred for the same. We observed that an increased line haul spend is required to move any shipment from the spot market to the contract carrier. Also, the relationship between % increase in line haul costs and number of spot shipments moved to contract carriers is non-linear, i.e., as we spend more on line haul costs using an index, the number of shipments that move from spot market to contract carriers start tapering down.

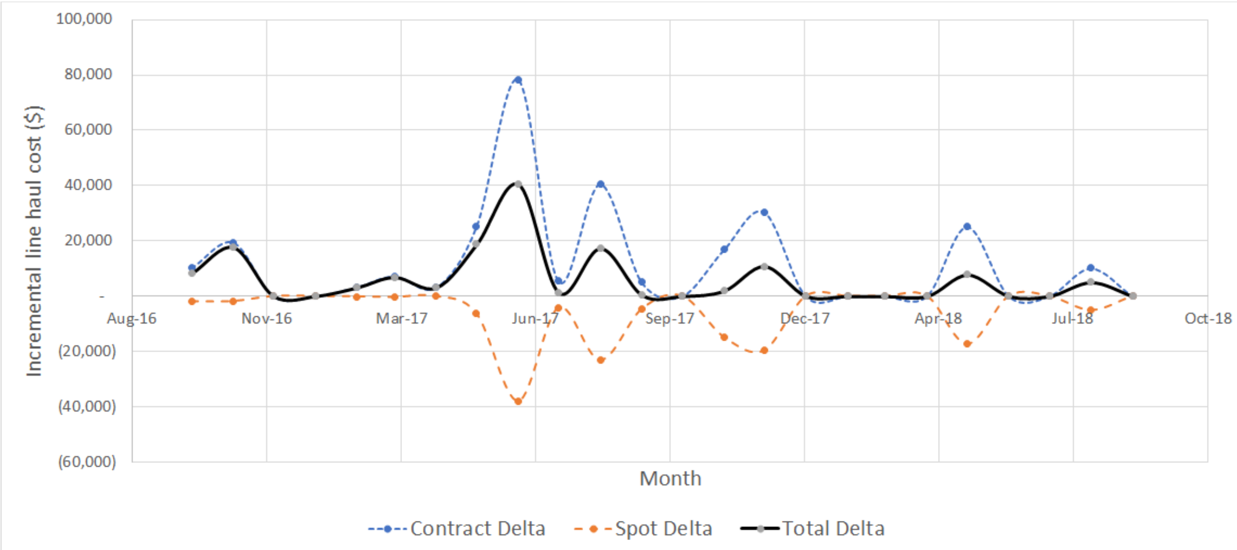

Figure 11. Monthly behavior of incremental line haul costs for Pennsylvania.

Figure 11 illustrates the monthly behavior of increment line haul costs for Pennsylvania. Contract Delta depicts the monthly incremental line haul costs for shipments fulfilled by contract carriers after deploying indexed contract rate. Spot Delta depicts the monthly incremental line haul costs for shipments fulfilled through spot market after deploying indexed contract rate. Total Delta depicts the net incremental line haul costs after deploying indexed contract rate. This comprises of the incremental line haul cost for spot shipments and the incremental line haul cost for contract carriers. With the use of an index-based price, we observed that the net line haul costs went up for shipments from Pennsylvania. This was primarily attributed to increased spend for contract carriers due to the index being greater than 1 during the period when the overall market was soft.

4.2 Model results for Wisconsin

Our sponsor company spent around $ 920,000 in line haul costs for approximately 800 shipments from the distribution center located in Wisconsin. We observed that the average line haul cost per mile for shipments from Wisconsin are the second highest among all the warehouses. The carriers accepted around 48% of shipments, which was below average for tail lane shipments, in comparison to other warehouses.

From our optimization model, we obtained an α value of 8 as a multiplier to maximize shipments moving from spot market to contract carriers.

