Dynamic Approach to Freight Transportation Pricing

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ABSTRACT

The tender acceptance rate significantly decreased between 2019 and 2021 for our capstone sponsor, Aqua Deal, a bottled beverage manufacturer. This poor primary carrier performance led to increased use of the spot market, higher transportation costs, and lower carrier service levels for Aqua Deal. In addition, during the COVID-19 pandemic, the truckload industry entered a tight market, where demand for trucking services outweighed the available market supply. This led to an increase in transportation costs and reduced tender acceptance rates for Aqua Deal. To address this issue, we explored the use of Index Linked Freight Contracts (ILFC). The purpose of ILFCs is to increase carrier acceptance by dynamically adjusting prices using an index. Using transactional data from 2019 to 2021, which covered both soft and tight markets, we built a logistic regression model to simulate potential carrier acceptance rate given price adjustment. The model predicted a 2% improvement in carrier acceptance but with a 4% increase in costs. We also explored other paths to increase carrier acceptance such as to avoid rushed shipments whenever possible.

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1. Introduction

1.1 Company Background

Our capstone sponsoring company, Aqua Deal[1], is one of the biggest bottled beverage manufacturers in the US, with over 36 plants. The company has been steadily growing at 16% annually and currently serves over 500 customers in the US with over 20,000 destination locations. Additionally, the company has become one of the largest shippers in the US, using 1.3M truckloads in 2021 alone. The company spent ~$1 billion in transportation annually, including all modes, between 2019 and 2021.

1.2 US Transportation Procurement

The for-hire US truckload procurement process has two main stages. The first stage is an annual reverse auction, where carriers are awarded the right to ship freight on allocated lanes during that year. In the second stage, an individual shipment is tendered to the main carrier in the TMS through a routing guide. However, truckload contracts are generally binding in price but not in volume tendered by the shipper or capacity provided by the carrier. This flexible term allows carriers to reject the load if the market or a spot price is higher than a contract price or if they do not have capacity at the time and location that carrier needs. Based on our analysis, Aqua Deal pays a premium of ~30% over the contracted rate if the load goes to the spot market.

[1] Aqua Deal is a pseudonym for our sponsoring company.

The US trucking industry is cyclical, depending on demand and supply of capacity. During a 'soft market', Aqua Deal achieves a higher acceptance rate by carriers, while during a 'tight market', the company faces more carrier rejections and higher shipping rates. The market became tight during the COVID-19 pandemic but was loose through 2019 and 2020 up until the pandemic. Therefore, the current tight market puts a lot of shippers, including Aqua Deal, under pressure to spend more time and money to secure capacity.

1.3 Motivation and Problem Statement

The main objective of this project is to reduce the use of the spot market by Aqua Deal, by exploring Index Linked Freight Contract for suitable lanes, carriers, and manufacturing plants or sources. Aqua Deal is interested in running a pilot with the goal of reducing the use of the spot market by dynamically adjusting price per load. This should result in an increased primary carrier acceptance rate and reduced total costs.

Currently, Aqua Deal awards its freight contracts on an annual basis as a fixed rate per lane (origin and destination pair). However, many carriers reject the fixed-priced loads due to freight market volatility if the spot market rate is higher or if they have no capacity. In 2020, the acceptance rate fell to ~88% from the previous year's rate of ~95%. As a result, the company was forced to pay a higher price in the spot market. This not only increased transportation costs but also reduced the service level to its customers for the rejected loads. Therefore, existing fixed-priced contracts proved to be somewhat ineffective during this 'tight market'. Our research focuses on dynamic pricing alternatives for Aqua Deal, so that in the long-term they can improve their tender acceptance rate using Index Linked Freight Contracts to avoid contract defection.

ILFCs reduce spot market use by making loads more attractive to a carrier by adjusting the contract price according to an index to dampen market volatility. As described in section 2.3, freight indices provide valuable insights into the freight market trends in terms of volume and price changes. Furthermore, these indices are updated regularly, allowing both shippers and carriers an opportunity to utilize the most recent price changes. Thus, with an index-based contract, shippers would pay the carriers more if the benchmark rate increased but would pay less if the benchmark rate dropped. To evaluate this pricing model, we built an index-linked contract using weekly DAT spot market rates, which is average trucking market rates, for selected lanes, carriers, and plants. Our model showed a 2% improvement in acceptance rate, with a 4% increase in shipping costs. To support our modeling, we also identified key lanes, carriers and plants where index-linked contracts can be the most successful.

The remainder of this report is organized as follows. Chapter 2 reviews the existing literature on freight procurement and the best industry practices. In Chapter 3, we discuss our research methodology and analyze the data to find candidate lanes, carriers, and plants for a research pilot. Chapter 4 presents a model to predict the primary carrier acceptance rate under an ILFC. In Chapter 5, we conclude by evaluating ILFC for Aqua Deal and suggesting areas for future research.

2. Literature Review

This capstone project examines the design and use of an Index Linked Freight Contract (ILFC) that would allow rates to adjust according to market conditions. This chapter covers three broad areas. First, it provides an overview of the US freight transportation industry. Second, it covers the relationship between the party that has transport requirements (Shipper) and the transport provider (Carrier) as well as the events that impact this relationship. Third, it briefly discusses freight indices and their current use in freight contracts.

2.1. Overview of US Trucking Industry

The US trucking industry generated $732.3 billion in revenue and employed over 3.36 million truck drivers in 2020 (Costello, 2021). The logistics industry consists of various transportation modes including trucking, parcel, rail, air, water, and pipeline. Trucking constitutes nearly 70% of the total logistics spend of the country and can be divided into Full truckload (FTL), Less than truckload (LTL) and private/dedicated fleet.

Aqua Deal primarily uses carriers FTL to move products between their manufacturing plants or sources and their retail customers. These movements are short haul with an average haul length of 200 miles. Aqua Deal built its manufacturing plants closer to its customers' DCs to respond to customer demand quickly and provide short delivery lead times.

The insights from this research will be relevant mainly for short-haul shipments as the cost structure and carrier behavior tend to be different for long-haul shipments. This is because short-haul loads tend to have higher fixed costs due to loading and unloading time, and drivers can come back to their point of departure on the same day, while long-haul drivers tend to stay overnight en route to or at the point of destination. Another important consideration is that this research focuses only on outbound shipments, from manufacturing plants[2] to

[2] Manufacturing plant is defined as 'Source' term in Aqua Deal's TMS system and in our data analysis.

customers, since inbound and inter-plant loads are handled by either suppliers or Aqua Deal's private fleet.

Aqua Deal works with two types of for-hire transportation providers: asset-based carriers, that own their own equipment, and non-asset (brokers) carriers, that act as a middleman between the carriers and shippers.

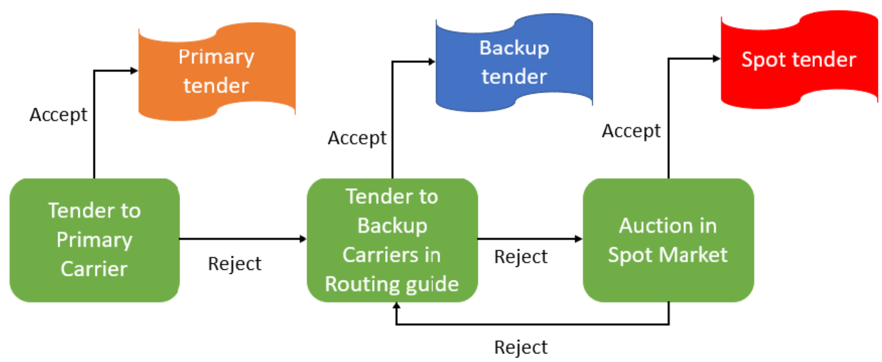
2.2. Shipper-Carrier Relationship and Contracting

In the US freight transportation industry, typically two parties are involved in a transaction. Shippers are manufacturers, distributors, wholesalers or retailers that have products to move. Carriers are transportation service providers that supply trucks and drivers to move these goods. Shippers in the US procure for-hire transportation services either through fixed long-term freight contracts or the spot market. Long-term contracts are typically awarded via annual reverse auction for all shipments on a lane, while the spot rates are for a single shipment (Acocella et al., 2020).

The cost per load (CPL) a shipper pays is impacted by their behavior. Like most shippers, Aqua Deal uses a TMS to tender loads to carriers. As seen in Figure 1, the shipper awards a load to a primary carrier, which is an automated process through its TMS. Because of the possibility of load rejection by primary carriers, a routing guide, a list of backup carriers, is used by the shipper for each lane. If a primary carrier rejects the load, the load is offered to a backup carrier from the routing guide. Typically, the price offered to a backup carrier is higher than the contracted price by 9-12% (Aemireddy and Yuan, 2019). Like the primary carrier, a backup carrier has a choice to either reject or accept the load. If a shipper cannot find a carrier within the routing guide, the shipper may choose to use the spot market. Hence, Aqua Deal is interested in minimizing the tender rejection rate as well as the use of the spot market since this leads to higher costs.

Figure 1.

Tender escalation process.



Source: (Aemireddy & Yuan, 2019)

Sinha and Thykandi (2019) highlighted some of the main factors contributing to the load rejection by carriers:

- Not enough tender lead time to secure a truck
- Volume surge on a specific lane
- New lanes
- Long loading and unloading times at origin and destination
- Service in an area of weather impact
- Inconsistent lane activity
- Lower rates at specific lanes

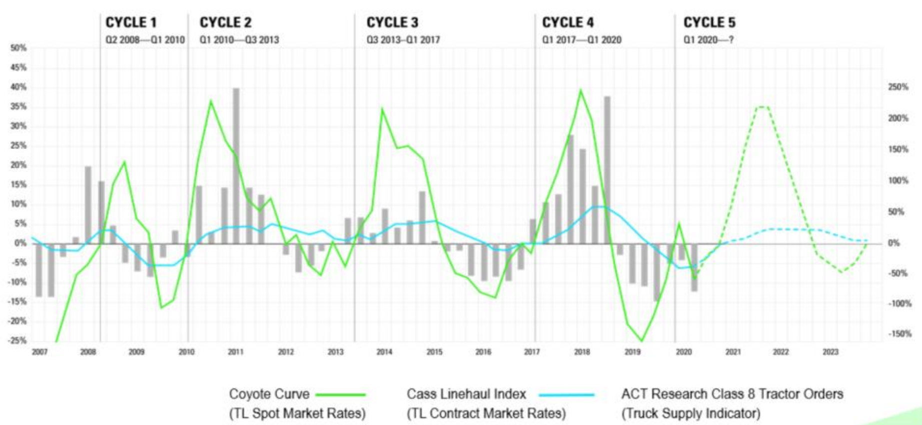
Our discussions with Aqua Deal showed that some of these factors can impact Aqua Deal's tender acceptance rate; hence, some of these characteristics were included in our analysis.

The truckload market moves in cycles, where prices change based on market demand and supply (Figure 3). The contract rates can be higher, lower, or the same as the spot market price.

When market demand for trucking is higher than the supply in the truckload industry and spot prices are higher than the contract prices, then the market is tight. Figure 2 illustrates how the truckload market moves in cycles, where cycles last around 10-12 quarters. Each cycle incorporates both soft and tight markets, where spot rates can fall below or rise above the contract price. The linehaul contract rates also follow similar market trends but with less volatility and lagging.

Figure 2.

Truckload market cycles.



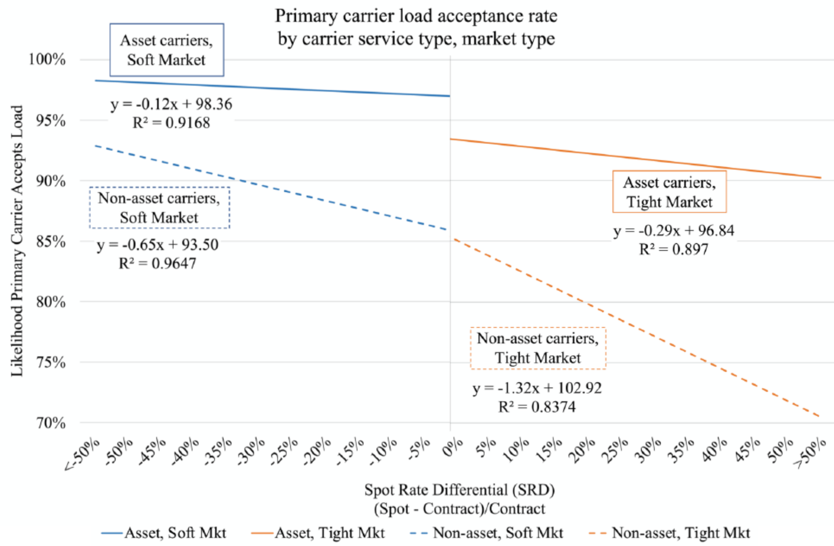
Source: coyote.com (2021)

According to research conducted by Aemireddy and Yuan (2019) for CH Robinson, a Fortune 500 provider of third-party logistics and multimodal transportation services, in the US truckload industry, 72% of the loads are accepted by the primary carrier, 21% are accepted by a backup carrier, and the remaining 7% are sourced through the spot market. This trend changes by market. During a tight market, the percentage of rejected loads by the primary carrier tends to increase, which also results in additional costs to shippers. Since the existing freight contracts are non-binding in volume, carriers have incentive to reject the load during a tight market opportunistically to increase their revenue. However, carriers can worsen their relationship with shippers if their tender acceptance performance falls significantly (Acocella et al., 2022a).

Acocella et al. (2022a) illustrates the behavior of both asset and non-asset-based carriers during tight and soft markets (Figure 3). The non-asset-based providers tend to have lower contract price reliability than the asset-based carriers in both tight and soft markets. In tight market conditions, both types of carriers are twice as likely to reject the load from their contract. Moreover, non-asset carriers are about five times more likely to reject the load than the asset carriers in both soft and tight markets. Figure 3 shows carrier contract stickiness model, using the probability of accepting a load and the value of SRD or Spot Rate Differential ((Spot-Contract)/Contract). The Figure shows the behavior of both asset carriers and broker's behavior in two different market conditions. The model assumes that soft market models apply when SRD is negative (spot price is below contract price) and tight market models apply when SRD is positive (spot price above contract price). The slope of each line represents the carrier's willingness to stick to the contracted loads. This graph also shows that non-asset carriers are more likely to respond to dynamic-priced contracts compared to asset-owned carriers because they have steeper curves with higher coefficients.

Figure 3.

Carrier Contract Price Stickiness Models.



Source: Acocella, (2022a)

As mentioned in section 2.1, truckload contracts are generally binding in price but not in volume, and often made for a period of 1-2 years. While the fuel-surcharge programs are common in the US truckload market, Index-based pricing models are not. Fuel surcharge (FSC) programs are used to share the risk of fuel price volatility between carrier and shipper. Fuel is a major component of a carrier's costs, and therefore, it can impact the carrier's economics. Smaller carriers are likely to face liquidity problems during any rapid fuel price spikes. Without an FSC, a significant number of smaller carriers would go bankrupt (Kanteti and Levine, 2011).

Sinha and Thykandi (2019) developed an index-based model, using an optimization using national average contract and spot line haul rates provided by DAT. The model assesses the impact of an index-based pricing model on tail lanes (lanes with few, intermittent, or sporadic demand) for 12 distribution centers in the US. They show that 8% of the auctioned shipments would have stayed within the contract instead of moving to the spot market using this model. The authors argue that using an index-based pricing model can lead to linehaul cost reductions but depends on a particular region's truckload market dynamics. In addition, the research project suggested that spot market loads tend to have on-time delivery performance issues, which result in penalties by shippers. Also, they suggest that asset-based carriers prefer to have index-based prices be updated as frequently as weekly to capture the market volatility, whereas brokers prefer to have less frequent updates.

2.3. Freight Indices and Index Linked Freight Contracts (ILFC)

A number of indices are used in the US truckload transportation industry, but there is no single recognized industry standard. According to Bignell (2013), indices serve several purposes such as providing visibility of price changes, financial derivatives, and as an input to contracted rates. The author analyses the freight indices currently being published in the US, while assessing their characteristics and suitability for both contract and spot markets. The paper suggests that while all indices lack some of the crucial characteristics, they can be better designed if disaggregated by geography and tender lead time. Bignell (2013) argues that indices should be based on the following 12 characteristics:

Index calculation and data collection:

1. *Accuracy:* Should be an accurate reflection of the real spot market
2. *Bias:* Should be rigorously computed and unbiased
3. *Familiarity:* Should be expressed in units familiar to the industry
4. *Balanced input:* Should be based on a sufficiently broad and balanced input
5. *Transparency:* Should be transparent and simple
6. *Disaggregation:* Should provide different levels of aggregated information in a clear and calculable hierarchy

Index structure:

7. *Frequent publication:* Should be published regularly and frequently (preferably daily via electronic distribution)
8. *Auditing:* Should be audited and monitored by an independent body
9. *Complaints:* Should have proper procedures for dealing with complaints
10. *Cost:* Should be low-cost
11. *Participation:* Should be supported by the major participants in the market
12. *Updating:* Should have procedures for updating and adjusting components or index structure as market conditions change

Bignell (2013) further analyzes several freight indices available in the market (DAT, Cass, Morgan Stanley etc.), and illustrates the key characteristics of each index according to the two parameters mentioned above. He concludes that DAT freight indices demonstrated the most important characteristics in the spot market compared to other indices because DAT offers both contract and spot rates at both national and regional levels. Specific products offered by DAT such as DAT Trendlines and DAT RateView™ provide holistic and comprehensive industry information by looking at specific lanes, different time scales, equipment types, which lets users determine what works best for their business.

Index Linked Freight Contracts (ILFC) are not common in the truckload industry but have been used in ocean container shipping. The goal of an ILFC contract is to share the risk between shippers and carriers in a volatile market when prices fluctuate. Existing fixed-price freight contracts need to become dynamic in nature to respond to market price changes for certain loads or lanes, which can benefit both carrier and shipper in terms of sharing risks. Baker (2019) suggested that carriers and shippers should pursue index-linked contracts to hedge against market volatility and avoid contract breaches. The author argues that the Baltic Index has become critical in the ocean freight industry, where both shipper and carrier can be guaranteed that their rate will be linked to the Baltic index and will move in the same direction to ensure that all parties get the right market price. This motivates both sides to stick to the contract. 657

In the truckload industry, Schneider Logistics (Schneider, 2019) suggested that inconsistent and low-volume lanes, or lanes with 100 loads or fewer per year, are hard to contract and thus suitable for index-linked contracts. In a pilot study, Schneider was able to achieve $70,000/month cost savings and 100% load acceptance rate by using index-linked contracts for a selected client.

2.4 Summary

In this chapter we reviewed: the truckload industry, shipper-carrier relationships given dynamic market conditions and existing freight indices, and the use of index-linked contracts in the ocean and truckload industry. We found that index-based contracts can be used to improve a carriers' stickiness to contracts as well as to share the risks between shippers and carriers. We also learned that DAT index data is most suitable for our research given its characteristics.

3. Methodology and Data Analysis

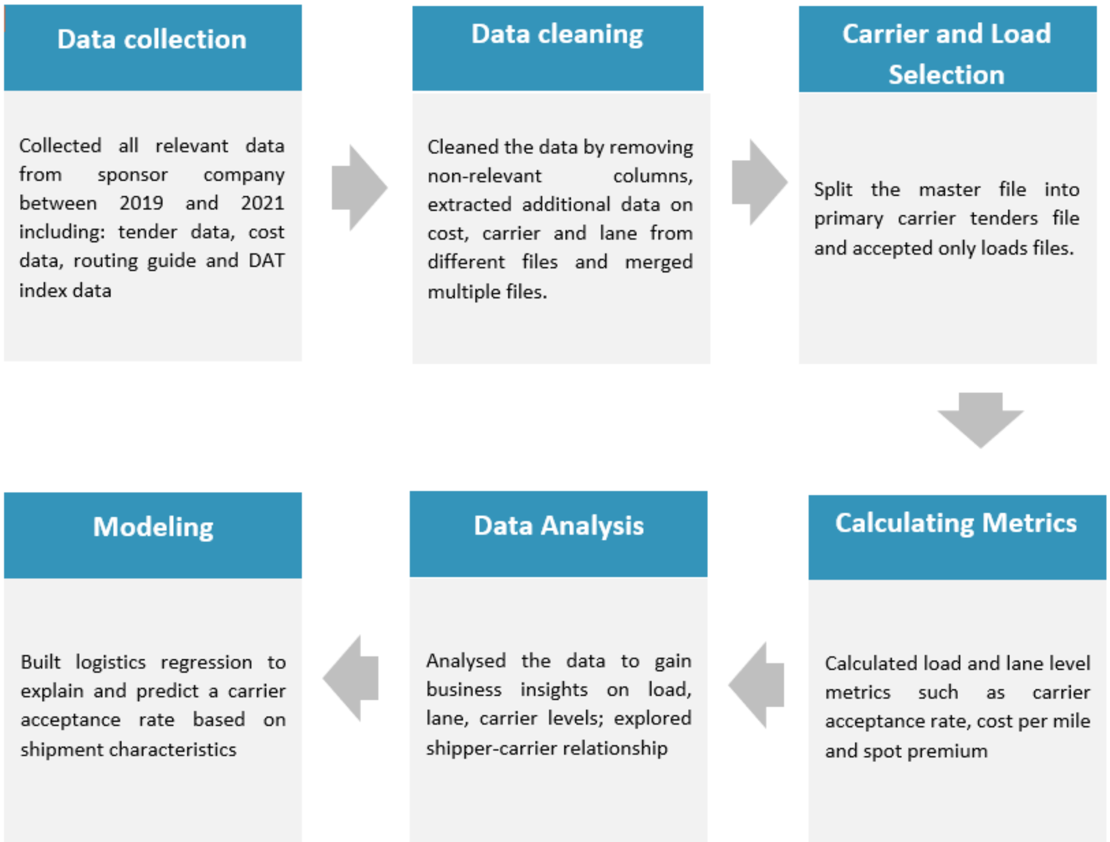
This chapter outlines the methodology used in our research. The focus of this methodology was to process and analyze the data and identify candidate lanes and carriers for a potential ILFC pilot. To do this we examined specific lanes, carriers, and manufacturing plants where an ILFC can be implemented to reduce the Aqua Deal’s use of the spot market.

We examined three years of Aqua Deal data, between 2019 and 2021, to understand the impact of the COVID-19 pandemic on the shipper's transportation costs before and during the event.

The project methodology is divided into 6 parts as shown in Figure 4: data collection, data cleaning, carrier and load selection, metrics calculation, data analysis and modeling. In the first part, we collected all the data and information provided by Aqua Deal. The second step included removing non-relevant columns and fields and extracting additional information from multiple data files. Third, we split the master file into a primary carrier load tender file and an accepted only shipments file. Next, we calculated all relevant metrics, including carrier acceptance rate, cost per mile and Spot Premium Ratio. Furthermore, we conducted data analysis to gain business insights at the lane, load, and carrier levels to see where ILFC might be suitable. Finally, in Section 5 we built a logistic regression model and conducted sensitivity analysis to predict carrier acceptance given an ILFC and to explain the importance of load characteristics to the model.

Figure 4.

Summary of methodology steps.



3.1 Data Collection & Cleaning

To evaluate the possibility of using Index Linked Freight Contracts for a pilot project, we identified potential lanes, sources, and carriers. The objective was to identify lanes, sources, and carriers with high load rejection rates, where an IFLC could reduce the carrier default rate and the use of the spot market. The initial datasets consisted of the following:

- *Load data.* This included files such as tender data (over 94 columns: origin, destination, tender bidding costs, dates, distance, zip codes, carrier names, spot/contract load etc.), carrier data (asset, broker), routing guide and tender file dictionary.

- *Cost data.* Linehaul cost information for each origin-destination pair.
- *DAT data.* DAT index data containing DAT contract and spot rates for each lane.

These files were retrieved from Aqua Deal's TMS system. They contained transaction details on more than ~24 million records, over 11 CSV files with 94 fields each. Given the data size (over 24GB), we used Pandas, the Python library for data manipulation and analysis. In addition, Microsoft Power BI and Excel aided our analysis.

Our data cleaning process started with removing the non-relevant columns and fields from the initial CSV files to reduce file sizes and keep only project-related data. Data dictionary and weekly calls with Aqua Deal helped us focus on relevant fields and remove redundant ones. We also removed missing data and duplicates. Additionally, we filtered out inbound and interplant shipments as well as customer pickups because Aqua Deal wanted to focus on loads that were handled by external carriers or brokers. Only full truck load shipments (FTL) were kept, as LTLs were out of scope. The initial tender files had 'deleted' shipments, which also were removed. To match the DAT data, we created a 'lane' field by concatenating the plant code and destination zip code. Furthermore, we added 'contract rate' and 'asset or broker' fields, the data which were extracted from different transportation cost and carrier profile files provided separately.

Moreover, we decided to split the master data file into two files: a file containing only accepted loads and a file containing loads only by primary carriers. This data split was instrumental in analyzing the carrier acceptance rate for primary carriers separately, as well as analyzing the loads that were accepted by both primary carrier and spot market carriers.

The next step of data manipulation was to calculate common transportation metrics such as primary carrier tender acceptance rate, Spot Premium Ratio, and cost per mile. In our analysis, we defined tender acceptance rate as 'TAC'[3]. TAC was calculated as the percentage of accepted loads over total number of loads tendered to the primary carrier. Spot Premium was calculated as the ratio of total linehaul spend to contract rate.