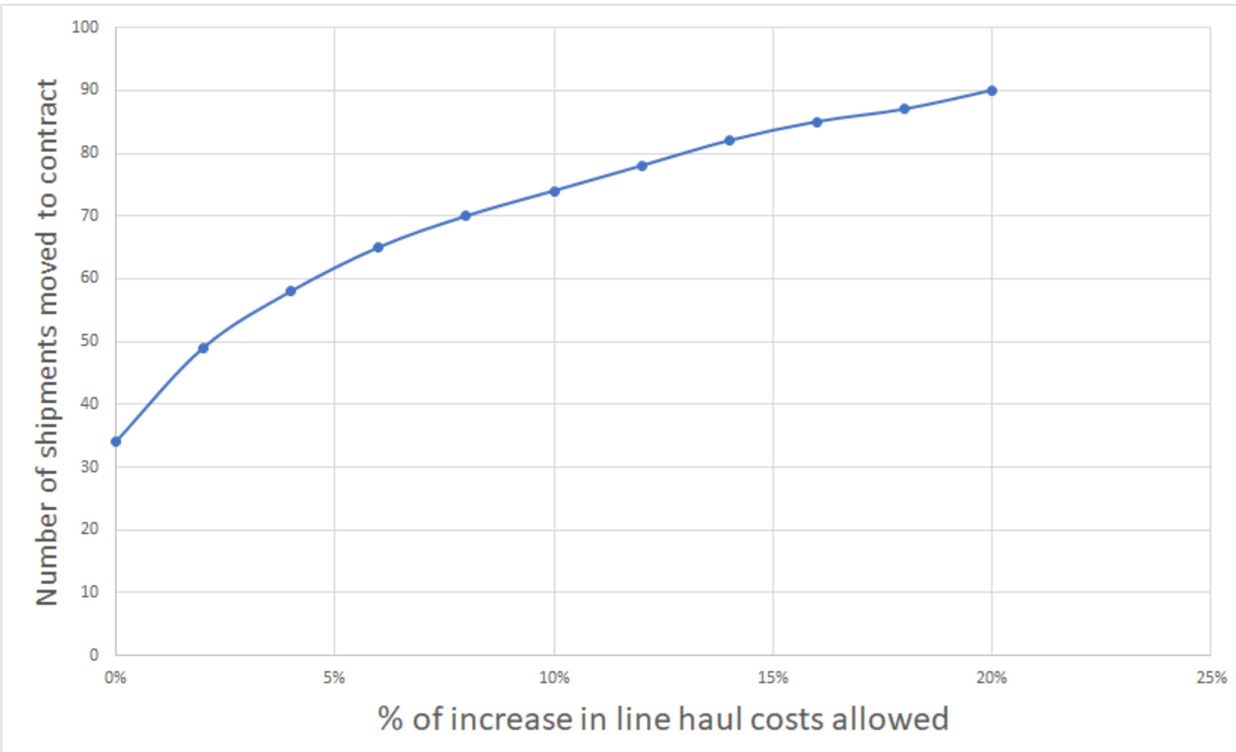

Figure 12. Change in acceptance ratio with varying line haul cost increase for Wisconsin.

Figure 12 depicts the trade-off between number of shipments moving to contract carriers and incremental cost incurred for the same. We observed that even without an incremental line haul spend, we could move 34 shipments (9%) from the spot market to the contract carrier. Also, the relationship between % increase in line haul costs and number of spot shipments moved to contract carriers is non-linear, i.e. as we spend more on line haul costs using an index, the number of shipments that move from spot market to contract carriers start tapering down.

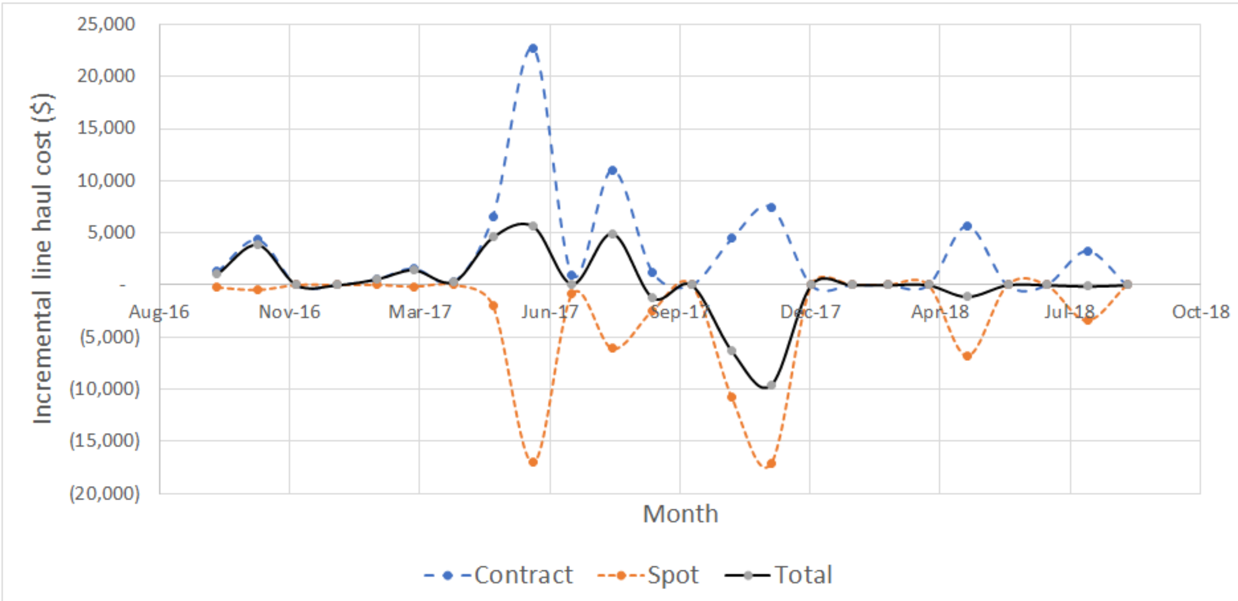

Figure 13. Monthly behavior of incremental line haul costs for Wisconsin.

Figure 13 depicts the trade-off between number of shipments moving to contract carriers and incremental cost incurred for the same. With the use of an index-based price, we observed that the net line haul costs went up for shipments from Wisconsin during the period when the market was soft. As the market tightened, our model predicts that index-based pricing will result in a net reduction of line haul costs.

4.3 Model results for California

Our sponsor company spent around $ 726,000 in line haul costs for approximately 1,062 shipments from the distribution center located in California. We observed that the average line haul cost per mile for shipments from California is the highest among all the warehouses ($ 4.62 per mile). The carriers accepted around 70% of shipments, which is the second highest in comparison to other warehouses.

From our optimization model, we obtained an α value of 12 as a multiplier to maximize shipments moving from spot market to contract carriers.