Table 1 illustrates final dataset fields after data engineering and manipulation. Appendix 1 provides the data dictionary for other useful fields we used for initial data exploration.

Table 1.

Final dataset columns for data analysis

Columns	**Details**
YEAR	*dataset included 3 years of data between 2019-2021*
WEEK	*Week number for a given year*
SHIPMENT_GID	*Unique Shipment ID*
TENDER_CARRIER	*Carrier that received the Tender*
SHIPMENT_CARRIER	*Carrier that ultimately delivered the Shipment*
ACCEPTANCE_CODE	*Tender acceptance status:* *A for Accepted* *Null for Rejected Tenders*
CARRIER_CAPACITY_STATUS	*The status of a carrier during tender process:* *Spot-Tender, when spot tender was offered to a carrier* *Under-Capacity, when carrier volume is below the offered RFP volume* *Over-Capacity, when carrier volume exceed the offered RFP volume*
TENDER_TYPE	*The status of a shipment after tender was accepted:* *Spot* *Not-Spot*

[3] 'TAC' is an internal term used at Aqua Deal to measure the tender acceptance rate for each carrier.

SHIPMENT_SPOT	*The status of the inital tender:* *Spot* *Not-Spot*
SHIPMENT_RUSH	*Rushed if Lead Time for Pickup is less than 48 hours from Tender Time*
SHIPMENT_DROP	*Drop if the Carrier can drop off the trailer at Destination and leave without waiting for unloading*
SHIPMENT_PRELOAD	*Preload if the Carrier can pickup a preloaded trailer at Source and not wait for loading*
MILES	*Distance*
BID_AMOUNT	*Bid amount submitted by Tender Carrier for Spot Tenders*
SOURCE_LOCATION_GID	*Plant/Warehouse Code*
ROLLUP_ORGANIZATION_CODE	*Code of the Plant and its associated Warehouses*
TOTAL_LINEHAUL	*Cost of total linehaul spend, excluding fuel and other Accessorials*
LANE	*origin-destination pair unique number based on plant code and destination zip code*
ASSET_BROKER	*Status of the carrier: asset owner or broker*
BUSINESS_YEAR	*Business year for Aqua Deal, from February-to-February contract cycle*
CONTRACT_RATE	*Contract rate for a given load in $/load*
PREMIUM	*Difference between total linehaul cost and contract rate*
TAC	*Tender acceptance rate by a primary carrier*

3.2 Data Exploration & Network Analysis

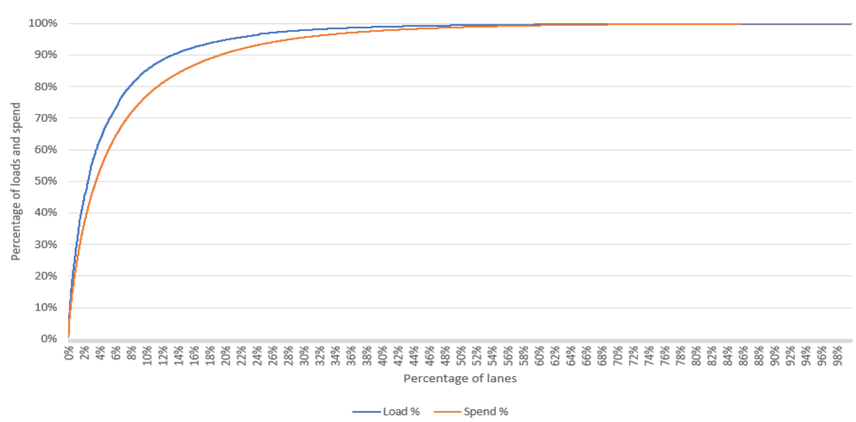
In this section we explore the processed data to gain some initial business insights from the shipper's network at the load and lane levels to understand the performance and their characteristics. The objective is to identify potential lanes and carriers for ILFC contracts.

3.2.1 Lane vs. Load distribution

Once the data was cleaned and processed, we explored it further to identify the main characteristics of the shipper's network at load and lane levels. As described earlier, lanes run from one of the manufacturing plants to a customer location, defined as 3-letter plant code and 3-digit zip code (or postal). The manufacturing plant is also referred to as a 'source'. Figure 5 shows that 80% of the loads are shipped through just 9% of the lanes in Aqua Deal's network. Additionally, only around 14% of the lanes contribute to 80% of the total linehaul costs. This indicates that Aqua Deal has a small number of high volume and high spend lanes.

Figure 5.

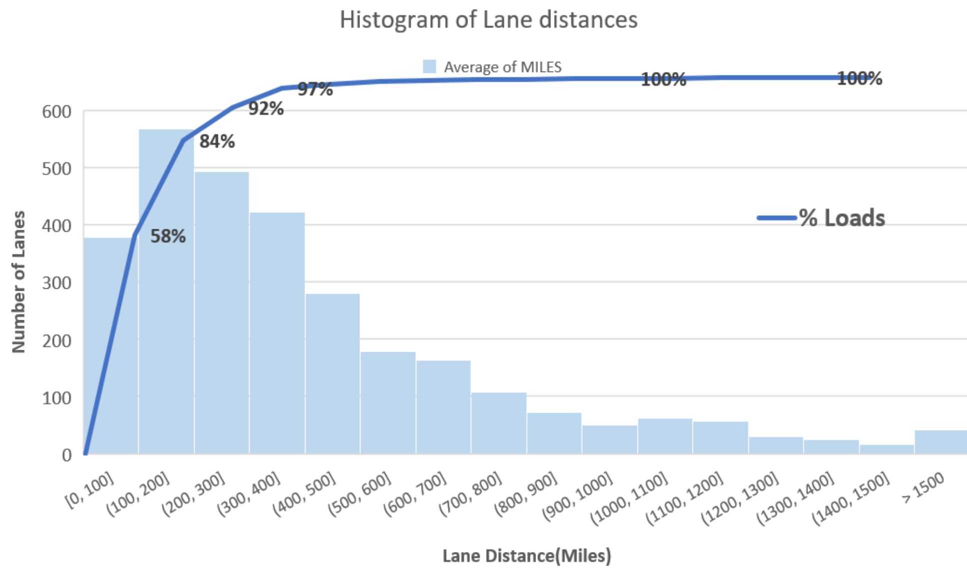
The percentage of loads and linehaul cost comparison to percentage of lanes.



As mentioned in section 2.1, Aqua Deal's manufacturing pants are close to its customers. Figure 6 illustrates that 84% of shipper loads are delivered within 200 miles, and 97% shipments are within 400 miles. The graph also shows that the highly dense lanes are within 100-300 miles.

Figure 6.

The percentage of loads and the number of lanes compared to a length of haul.



3.2.2 Average Cost Per Mile and Shipping Volume

In this step, we explored both cost per mile and the number of loads during the entire period. As shown in Figure 7, the cost per mile had a strong upward trend over time, meaning that the cost per mile continued to increase before becoming stable during 2019 and dropping significantly during the March - April period in 2020. The initial data point in early 2019 shows a rate of $3.26 per mile, while the final data point is at $5.49, which indicates an almost 68% cost increase just in two years since trucking entered a tight market. The cost per mile continued to increase even though the number of loads dropped significantly by the end of 2021. This increase means that there is no correlation between the cost per mile and number of loads that the carrier is shipping; thus, the cost is driven by market demand and supply dynamics. Furthermore, we also learned that cost per mile for the shipments kept increasing over time in the same period. Since Aqua Deal's product is seasonal, demand is cyclical over the course of the year. During the peak season of 2019, the company shipped over 17,000 loads in a day, whereas during the peak season of 2021 company shipped over 22,000 loads in a single day, almost a 29% demand increase.

Figure 7.

Total number for loads and cost per mile over time for 2019-2021 period.

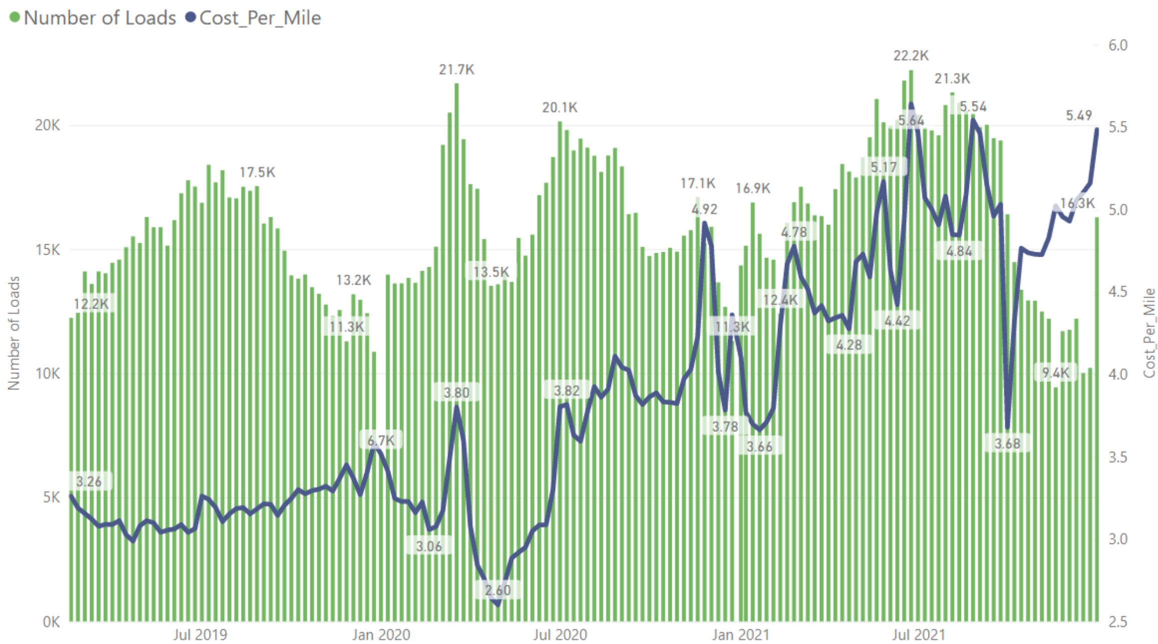
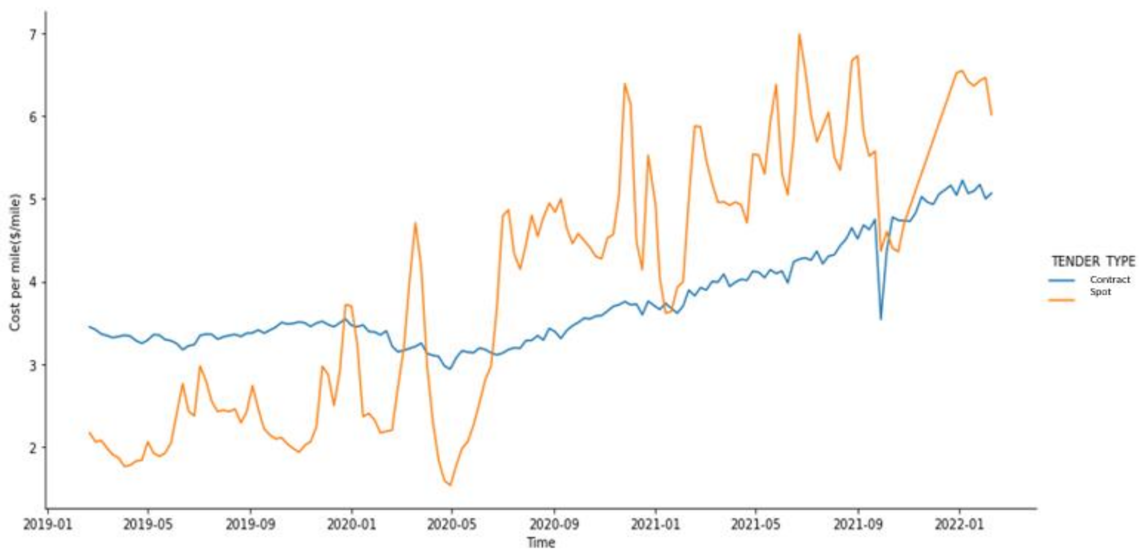


Figure 8 shows the cost per mile over time separately for spot and contracted loads. The graph illustrates how the price of spot load can dynamically change depending on the market conditions: whether a tight or soft market. This plot also demonstrates the truckload industry and our shipper's experienced truckload market cycles, as shown in Figure 3. Both costs per mile for spot and contract loads have increased since 2019. Aqua Deal had higher contract rates than spot market rate for its loads during the soft market and had lower rates than spot market rates during the tight market, which led to increased rejection rates.

Figure 8.

The cost per load over time for both spot and contracted loads for Aqua Deal.