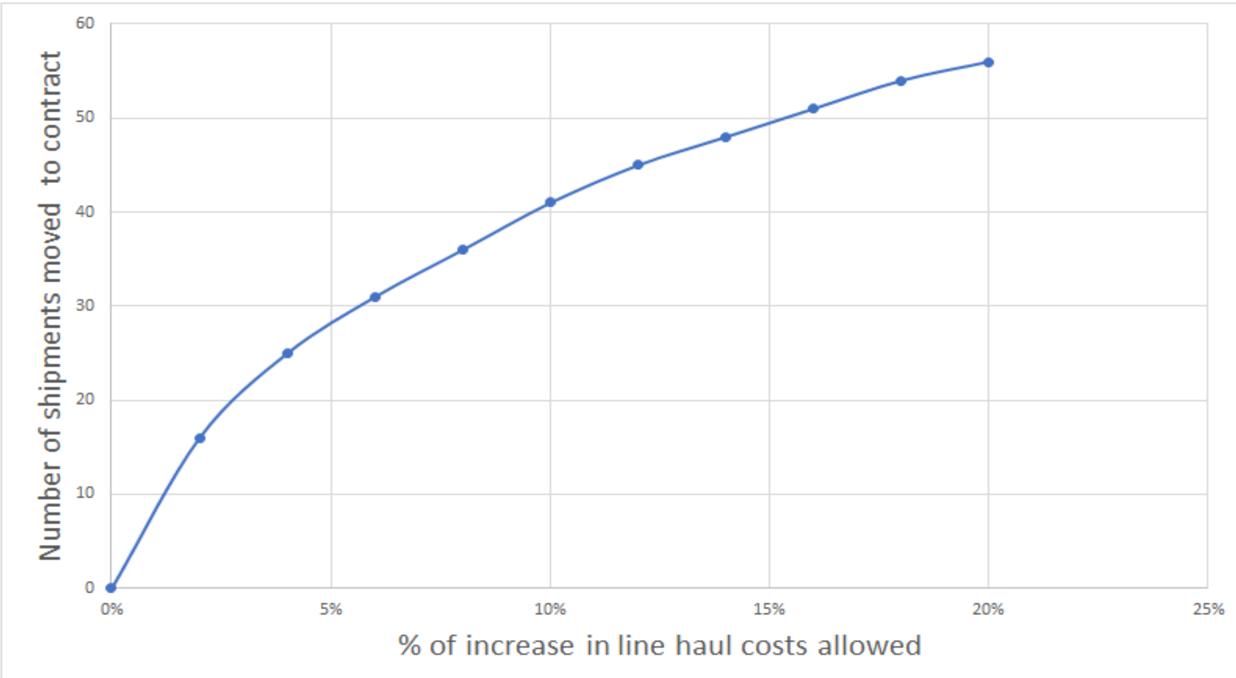

Figure 14. Change in acceptance ratio with varying line haul cost increase for California.

Figure 14 depicts the trade-off between number of shipments moving to contract carriers and incremental cost incurred for the same. We observed that an increased line haul spend is required to move any shipment from the spot market to the contract carrier. Also, the relationship between % increase in line haul costs and number of spot shipments moved to contract carriers is non-linear, i.e. as we spend more on line haul costs using an index, the number of shipments that move from spot market to contract carriers start tapering down.

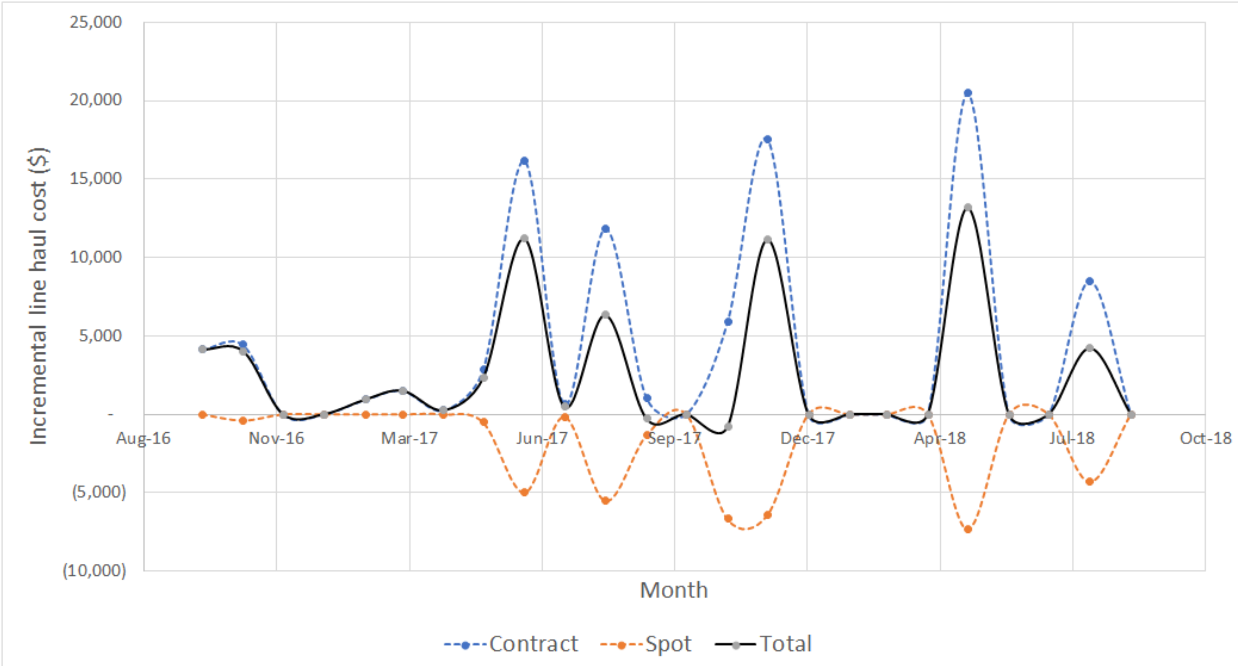

Figure 15. Monthly behavior of incremental line haul costs for California.

Figure 15 depicts the trade-off between number of shipments moving to contract carriers and incremental cost incurred for the same. With the use of an index-based price, we observed that the net line haul costs went up for shipments from California, irrespective of whether the market was tight or soft. In general, the decrease in the line haul costs for spot market could not offset the increase in line haul costs for contract carriers due to the index-based price.

4.4 Model results for Missouri

Our sponsor company spent around $ 2.2 Million in line haul costs for approximately 2,700 shipments from the distribution center located in Missouri. We observed that the average line haul cost per mile for shipments from Missouri is the lowest among all the warehouses ($ 0.84 / mile). The carriers accepted around 61% of shipments, which is above average in comparison to other warehouses.

From our optimization model, we obtained an α value of 7 as a multiplier to maximize shipments moving from spot market to contract carriers.

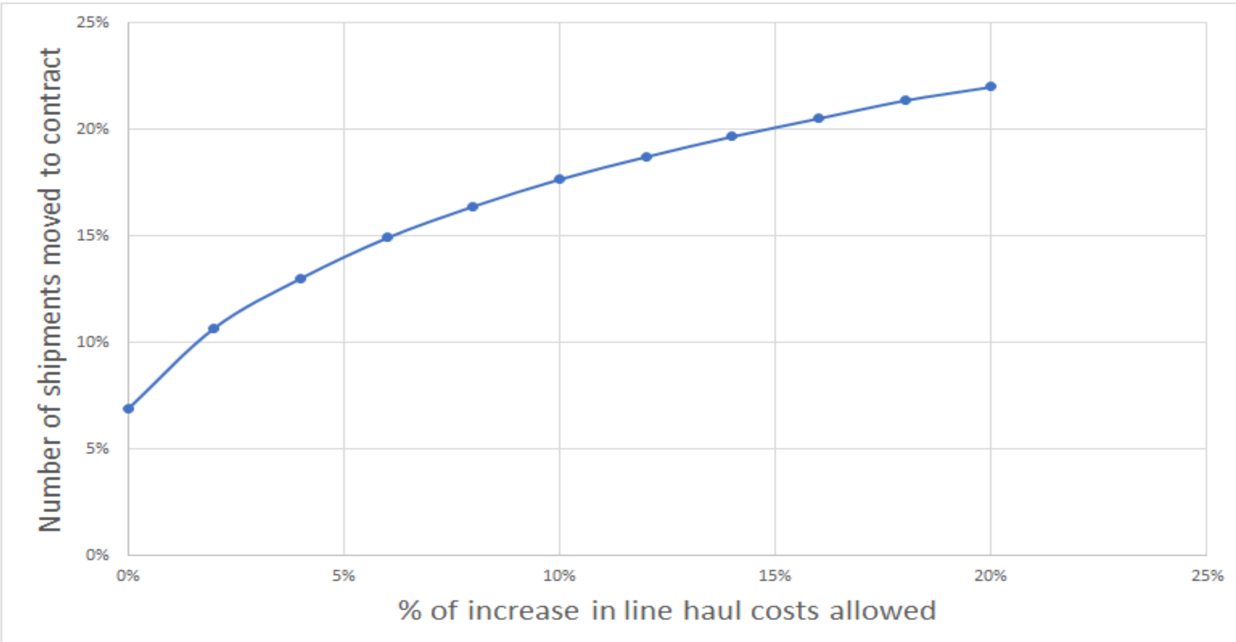

Figure 16. Change in acceptance ratio with varying line haul cost increase for Missouri.

Figure 16 depicts the trade-off between number of shipments moving to contract carriers and incremental cost incurred for the same. We observed that even without an incremental line haul spend, we could move 65 shipments (7%) from the spot market to the contract carrier. Also, the relationship between % increase in line haul costs and % of spot shipments moved to contract carriers exhibits a non-linear, tapering behavior.