3.2.3 Carrier Acceptance Rate, Spot Premium and DAT Data

In this step the carrier acceptance rate (or TAC), Spot Premium, and DAT index data were evaluated to characterize the relationships between them and how these metrics changed over time for Aqua Deal (see Figure 9). TAC was high, above 95% during all of 2019 and early 2020, but started dropping at the start of the pandemic with the lowest TAC being below 80% during the summer of 2021. We consider the period after March 2020 as a 'tight market' although the actual consistent decline in TAC was observed from July 2020 onwards by Aqua Deal. The TAC rate has a cyclical pattern - similar to truckload market cycles, where TAC comes down in the tight market and goes up in the soft market. Consequently, when TAC rate goes down, the cost per mile increases due to higher spot rates (Figures 7 and 8). Figure 10 breaks down the TAC for each year separately.

Figure 9.

Primary carrier acceptance rate (TAC) between 2019-2021.

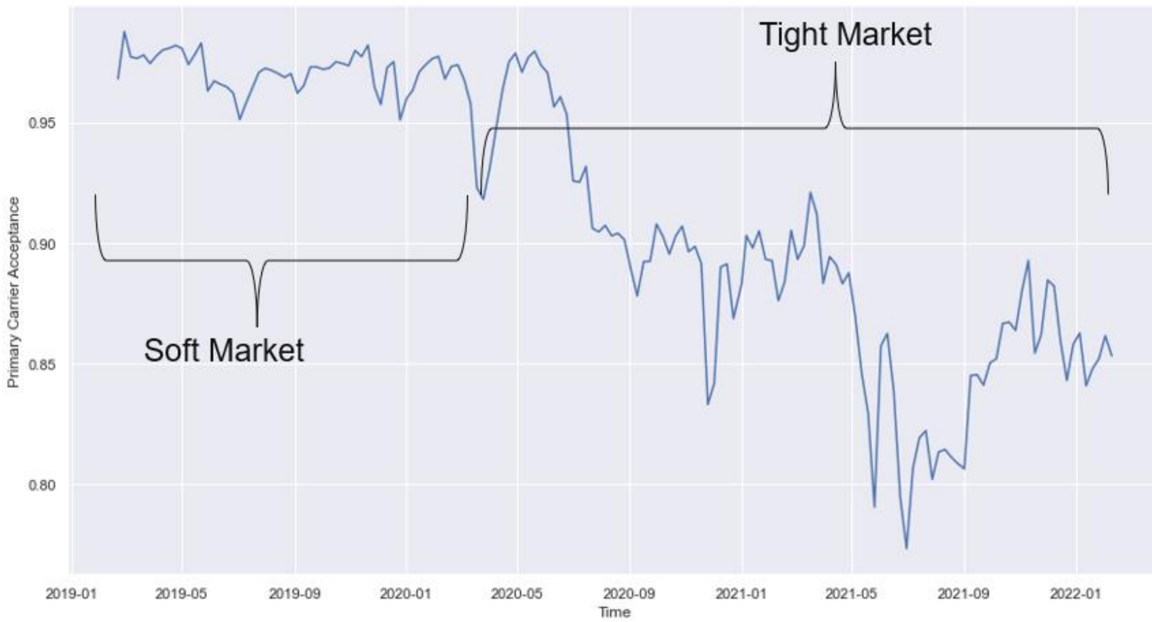
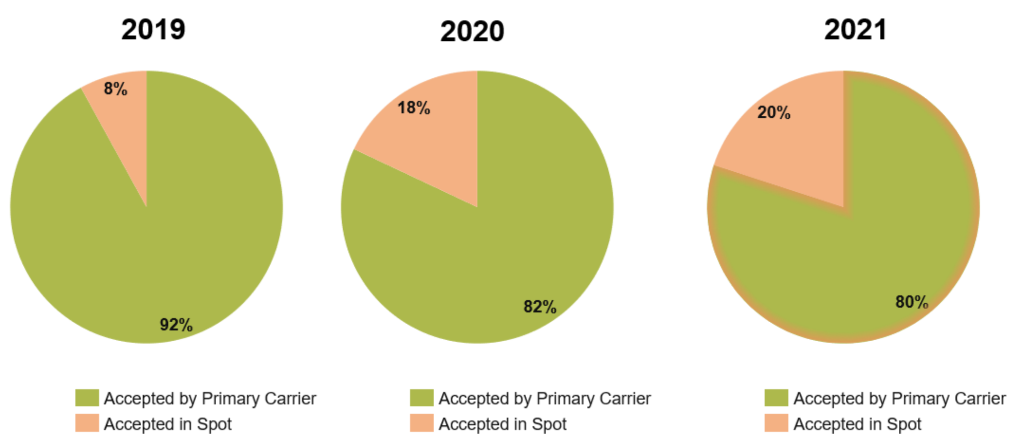


Figure 10*.*

Primary carrier acceptance rate (TAC) breakdown for each year between 2019-2021.



The Spot Premium is how much more Aqua Deal paid to a carrier above the contract price; the Spot Premium Ratio is the difference between the total linehaul costs minus the contract price divided by the contract price for that lane. The Spot Premium and Spot Premium Ratio are defined as follows:

$$Spot\ Premium_i = Linehaul\ Cost\ for\ a\ Spot\ Load\ on\ lane\ i\ - Contract\ Rate\ for\ lane\ i$$

$$Spot\ Premium\ Ratio_i = \frac{Linehaul\ Cost\ for\ a\ Spot\ Load\ on\ lane\ i - Contract\ Rate\ for\ lane\ i}{Contract\ Rate\ for\ lane\ i}$$

To evaluate the shipper's Spot Premium costs with overall truckload market spot market trends in the US, we used DAT data. We obtained DAT's national spot and contract rate data, with weekly average rates, for similar periods and lanes. Then we calculated the DAT Premium Ratio for each load and lane, where the shipper has its operations. The DAT Premium Ratio is defined as follows:

$$DAT\ Premium\ Ratio_i = \frac{Weekly\ Average\ DAT\ Spot\ Rate\ for\ lane\ i\ - Contract\ Rate\ for\ lane\ i}{Contract\ Rate\ for\ lane\ i}$$

DAT Premium Ratio is a term that we use to denote a market premium on the shipper's contract price. Also, the ratio shows how much more or less a carrier contract rate is compared to the DAT's spot rate in percentage value at a weekly level. Figure 11 shows that the DAT Premium Ratio and Spot Premium Ratio are strongly correlated (71%) and have similar trend and volatility, indicating that Aqua Deal has paid premiums similar to market, and also that the DAT index can be used for ILFC pilot as an input to predict future prices.

Figure 11.

Spot Premium Ratio and DAT Premium Ratio between 2019-2021

The Figure shows that during the soft market (before the pandemic) Spot Premium Ratio followed a similar trend as DAT Premium Ratio but had higher volatility in the tight market. Both ratios exhibit a strong upward trend since May 2021, which shows a strong demand for trucking. Additionally, the Spot Premium Ratio trend line is above the DAT ratio during the tight market, indicating that Aqua Deal may have been paying its carriers more than the national average to maintain a higher acceptance rate or due to a shorter haul length.

3.2.4 Carrier Profile: Asset Owned Carriers vs Brokers

In this section we extend our analysis to carrier performance and profile – to determine how asset and non-asset-based carriers behave. This analysis provides further insights to help Aqua Deal narrow down the pilot focus by choosing one of the carrier types and focusing on those carriers to reward them with index-linked contracts to improve their tender acceptance rate.

We analyzed how a carrier profile can impact the total transportation costs and load acceptance rate. Our analysis showed that (Table 2) brokers tend to have higher acceptance rates than asset-based carriers for Aqua Deal. However, as shown in Table 3, brokers also tend to have a lower Spot Premium Ratio and DAT Premium Ratio compared to asset-based carriers, indicating higher contract prices and hence lower the difference with Spot or DAT rates. Additionally, as mentioned in section 2.2, non-asset carriers are more sensitive to changes in the spot market than asset carriers in both soft and tight markets. Hence, brokers will be more suitable for Aqua Deal's ILFC pilot to further reduce the use of the spot market and improve carrier acceptance rate.

Table 2 summarizes the transportation cost data for Aqua Deal for all the loads. The Table shows that the percentage of spot loads increased significantly for asset carriers between 2019 and 2021, from 3% in 2019 to 9% in 2020 and 8% in 2021. For the similar period, the percentage of spot loads for brokers also increased significantly, from 13% in 2019 to 28% in 2020 and 32% in 2021. Non-asset brokers handle more spot loads than asset carriers. As a result, the percentage increase of spot loads resulted in an overall increase in total linehaul costs for Aqua Deal. The total linehaul remained similar for asset owners over the 3 years, but brokers experienced a significant cost increase or almost doubled. For example, total linehaul cost spent on brokers was $236 million in 2019, but the amount increased to $458 million in just two years. Moreover, Table 2 illustrates that the average rate per mile continued to increase from 2019 and in 2021 as the truckload industry entered a tight market. The Table also shows that the TAC rate was consistently higher for brokers than for asset-based carriers in all three years despite having a higher percentage of spot loads. This indicates that most of shippers' spot loads are moved by brokers. Finally, the TAC rate continued to decline for both brokers and asset-based carriers from 2019 to 2021.

Table 2.

Total shipping and cost details breakdown for asset and non-asset carriers

ASSET BROKER	BUSINESS YEAR	TOTAL LOADS	SPOT LOADS	LINEHAUL SPEND (in million) USD	Cost per mile	% of spot loads	Avg. TAC
ASSET	2019	295,607	8,005	$108	3.80	3%	94%
BROKER	2019	468,755	61,429	$237	2.97	13%	99%
ASSET	2020	272,862	23,363	$94	4.04	9%	88%
BROKER	2020	574,503	162,008	$308	3.51	28%	94%
ASSET	2021	264,693	22,439	$110	5.05	8%	82%
BROKER	2021	619,939	196,822	$459	4.91	32%	87%

Table 3 shows the total spend, shipper's spot premium comparison with DAT premium for only primary carrier loads where DAT data was available. This is a subset of Aqua Deal's total volume. It shows that Aqua Deal incurred significantly higher total linehaul spend in 2020 and 2021 compared to the initial contracted budget. This can be explained by the higher percentage of spot loads in 2020 and 2021 compared to 2019, which were handled mostly by brokers. Additionally, Table 3 illustrates that the Spot Premium Ratio also increased dramatically between 2019 and 2021, from 29% to 77% for the asset carriers and 12% to 48% increase for brokers. In the meantime, DAT Premium Ratio demonstrated a slower increase, from 24% to 57% for asset carriers and from -3% (lower than contract rate) to 21% for brokers, between 2019 and 2021. This shows that Aqua Deal paid its carriers higher premiums compared to other shippers in the spot market for similar lanes.

Table 3[4].

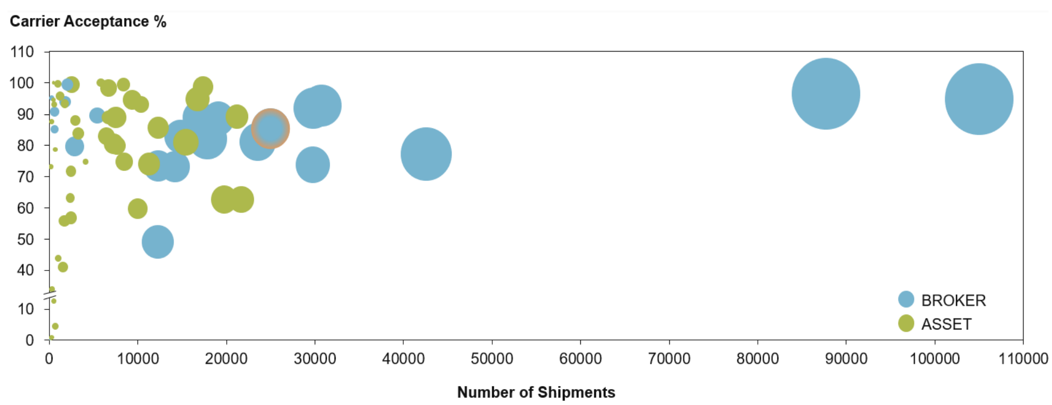
Total Spend, Spot Premium comparison with DAT data

Business Year	ASSET BROKER	Contract Spend ($ million)	Linehaul Spend ($ million)	DAT Spot Spend($ million)	DAT PREMIUM RATIO Spot(%)	SPOT PREMIUM RATIO (%)
2019	ASSET	$70.9	$72.2	$76.8	24%	29%
2019	BROKER	$138.3	$138.4	$128.8	-3%	12%
2020	ASSET	$62.0	$67.6	$84.6	39%	56%
2020	BROKER	$139.1	$144.5	$167.3	25%	59%
2021	ASSET	$60.4	$69.6	$92.3	57%	77%
2021	BROKER	$188.8	$197.8	$215.7	21%	48%

Figure 12 illustrates the relationship between carrier volume and TAC. Since the bubble size indicates the total number of loads handled, the highest volume contracts in the network were awarded to a few selected brokers that are likely not ideal candidates for the pilot due to high performance (TAC ~93%) despite securing the largest contracts. However, we identified the number of brokers with high volume and low TAC performance as potential pilot candidates and provided this list to Aqua Deal.

Figure 12.

Carrier performance: TAC and total number of shipments.



[4] Table includes the data for only primary carrier loads where DAT data was available

3.2.5 Lane Characteristics: Volatility, Cadence and Volume

We identified potential carriers for a pilot, analyzed network characteristics such as load and lane characteristics, cost per mile, and Spot Premium Ratio in comparison with industry standards. Then we explored whether lane-specific characteristics such as volatility, volume and cadence impact the percentage of spot loads and cost per mile. After discussions with Aqua Deal, we decided to focus on 2021 data only, since this year's data showed the higher rejection rate and increased transportation costs. Specifically, we assessed each lane based on a number of performance characteristics including volume, volatility, and cadence, using descriptive characteristics such as the number of total loads and spot loads in a lane, the average length of haul, linehaul costs, and the cost per mile.

Table 4 illustrates our categorization of lanes based on volume, volatility and cadence characteristics into 'low', 'medium' and 'high' levels. A lane volume was calculated for each lane for each week based on the volume available at each lane. Specifically, we compared the number of loads available at all lanes at each week. The high-volume lanes are defined as the 95% percentile of volume distribution among lanes, medium-volume is defined as lanes between the 70% and 95% percentiles, and finally low-volume falls below the 70% percentile.

Table 4. *Lane characteristics analysis*

Volume	Volatility	Cadence	Avg Miles	Number of lanes	% of spot	Per mile rate	% of total spend	% of total shipment	Avg TAC
high	high	high	184	6	44%	$3.8	1%	1%	91%
high	low	high	99	5	25%	$5.4	1%	1%	96%
high	medium	medium	200	16	24%	$3.3	3%	3%	88%
high	medium	high	98	253	22%	$4.7	49%	66%	91%
low	high	medium	399	4	100%	$4.3	0%	0%	50%
low	high	low	542	117	90%	$3.5	0%	0%	23%
low	low	medium	280	19	87%	$5.4	0%	0%	66%
low	low	low	692	2119	75%	$2.9	1%	0%	18%
low	medium	low	610	1454	74%	$3.0	3%	1%	37%
low	medium	medium	477	194	72%	$3.6	1%	0%	59%
medium	high	low	331	59	76%	$3.8	1%	0%	61%
medium	high	medium	296	112	60%	$3.8	3%	2%	88%
medium	low	high	154	1	54%	$6.3	0%	0%	90%
medium	medium	low	472	159	54%	$2.8	1%	1%	79%
medium	high	high	200	6	52%	$4.4	0%	0%	87%
medium	low	medium	210	2	48%	$5.1	0%	0%	73%
medium	medium	medium	320	753	48%	$3.4	18%	11%	88%
medium	medium	high	167	314	36%	$4.6	16%	13%	89%

This analysis showed that the lanes with high volume tend to have lower use of the spot market than medium and low volume lanes. At the other end of spectrum, the percentage of spot loads in low volume lanes ranged between 72% and 100% in 2021 in Aqua Deal's network.

The volatility column was computed as the coefficient of variation (CV) of the weekly load which provided dispersion of loads around the mean. Value below 0.2 is considered low and above 1 was considered high. Lanes with CV between 0.2 and 1 were considered medium in volatility metric. This metric allowed us to understand the dynamics of weekly volume change in all lanes, and further understand the relationship between rejection rates and lane volatility. Our analysis demonstrated that lanes with high volatility tend to have higher rejection rates, indicating a strong correlation between volatility level and rejection rate ranging between 44% and 100%.

Cadence is the percentage of weeks that had at least 1 load over the previous 4 weeks. It can have five values that are: 0%, 25%, 50%, 75% or 100%. 0% with represent no load in previous four weeks for the lanes and 100% represents at least 1 load in all of the previous four weeks. Thus, cadence metric measures the consistency of loads on a lane on a weekly basis. We then classified the lanes based on cadence performance – low, medium and high as mentioned above. Lanes with average cadence of more than 90% were considered high and less than 50% were considered low. Rest lanes with cadence between 50%-90% were considered medium. We observed a moderately strong correlation between the cadence level and rejection rate. For example, lanes with high cadence performance have lower rejection rates. In our analysis, we observed that low cadence lanes had rejection rates between 54% and 90%.

Average Length of Haul is also positively correlated with the percentage of spot loads (70%). Since the majority of loads in a shipper's network are within the short haul distance, longer haul lanes tend to have a higher percentage of spot loads.

One of the key takeaways from our analysis is that the highest percentage of spot shipments occurs in lanes with low and medium volumes, with high and medium volatility, and with low and medium cadence characteristics. However, these lanes have very low percentage of transportation spend and hence we looked at lanes with the highest total spend, with low percentage spot, but where the potential biggest cost savings can be gained. Alternatively, Aqua Deal can investigate lanes with low/medium volume, high/medium volatility and low/medium cadence, the lanes that typically show the highest percentage of spot shipments.

3.2.6 Load Characteristics

This section covers three load characteristics of Aqua Deal's shipments: Shipment Preload, Shipment Drop, and Rushed Shipment. Preload shipments or 'drop and hook' are defined at the origin, where the driver drops an empty trailer and picks up a pre-loaded full one. This ensures faster turnaround for carriers and reduces waiting time. In Drop shipments, defined at the destination, the driver delivers a full container and departs without having to unload. Rushed shipments are defined as any load requirement to the carrier for the truck to be placed within 48 hours of the request compared to the regular 72 hours. Rushed shipments provide lower lead time to carriers, and this section examines its impact on primary carrier acceptance decisions.

Table 5 shows the trends in these characteristics for the three-year period 2019-2021. It is evident that the percentage of Drop shipments and Preloaded shipments declined over the three years, while the percentage of rushed shipments increased from ~14% in 2019 to ~24% in 2021.

Table 5.

Load Characteristics distribution (2019-2021)

YEAR	Total Loads	% Rushed	% Origin Preload	% Destination Drop
2019	764,462	14%	34%	18%
2020	848,699	21%	28%	13%
2021	924,850	24%	25%	10%

We also looked if there are correlations between Preload, Drop and Rushed to see if the Preload and Drop shipments have low Rushed but no correlation was found among them.

In terms of Acceptance Rate (TAC), both Drop shipments and Preloaded shipments have higher average TAC compared to live load or unload shipments as shown in Figure 13. A long tail of TAC for the Drop category of Shipment Drop was also observed, highlighting high variability of TAC for this category.

Figure 13.

Load Characteristics TAC comparison

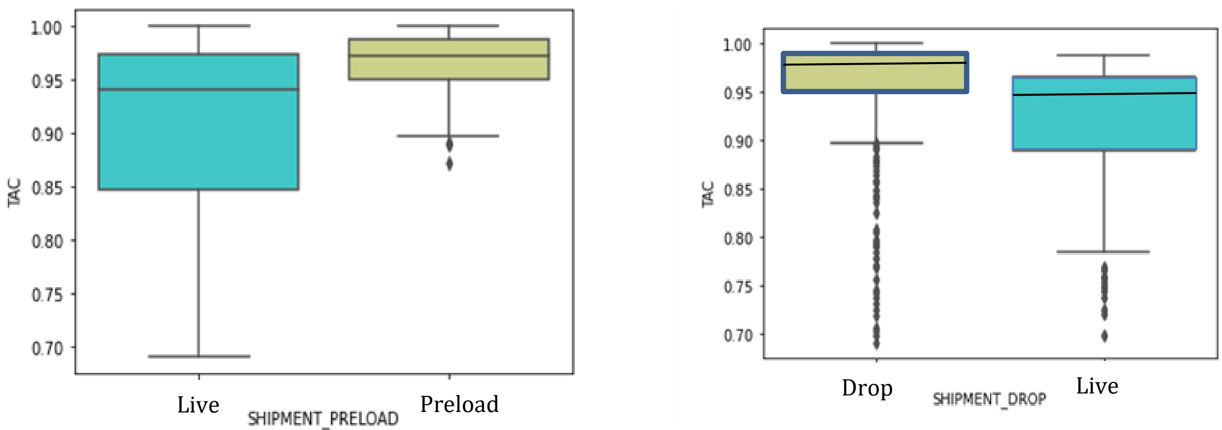


Table 6 summarizes the rushed shipment analysis. Almost two-thirds of all spot shipments were rushed, while only 8% of the contract shipments were rushed, highlighting a greater likelihood of rushed shipments going on spot. As the spot loads compared to total loads increased three times from 2019 to 2021, the total number of rushed shipments also doubled. In terms of load cost, data suggested that rushed shipments are costlier than non-rushed shipments. The cost per mile for rushed spot shipment was at least 30% higher in 2021 than non-rushed contract and at least 15% higher than non-rushed spot shipments, highlighting an opportunity for Aqua Deal to focus on to reduce their transportation spend. Based on the number of loads and spend in 2021, Aqua Deal would have saved ~$61M if rushed shipments were avoided. While many rushed shipments are unavoidable due to customer requests, the potential savings are so large as to warrant the exploration of root causes and identifying ways to avoid rush shipments.

Table 6.

Rushed shipment analysis

BUSINESS YEAR	TENDER_TYPE	% total loads	% total linehaul spend	Rushed %	Not Rushed cost per mile	Rushed cost per mile
2019	Contract	91%	87%	8%	3.37	3.31
2019	Spot Bid	9%	13%	66%	2.08	2.53
2020	Contract	78%	60%	8%	3.37	3.21
2020	Spot Bid	22%	40%	68%	3.80	4.39
2021	Contract	72%	55%	7%	4.48	4.24
2021	Spot Bid	28%	45%	67%	5.13	6.07

3.3 Summary

Our methodology section covered several important research areas: data cleaning and processing, data analysis to explore load and lane characteristics, and the effect of cost per mile over time during both soft and tight markets. We explored carrier acceptance rate and Spot Premium in comparison with DAT data. The section also discussed characteristics of asset-owned carriers and brokers regarding acceptance rate, Spot Premium, and overall transportation spends. We analyzed lane-specific parameters such as volume, volatility and cadence and provided initial recommendations as to where ILFC contracts would be suitable to implement to gain higher cost savings and improve acceptance rate. Finally, our analysis showed that rushed shipments account for at least 65% of the spot loads; thus, rushed loads should be avoided, when possible, to reduce the use of the spot market and potentially save costs.

4. Data Modeling and Results

Once the carrier, lane and load characteristics were analyzed and their impact on the primary carrier acceptance was assessed, modeling was done to identify how they interact and influence the carrier's load acceptance decision and to check the significance and sensitivity of these characteristics.

Regression analysis is used to explain the variability of a dependent variable compared to one or more independent variables. There are two other broad applications of a regression analysis. The first is using the model to identify the relationship between a dependent variable (Y) and independent variables (X's). The second application is using the model to predict the outcome variable (Y) given a set of independent or explanatory variables (X's).

To understand the impact of different load characteristics and to identify the lanes and carriers that exhibit a linear relationship, an explanatory model was built using a regression analysis.

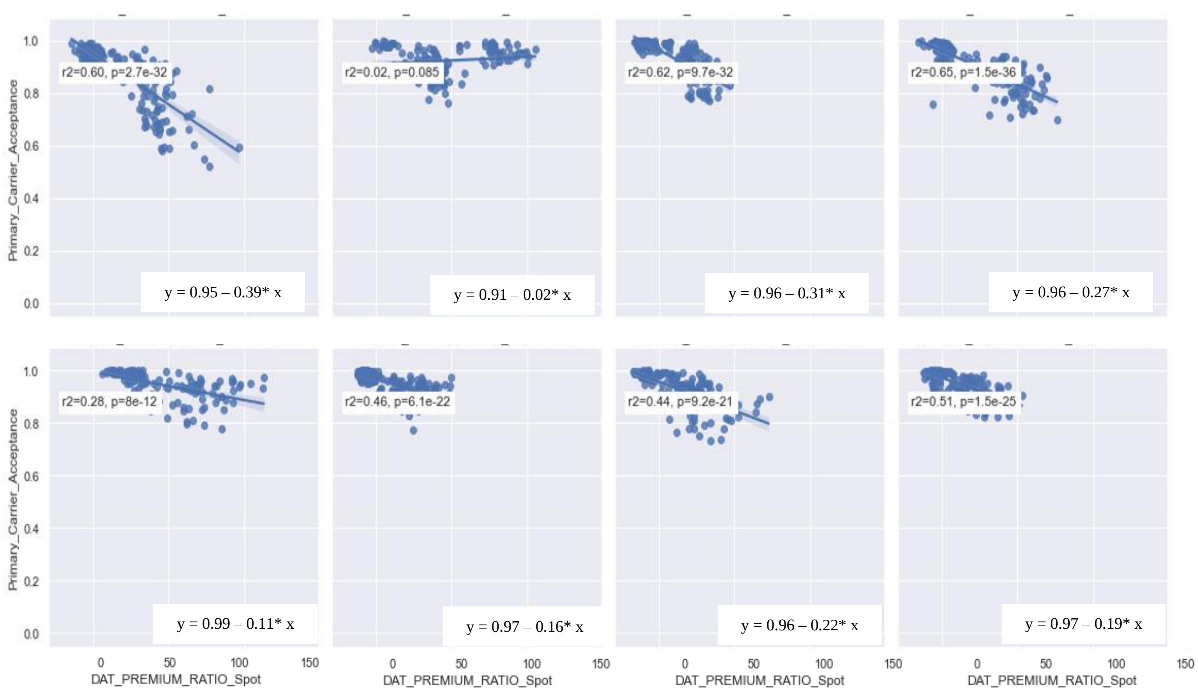
4.1 Modeling for Primary Carrier Acceptance with DAT Premium Ratio

Our analysis is restricted to the 70% of the lanes of Aqua Deal where DAT data was available. In this analysis, the objective is to identify the sources (manufacturing locations) that exhibit a linear relationship between the DAT rates and the primary carrier acceptance ratio to index the contract rate with that of DAT. By doing so, we will identify potential sources to include in an Index Linked Freight Contract (ILFC) pilot.