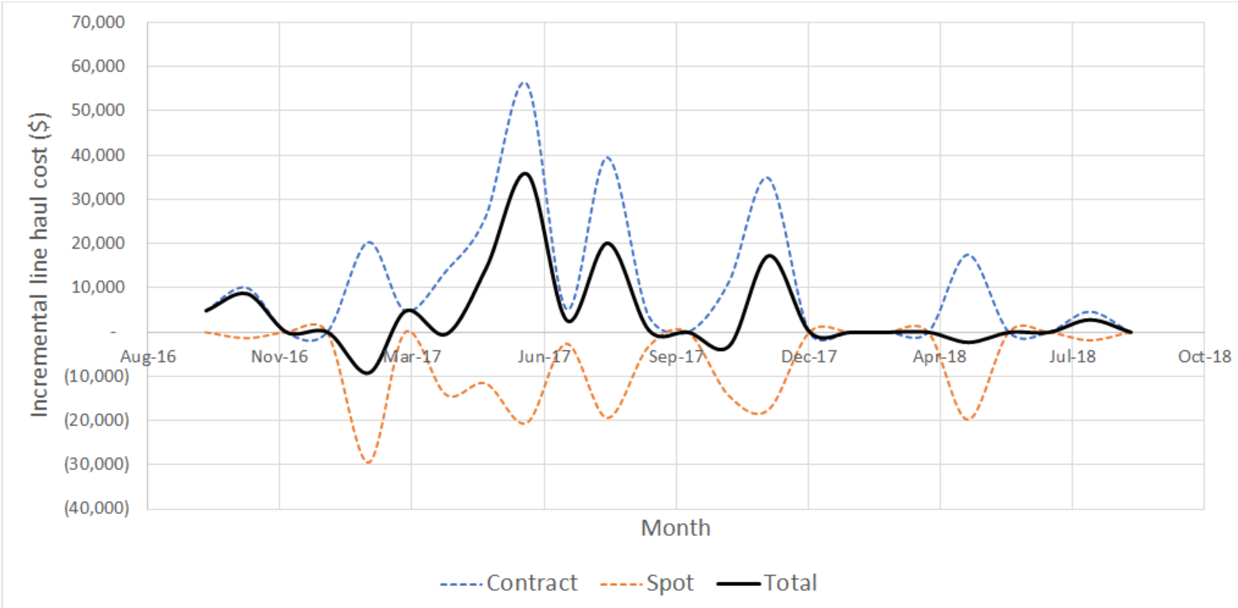

Figure 17. Monthly behavior of incremental line haul costs for Missouri.

Figure 17 depicts the trade-off between number of shipments moving to contract carriers and incremental cost incurred for the same. With the use of an index-based price, we observed that the net line haul costs went up for shipments from Missouri, irrespective of whether the market was tight or soft. In general, the decrease in the line haul costs for spot market could not offset the increase in line haul costs for contract carriers due to the index-based price.

5. Discussion and Conclusion

Our objective was to evaluate the effectiveness and value of index-based contracts for truck load in North America. We deployed an optimization model to analyze the month to month impact of an index-based price on tail lane shipments from 12 distribution centers. This section summarizes our findings and areas of further refinement to our model.

5.1 Summary of Main Findings

Table 4

Financial impact of index-pricing for the selected warehouses

	Wisconsin	Pennsylvania	California	Missouri
Shipments moved in training period	19	64	11	96
Shipments moved in testing period	20	37	25	31
Auction Ratio for training period (original)	36%	32%	17%	35%
Auction Ratio for training period (index)	27%	27%	12%	25%
Auction Ratio for testing period (original)	73%	48%	40%	48%
Auction Ratio for testing period (index)	69%	46%	36%	46%
Alpha	8	6	12	7
Cost diff. Contract (test period) $	20,887	82,476	52,480	68,310
Cost diff. Spot (test period) $	-38,106	-57,028	-24,741	-53,559
Cost diff. Total (test period) $	-17,218	25,488	27,690	14,751

Table 4 summarizes the impact of introducing index based pricing for the four warehouses we shortlisted. We observed that there is a significant difference in the market dynamics for shipments from various distribution centers. An index-based pricing results in a net reduction in line haul costs only for shipments from certain warehouses located in Wisconsin, and Missouri. For shipments from other warehouses, an index-based price can result in a net increase in line haul spend. However, this may be partially offset by the cost savings associated with reduced penalties associated with customer non-compliance of shipments fulfilled through the spot market. Our sponsor company had observed that shipments fulfilled through spot market often tend to be not delivered to the customer on-time. This results in penalties by the customers for those shipments. By deploying an index-based pricing, the number of shipments that are fulfilled through the spot market would be reduced, resulting in lesser penalties and hence, higher cost savings.

In the discussions with transportation partners of our sponsor company, we found out that even in cases of surplus capacity, certain asset owners were not willing to accept loads if the new indexed rate offered is below a threshold value. This is because asset owners, after conducting their internal cost benefit analysis, prefer to keep their assets available for spot market shipments than commit to our sponsor company at a reduced line haul rate.

We also observed some apprehensions about the index with some transportation brokers who were worried about any potential impacts to their profitability. The reason provided by brokers was that they procure their capacity from asset-owners at a fixed annual rate. Whenever an index results in rates lower than the agreed upon line haul rate, it would result in losses for the brokers.

We noticed some differences among carriers in terms of their preferred update frequency of the index. In the scenario where the contract price between the shipper and carrier changes on a monthly basis, the brokers were anxious that they might not be as profitable as planned. They were unsure whether they could implement a similar alternate pricing model with the asset owners. In contrast, the asset owners preferred the rate to be updated as frequently as once a week so that their returns are a representation of the current market scenario.

5.2 Areas of Future Research

Our analysis utilized national DAT index, and price and acceptance ratio variations between contract and spot shipments to develop a monthly index for contract line haul rates at a warehouse level. While changes in spot premiums explain a portion of changes in acceptance ratios, we believe that this model can be refined by incorporating the following features:

The scope of our Capstone was limited to shipments in tail lanes. These lanes are characterized by low, intermittent shipments. The relationship between auction ratio and spot premium may be different for lanes with different market dynamics. Applicability of the developed model needs to be explored for shipments of all the lane types.

A national index was used to derive the index in our optimization model. We observed that shipments from certain warehouses tend to have distinct patterns in comparison with the national trends. A regional index can be utilized to capture market dynamics at a more granular level.

Our sponsor company provides forecasted volumes to the carriers a year in advance while setting the contract rates. However, these forecasts may not capture the shipment volume volatility. This results in under utilization of assets of carriers or increased load rejections. Further research can be conducted on the benefits of having a granular forecast of shipment volumes and more frequent data sharing between shippers and carriers.

Our model utilizes trailing market indicators (DAT index of the previous two months) to calculate an indexed contract rate. However, anticipated events like weather anomalies, changes in regulations, seasonality of products being shipped etc. can significantly alter the demand-supply characteristics of the transportation market. Using leading indicators of the trucking market to develop the index is an avenue for future research.

Our study assumed that an index will be applicable to the line haul rates of all contract carriers. A further refinement to this model can have an index contract rate applied only to selected carriers for each lane. This necessitates further research on how to identify carriers who can be offered an indexed price. Our methodology involved monthly aggregation of the data, which was appropriate for our sponsor company. Depending on the market situations, the frequency of updating the index can be as high as weekly or as low as quarterly. The impact of this time horizon on carrier behavior and line haul costs need to be further explored.

Our optimization model incorporated several parameterized constraints to ensure results are in line with the business requirements of our sponsor company. Currently, we have set upper and lower bounds of the index at 2 and 0.9 respectively. Further discussions with a larger group of shippers and carriers are required to validate or refine these constraints. Another areas of future research would be to have flexible limits for the index that can change with the market dynamics.

We aggregated shipments at a monthly and warehouse level to understand the impact of spot premiums on carrier rejections. The probability of an individual shipment being rejected based on various shipment attributes such as lane distance, day or time of shipment, lead time, carrier characteristics etc. requires further exploration.

We established a linear relationship between auction ratio and spot premium for each region. However, if the index falls below 1, the indexed contract rate will fall below the original agreed-upon line haul rate between the shipper and carriers. This might result in rejections beyond what was predicted by the linear relationship. More sophisticated analytic techniques might be required to model the behavior when index falls below 1.

We believe that our study can be leveraged by our sponsor company and other shippers to reduce the percentage of shipments going to the spot market. While this requires an upfront investment to incorporate process, technology and contract changes, the accrued benefits make it a prudent investment.

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