Figure 14 represents the relationship between the Primary Carrier Acceptance rate and the DAT Premium Ratio for the top 16 sources covering ~ 65% of total primary carrier loads. Each data point represents the weekly average primary carrier acceptance ratio and the corresponding previous week's DAT Premium Ratio. We used the previous week's data because Aqua Deal will have visibility of only the previous week's data to index current week rate. We observed that five sources[5] exhibit a statistically significant correlation between the two with an R-squared value of at least 50%. Also, we observed that for these shortlisted sources, a higher DAT Premium Ratio is correlated to lower primary carrier acceptance.

Figure 14.

Relationship between Primary carrier Acceptance Rate and DAT Premium Ratio



[5] Actual source names are not provided to maintain confidentiality.

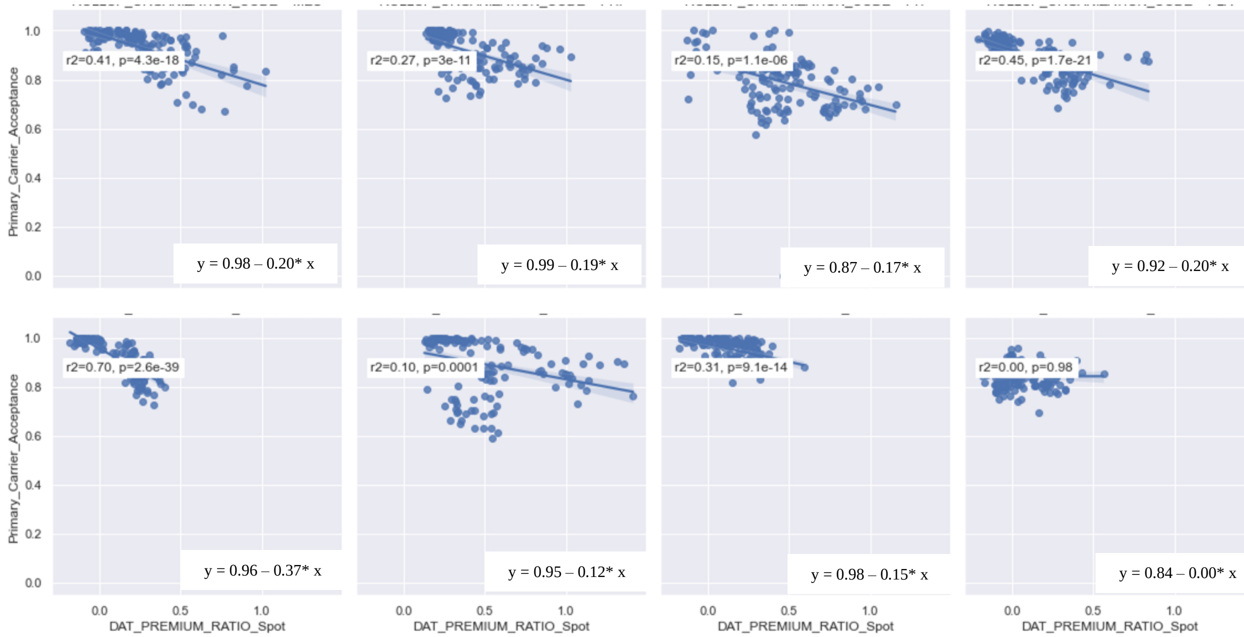
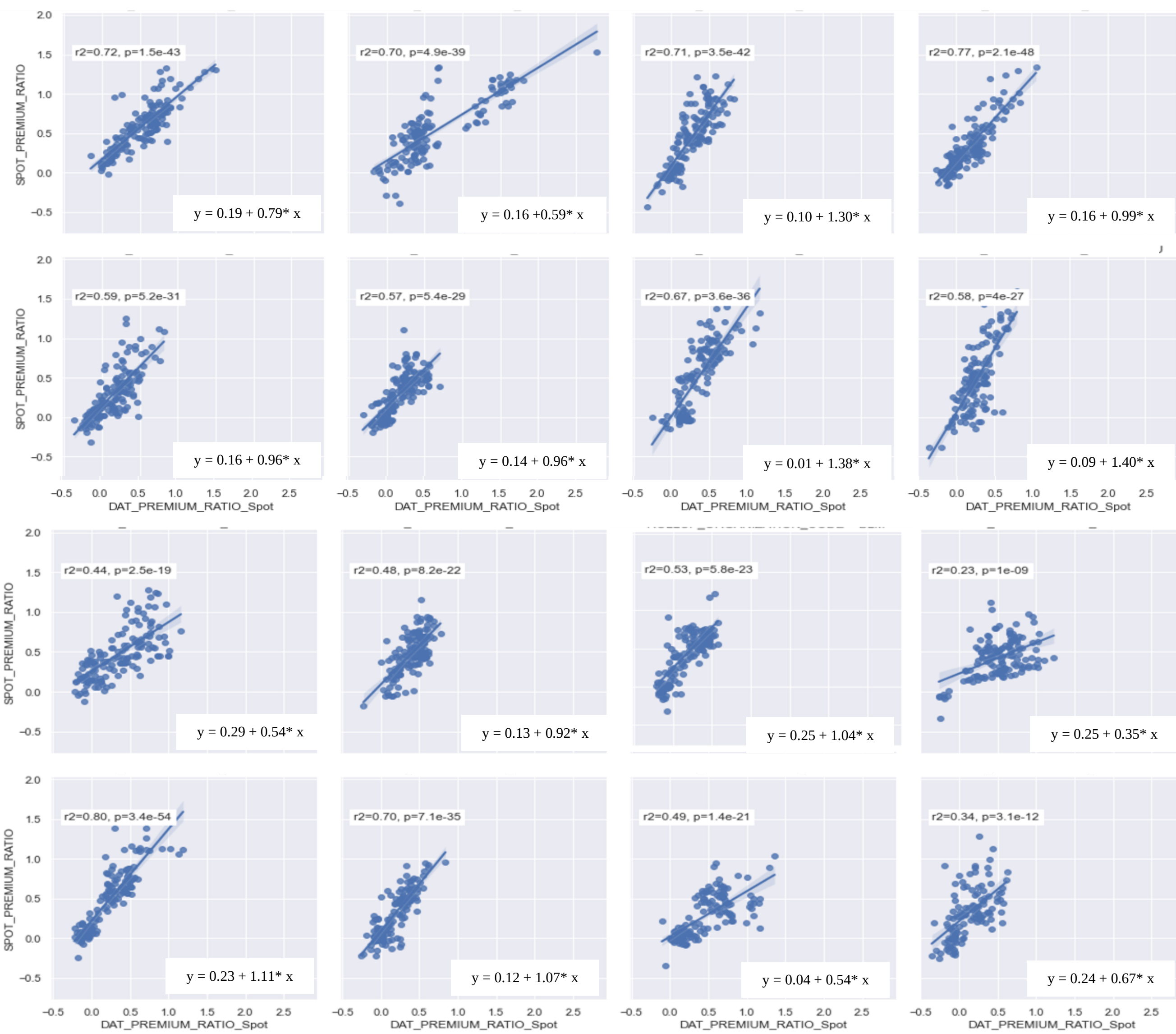


Figure 15 represents the relationship between weekly DAT Premium Ratio and weekly Spot Premium Ratio for the top 16 source plants representing ~60% of total loads for the rejected loads by primary carrier. Each data point represents the weekly Spot Premium Ratio and the corresponding week's DAT Premium Ratio

We observed that all five shortlisted sources exhibit a statistically significant correlation between the two with an R-squared value of at least 50%, with three sources having R-square of more than 70%. We also observed the trend between the two to be positive meaning that a higher DAT Premium Ratio also leads to a higher Spot Premium Ratio for the identified sources, which justifies the selection of DAT as an index for Aqua Deal in our further analysis.

Figure 15.

Relationship between Spot Premium Ratio and DAT Premium Ratio



4.2 Primary Carrier Acceptance Decision Model

Once we Identified the potential sources to include in a pilot, we developed a Logistic regression model to predict the probability of tender acceptance by primary carrier given a set of load parameters and the DAT index. A logistic regression model is a statistical model that models the probability of a discrete binary event by having the log-odds for the event be a linear combination of more or more independent variables. The reason for using logistic regression for this problem is that our dependent variable, load accepted or rejected by the primary carrier, is a binary variable. The probability that each load that belongs to the class of acceptance or rejection can be represented by a logistic response function is shown below:

Probability (Primary Carrier Acceptance) = $1/(1 + [exp^{-(\beta 0+\beta 1*X1+\beta 2*X2+......+\beta nXn+\varepsilon)}])$

In the equation above, the $\beta's$ are the estimated coefficients of each of the independent variables in the model. The above equation can also be represented in the form of odds, the ratio of the probability of outcome belonging to one class to that of probability of outcome belonging to another class. This can be represented in the form of logit function (Shmueli et al., 2017):

Log(odds)= $\beta 0 + \beta 1 * X1 + \beta 2 * X2 + \ldots\ldots + \beta nXn$ where $\beta 0$ is the constant and $\beta 1, \beta 2 \ldots\ldots \beta n$ are the coefficients of variables $X1, X2 \ldots Xn$

To build the logistic regression model we used the variables mentioned in Table 7: **DAT Spot Premium Ratio**, **ASSET_BROKER**: a binary variable used to denote whether the load was tendered to the Asset or Broker, **ORIGIN:** a binary variable to denote whether the shipment was pre-loaded or loaded live at the origin, **DESTINATION:** a binary variable to denote whether the shipment was dropped or unloaded live at the destination, **SHIPMENT_RUSH:** a binary variable called SHIPMENT_RUSH to denote if the shipment was rushed(to be asked to complete within 48 hours) or not and **BUSINESS_YEAR:** a categorical variable called to denote the year of tender as variables. For calculating DAT Premium Ratio, we used the previous week's DAT Rate because in practice the shipper will know only the previous week's index. This is the only numerical variable used in a model with a range between -0.3 to +1.5 in our dataset.

We also filtered loads that originated from the selected five sources and used them as a categorical independent variable named SOURCE. The output variable took a value of '1', which means the primary carrier accepted the load, or a value of '0', which means the primary carrier rejected the load.

Table 7.

Logistic regression variables

Output Variable:
Primary Carrier Acceptance- 1- Accepted, 0-Rejected
Input Variables:
ASSET_BROKER- 1- Broker, 0-Asset DESTINATION- 0- Live unloading, 1- Destination Drop ORIGIN– 0 – Live Loading, 1 – Origin Pre-load SHIPMENT_RUSH- 1- Rushed, 0- Not-Rushed BUSINESS_YEAR- 2019,2020, 2021 SOURCE – Source 1, Source 2, Source 3, Source 4, Source 5 DAT_PREMIUM_RATIO- Numerical variable

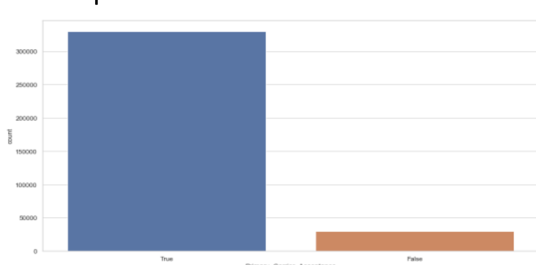
As shown in Table 7, we used the five most relevant sources in our model since these sources provided a strong correlation with the DAT Premium Ratio and the Primary Carrier Acceptance value for loads shipped from these sources. Figure 16 illustrates the relationship between DAT Premium Ratio and TAC value for high-volume sources. We identified that five sources showed the highest R squared value and therefore there is a strong correlation between the Primary Carrier Acceptance value and the DAT Premium Ratio. Hence, these sources can be significant independent categorical variables for our logistic regression analysis.

4.2.1 Imbalanced Data

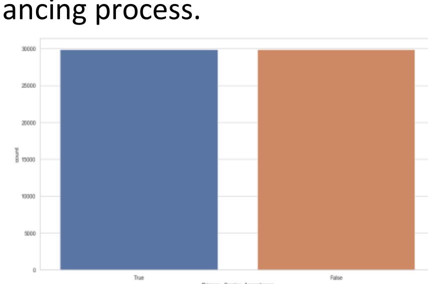
In our dataset, the average acceptance ratio of primary carriers is 92%. In other words, the frequency of observations in our load dataset in which the primary carrier accepted the load is much higher than the instances in which the primary carrier rejected the loads. If modeled with this imbalanced dataset, the predictive classification model trained with this imbalanced dataset may be biased towards the majority class, which is accepted in our case. Therefore, we decided to balance the data using under-sampling before running logistics regression. In under-sampling, we took 100% of the dataset belonging to the minority class (rejected loads in this case) and randomly sampled an equal amount of data from the majority class (accepted loads) so that the two classes were balanced. To ensure that the variability of the underlying dataset was preserved, we also compared the histograms of independent variables in both the original dataset and sampled dataset to ensure they were close to each other.

Figure 16.

Input variables before and after the balancing process.



Before balancing



After balancing

4.2.2 Logistics Regression Model Outcome

The model results are shown in Table 6. The model performed with 76% accuracy on the test set. The model also showed significant p values for the chosen variables, indicating their strong impact on the output variable: the Primary Carrier Acceptance value.

In the model results shown in Table 8, a positive coefficient value denotes a positive correlation with primary carrier acceptance. For example: if we check the Destination drop category of variable destination, the coefficient of the model for this variable is 1.64 with odds(exp(1.64)) of 5.16 and probability(exp(1.64)/(1+ exp(1.64)) of 0.84. This means that likelihood of primary carrier acceptance for loads with drop option at the destination is higher than for loads with live unloading, with all other variables remaining the same.

Table 8.

Model Output

Variable	Criteria	Coefficient	p-value	Odds	Probability
Intercept	Baseline	-0.46	<0.01	0.63	0.39
DAT_PREMIUM_RATIO		-2.34	<0.01	0.10	0.09
SOURCE	Source 1	0.43	<0.01	1.54	0.61
	Source 2	0.15	<0.01	1.16	0.54
	Source 3	0.78	<0.01	2.18	0.69
	Source 4	0.58	<0.01	1.79	0.64
ORIGIN	Origin Pre-load	2.23	<0.01	9.30	0.90
DESTINATION	Destination Drop	1.64	<0.01	5.16	0.84
SHIPMENT_RUSH	Rushed	-1.65	<0.01	0.19	0.16
BUSINESS_YEAR	2020	-0.34	<0.01	0.71	0.42
	2021	-1.15	<0.01	0.32	0.24
ASSET_BROKER	BROKER	1.70	<0.01	5.47	0.85

4.2.3 Logistics Regression Model Performance

Numerous tools can be used to measure the performance of our model. Some of these, which are shown in Figure 17, are a confusion matrix, Receiver Operating Characteristics (ROC) curve, accuracy, precision, and F1 score. A confusion matrix is the summary of prediction results of a classification problem. It is a 4 by 4 matrix providing the four different combinations of the predicted and actual number of samples. For example, the first table in Figure 18 represents a confusion matrix for our model. If we compare the four quadrants, the model has predicted 4,452 samples in the correct positive class and 4,609 samples in the correct negative class. The rest number of the samples are misclassifications of the model on the test dataset.

The ROC curve summarizes the relationship between the true positive rate and false positive rate for the model using different probability thresholds (from 0 to 1). The true positive rate is calculated by dividing the number of true positives by the sum of the number of true positives and false negatives. It describes how good the model is at predicting the positive class when the actual outcome is positive. The false positive rate is calculated as the number of false positives divided by the sum of the number of false positives and the number of true negatives. Area under curve (AUC) is the area occupied under the ROC curve. A no-skill classifier is one that cannot discriminate between the outcome class and predict random or constant class will have AUC of 0.5. An AUC value closer to 1 is desirable. Our model has an AUC value of 0.8, which is higher than the no0skill classifier and shows that our model is robust.

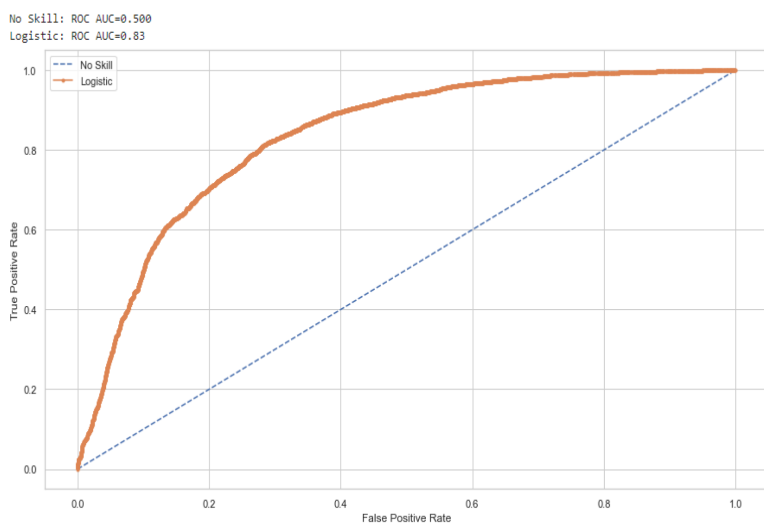
Our model also has an accuracy score of 0.76, which means the model predicts the right outcome 76% of time. In terms of F-score, which is another metric to determine how good the model is at predicting positive class (precision) or differentiating between proportion of true positive outcomes, the model score is more than 0.7, which highlights good classification.

Figure 17.

Model Performance: Classification report and Receiver Operating Characteristics (ROC) curve

		Actual values	
		TRUE	FALSE
Predicted values	TRUE	4452	1364
	FALSE	1521	4609

	Precision	Recall	F1-score
FALSE	0.77	0.75	0.76
TRUE	0.75	0.77	0.76



4.2.4 Logistics Regression Model Interpretation

Table 9 summarizes the impact of each of the variables on the primary carrier acceptance model.

Table 9

The impact of each of the variables on the primary carrier acceptance model

Variable	**Details**
DAT_PREMIUM_RATIO	As we can see that the coefficient of this variable is negative, which means the higher the DAT_PREMIUM_RATIO, the more likely the primary carrier rejects loads. This means that as the DAT_PREMIUM_RATIO increases the rate offered in the spot market increases compared to contract rate which incentivizes primary carriers to tender load in the spot market. This is also justified by the negative linear trend shown in Figure 18 for the actual weekly primary carrier acceptance and DAT_PREMIUM_RATIO with a range between -0.3 to +1.
ORIGIN	Pre-loading at ORIGIN has a positive impact on Primary carrier acceptance compared to live loading.
DESTINATION	Drop at Destination has positive impact on Primary carrier acceptance compared to live offloading. Basis, the coefficient values, it is also found that ORIGIN Preload is more impactful than DESTINATION Drop in influencing the primary carrier acceptance.
SHIPMENT_RUSH	Rushed shipments have a negative impact on primary carrier acceptance compared to non-rushed loads.
ASSET_BROKER	Broker carriers tend to have a positive impact on primary carrier acceptance compared to Asset carriers among the five sources selected. This is evident from fact that all the top 10 carriers for Aqua Deal are broker carriers and there is ~23% increase in total loads for Broker carriers in 2021 vs. 2019
BUSINESS_YEAR	These variable captures market tightness. Given 2021 is the tightest year, it has the highest influence on primary carrier acceptance.
SOURCE	Different sources have different impact in primary carrier acceptance with Source 3 having highest TAC influence

Next, we will use the results from the modeling to suggest the design of Index Linked Freight Contract and see the results.

4.3 Discussion - Design of Index Linked Freight Contract (ILFC)

The key step in the implementation of index-based contracts in the transportation industry is the design choices (Acocella et al., 2022b), specifically the choice of the index, collar, and initialization price. For Aqua Deal, we also added two additional choices that they need to consider: frequency of update and level of aggregation. We believe that these choices, along with model results, can help Aqua Deal make choices for the design of Index Linked Freight Contracts. Using the above design choices along with the model developed in the previous section, we designed an Index Linked Freight Contract and calculated the impact on primary carrier acceptance rate and the expected cost for Aqua Deal, which we will discuss in section 4.3.6.

4.3.1 Index Choice

In the transportation industry, DAT National Index, the Cass National Linehaul Index and Morgan Stanley Freight Index are just few of the indices. The index choice must be agreed on by both shipper and carrier. In Aqua Deal's case, we recommend that they use the weekly DAT spot rate as an index. It is robust and has a wide coverage basis of $110 billion in actual freight payments across 65,000 lanes.

There are two key reasons for Aqua Deal to use the DAT spot rate as an index: First, they have bought the access to weekly DAT spot rates for lanes representing ~70% of the lanes. Second, we see a high positive correlation of 0.80 between the DAT Premium Ratio and Spot

Premium Ratio (National Aggregate) for Aqua Deal's spot shipments. We recommend using the week-over-week change in DAT spot rates ($DAT\ Spot\ Rate_{t-1}/DAT\ Spot\ Rate_{t-2}$) as an index to update the contract price for each lane on a weekly basis to reflect the changes in market price.

4.3.2 Collar

A collar is an upper and lower bound on the amount an index can fluctuate each week. For example, if there is sudden fluctuation in the weekly DAT rate due to an external event, both shipper and carrier may not expect the fluctuation to impact pricing. Shippers can thus use the collar to control the fluctuations in a weekly index and set the maximum or minimum allowed Index rate at any time t. This can be done in our case by bounding the Index between upper and lower limit mutually agreed by shipper and carrier at the beginning. We recommend that both shipper and carrier agree to mutually agreed collar so that the index prices do not fluctuate to an extent that impacts the financial planning.

4.3.3 Initialization Price

The shipper and carrier must agree on an initial price, which can be derived from the benchmark rate with a factor for lane based on historical performance:

$$Contract_{t0,lane} = \alpha_{lane} * \ Benchmark\ Rate_{t0,lane}$$

α_{lane} can be estimated by looking at the historical rate of the price at which the carriers have consistently accepted the loads for the shipper or it can be derived from the relationship between Primary carrier acceptance and Spot premium from the previous contract price along with the benchmark reports. This is discussed in more detail in Acocella (2022b).

4.3.4 Update Frequency

In terms of frequency of update**,** both shipper and carrier must decide on the frequency. This can be done weekly, monthly, or even quarterly, depending on the available resources and system capability. The shipper and carrier can also consider updating on achieving a minimum threshold such as 5% over which to change the index rate to prevent minor fluctuations in the market from impacting index rates.

4.3.5 Levels of aggregation

For level of aggregation choice, we can define the index at the source level, lane level, or carrier level, depending on other factors such as ease of implementation and data availability.

4.3.6 Testing Index Linked Freight Contract for Sample Data

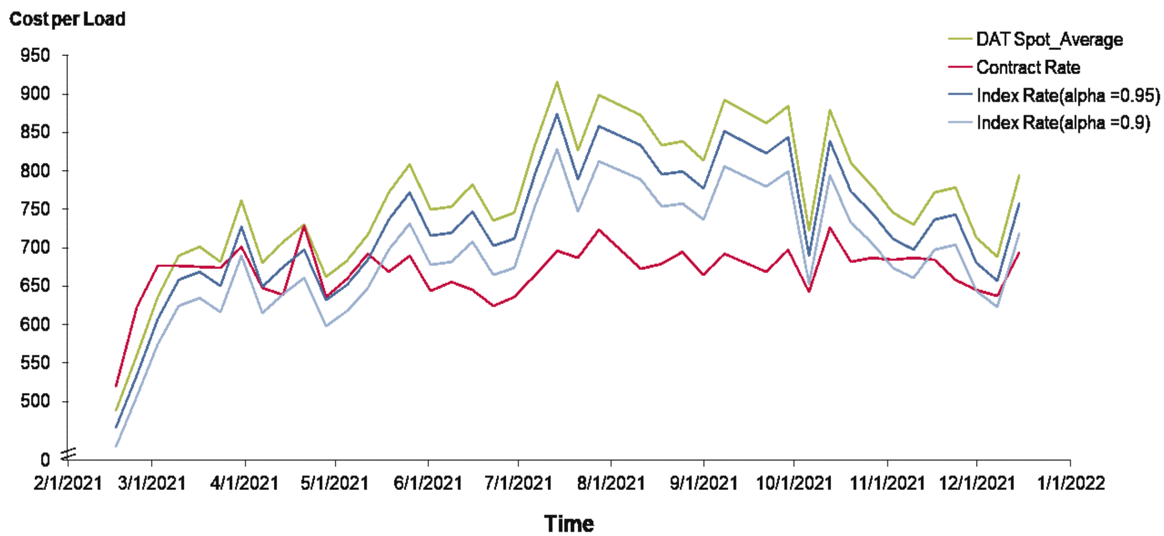
To provide a proof of concept, we tested the design choices discussed above to design and test Index Linked Freight Contract for a sample carrier and source. We selected Source 1 and filtered out all loads in 2021 for a sample carrier which represented ~15% loads (highest among all carriers operating out of Source 1). The data represented ~2600 loads over the period of eight months across 32 lanes. Using the model and variables shown in Table 6, we derived the as-is primary carrier acceptance probability using the independent variables: around 88%. Then, using the concepts outlined in sections 4.2.1-4.2.6, we derived an index using the week-on-week change in DAT Spot rate($I_t = DAT\ Spot\ Rate_{t-1} / DAT\ Spot\ Rate_{t-2}$) to update the initial price. The initial price was set as the contract price for all lanes assuming the rates during the contract represented the benchmark price for each lane.

Appendix B shows the results of the analysis on the sample lanes as an outcome of using index linked freight rate in place of a flat contract rate and assuming the relations in the logistics regression hold. Using DAT spot rates as an index, the average probability of acceptance by the primary carrier increased in 19 out of 32 lanes and remained the same in 8 lanes. In total, the average probability of acceptance by the primary carrier increased from 0.88 to 0.90 for all lanes combined, showing the impact of using a probabilistic model on the primary carrier acceptance rate. In terms of cost, we also saw an increase in expected total cost among these 32 lanes by 4% over the actual spend, highlighting the tradeoff between the primary carrier acceptance and the expected cost increase for the shipper. It is also interesting to note that we observed a decrease in primary carrier acceptance rate for some lanes where the initial price was set higher than the DAT rate and hence, as the index pegged against DAT, the DAT Premium Ratio increased, which reduced the primary carrier acceptance rate.

Figure 18 shows the trend of indexed rate contracts with varying value of α which is a multiplying factor for the initialization price. The Contract rate is the weekly average contract rate for the 32 lanes combined, DAT Spot_Average is the average weekly DAT rate for the 32 lanes combined and the Index rates are the indexed rates using DAT as an index and using $\alpha * Contract\ rate$ as initialization price with two α values of 0.95 and 0.9. Hence, we see that as the alpha value decreases, the indexed rate can be adjusted to reflect the DAT trend and maintain the average cost per load in between Contract rate and DAT rate with varying levels of acceptance. This is because as the gap between DAT and Index rate decreases, DAT_PREMIUM_RATIO also decreases which leads to increase in primary carrier acceptance rate.

Figure 18.

Index rates with varying initialization price



5. Conclusion

5.1 Summary

The research analyzed the factors that determine primary carrier acceptance for Aqua Deal and estimated how an Index Linked Freight Contract could potentially mitigate the volatility risk of the transportation rates and improve primary carrier acceptance. This becomes more relevant in a tight market, where demand exceeds supply of transportation and carriers have an incentive to provide capacity in the spot market to improve their profitability. We also examined the DAT index, which is representative of the freight market, and identified a strong correlation of 0.8 of the DAT premiums over contract rates with that of actual spot rates paid by Aqua Deal for the rejected loads. Then we identified the source locations where carriers are more responsive to the changes in DAT in their load acceptance decision.

Using logistic regression, a probabilistic model to predict the probability of primary carrier acceptance was developed, as summarized in Table 6. Table 6 shows the key variables that statistically significantly impact the primary carrier acceptance decision and the direction in which change in one variable will lead the probability of primary carrier acceptance. This model also only considers loads from the five sources which exhibit a linear relationship between weekly DAT Premium and their average weekly carrier acceptance.

One of the key considerations for Aqua Deal here is to address the fact that the model is predicting the probability of acceptance-based behavior for poor performing carriers and rewarding them with high prices along with carriers that are already performing well. Hence the key is to clearly segregate the poor performing carriers whose acceptance decision is sensitive to changes in the spot market.

Our model suggests that different load characteristics, such as using drop trailers at origin and destination, improves primary carrier acceptance. We also saw that rushed shipments reduce acceptance rates and hence must be avoided by the shipper whenever possible. For sample sources, we also observed broker carriers have a higher probability of primary carrier acceptance compared to asset-based carriers.

We then provided a brief overview of the design choices for the Index Linked Freight Contract such as choice of index, collar, initialization price, frequency of update and level of aggregation. We tested these concepts for a sample source and carrier on 2021 data and saw a ~2% overall improvement in probability of primary carrier acceptance using an DAT index to make the offered contract price dynamic but with a ~4% increase in expected cost for the shipper. As Aqua Deal's primary objective is to reduce spot shipments and transport cost, the Index Linked Freight Contract may not be the best method to achieve this aim. Based on rushed shipment analysis, the total number of rushed shipments has doubled in past 3 years. These are not only costlier to Aqua Deal, but they also negatively impact the carrier acceptance decision. Aqua Deal should consider focusing on identifying the root causes of rushed shipments and decrease their occurrence.

5.2 Managerial Insights

This research has several managerial insights.

1. Aqua Deal should target certain lanes that are more prone to spot

Low Volume, High Volatility, Low cadence, and high distance lanes have highest percentage of spot loads. The carrier and lane analysis helped us identify the lanes where there is a high number of spot loads. Aqua Deal should pay special attention to these tail lanes and may use current market rates to tender loads among carriers to prevent any service impact since the contribution of these lanes to the overall spend is negligible.

2. Aqua Deal should look for ways to increase the use of drop trailers

Our model suggests the probability of primary carrier acceptance goes up for loads that are preloaded ast source and dropped at the destination compared to loads that are live loading and unloading. This makes intuitive sense since uncertainty as to dock availability leads to longer detention of trucks at the source and destination, thus reducing the asset utilization for carriers.

3. Aqua Deal should avoid rushed shipments and identify their root causes

Our model suggests the probability of primary carrier acceptance goes down if the shipment is rushed. Recall that rushed shipments are loads that are requested to be completed within 48 hours. Rushed shipments do not provide enough time for the carrier to make informed decisions as to the placement of the vehicle; hence, shipment may end up being rejected by the primary carrier. We have also seen from previous analysis that these rushed shipments were ~35% costlier in spot compared to contract rates in 2021. Aqua Deal should avoid rushed shipments to reduce the probability of rejection of loads by the primary carrier and avoid the higher cost in the spot market.

4. Aqua Deal should increase the business contribution of Brokers

As seen from the carrier analysis, brokers exhibit better performance in terms of accepting loads compared to asset-based carriers. The top four carriers of Aqua Deal are brokers, representing ~35% spend in 2021 with an average acceptance rate of ~94%. This higher acceptance ratio comes at a higher cost for the shippers however. As shown in Table 3, broker carriers have lower DAT Premium Ratio and Spot Premium Ratio compared to asset carriers, meaning a lower gap between DAT or spot rate from contract rate and hence a higher contract rate.

5.3 Future Research

There are many areas of our project can be explored further. In our probability-based model to predict the primary carrier acceptance, the addition of lane characteristics such as volume, volatility, distance, and cadence can be a promising direction for future research. Although we have discussed the initialization price for setting up the initial price, extensive research can be done to identify the right factor to be used at the lane level to derive the initial price for setting up Index Linked Freight Contracts.

Although we have focused on the DAT Spot rate, Aqua Deal also collected additional market information such as DAT Contract rate, Source load to truck ratio (LT) and destination load to truck ratio, etc. This information can be studied further to refine the design of the index.

Since the data is imbalanced in the sense that the number of acceptances exceeds 90%, the application of more sophisticated machine learning models such as weighted logistics regression is promising. For the same reason, additional metrics and scores can be used apart from the confusion matrix and AUC curve to test the model.

Root cause analysis could also be conducted on rushed shipments and cost benefit can be derived if it can be reduced. We have seen that the percentage of spot loads for Aqua Deal increased from 9% in 2019 to 28% in 2021 and more than two-thirds of the spot shipments were rushed. Rushed spot shipments are at least 35% more expensive, and extensive work on root cause analysis can help the shipper reduce these expenses, which can provide cost saving opportunities of ~$60M for Aqua Deal based on 2021 numbers.

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APPENDIX A- Data dictionary of selected variables

Variable	**Description**
ACCEPTANCE_CODE	A for Accepted Null for Rejected Tenders
BID_AMOUNT	Bid submitted by Tender Carrier for Spot Tenders
CARRIER_CAPACITY_STATUS	Spot-Tender Under-Capacity Over-Capacity
CARRIER_CAPACITY_USED	Carrier Capacity used up by Shipment Carrier up to this Shipment
CARRIER_HOW_RESPONSE	
CARRIER_RESPONSE	
CUSTOMER	Customer Name
CUSTOMER_LOCATION	Destination Address
CUSTOMER_TYPE	DC DTS Club DTS Non-Club
DECLINE_REASON	
DEST_LOCATION_GID	Unique ID for Destination Location
DOMAIN_NAME	NBL - US Shipments NBL/MX - Mexico Shipments
LAST_STOP_ONTIME	On-Time Destination Actual Arrival is Missing Missed Pickup Late Time Late Time and Date Buffered Delivery Time Missing or is in the Future
LOAD_TYPE	Delivery Transfers

	CustomerPickup Inbound
MILES	Distance
Spring Falls_LOADING_DELAY	Loading Delay at Source Location in minutes
PLANNED_COST	Planned Cost for Shipment
RESPONSE_METHOD	Carrier Response Method
SHIPMENT_CARRIER	Carrier who delivered the Shipment
SHIPMENT_DROP	Drop if the Carrier can drop off the trailer at Destination and leave without waiting for unloading
SHIPMENT_GID	Unique Shipment ID
SHIPMENT_PRELOAD	Preload if the Carrier can pickup a preloaded trailer at Source and not wait for loading
SHIPMENT_RUSH	Rushed if Lead Time for Pickup is less than 48 hrs from Tender Time
SHIPMENT_SPOT	Spot Not-Spot
SHIPMENT_START_TIME	Shipment Start Time at Source (usually same as Pickup Appointment)
SHIPMENT_STATUS	Shipped Missed Pickup - Carrier Accepted and did not show up Deleted-Other - Shipment Deleted Accepted then Declined
SHIPMENT_STOPS	SINGLE MULTIPLE
SHIPMENT_TRANSPORT_MODE_GID	NBL.TRUCK NBL.TRANSFER NBL.DROP NBL.DTS NBL.TANKER NBL.TEAM

	LTL NBL.INBOUND
SOURCE	Plant/Warehouse Name
SOURCE_LOCATION_GID	Plant/Warehouse Code
SOURCE_ON_TIME	On-Time Source Actual Arrival is Missing Missed Pickup Late
SOURCE_REGION	Group of Plant/Warehouses in one region
STATE	Destination State
SUPPLY_CHAIN_LOAD_TYPE	Delivery Deployment Transfer CustomerPickup Operational Transfer Repacker Inbound
SUPPLY_CHAIN_REGION	Associated with location of Plant/Warehouse Central Northeast West Southwest
TENDER_RESPONSE_TIME	Time of Bid Submission
TENDER_TYPE	Spot for Spot Shipments and Ordinary for rest
TOTAL_SPEND	Total amount spent on Shipment by Spring Falls
'Unnamed: 0'	S.No
WEEK	Shipment Start Time Week
X_LANE_GID	Combination of Source Region and Destination Region

YEAR	Shipment Start Time Year
ZIP_CODE	Destination Zip Code

APPENDIX B- Outcomes of probability of Primary Carrier Acceptance for the sample lanes

		2656	*0.88*	*0.90*	*2%*
LANE	***Initialization Rate***	***Total Loads***	***Average Primary carrier Acceptance Current***	***Average Primary carrier Acceptance New***	***Increase in Acceptance***
SOU224	*342.9*	*354*	*0.92*	*0.91*	*-2%*
SOU211	*653.8*	*306*	*0.89*	*0.92*	*3%*
SOU282	*663.0*	*269*	*0.91*	*0.91*	*0%*
SOU233	*449.5*	*237*	*0.92*	*0.89*	*-2%*
SOU283	*604.5*	*213*	*0.79*	*0.84*	*7%*
SOU234	*478.1*	*188*	*0.87*	*0.90*	*4%*
SOU210	*795.6*	*142*	*0.82*	*0.94*	*14%*

SOU240	*742.6*	*139*	*0.89*	*0.89*	*0%*
SOU241	*749.4*	*130*	*0.90*	*0.83*	*-8%*
SOU220	*552.3*	*115*	*0.88*	*0.90*	*3%*
SOU235	*436.4*	*111*	*0.88*	*0.94*	*6%*
SOU281	*981.7*	*100*	*0.79*	*0.92*	*17%*
SOU278	*478.4*	*74*	*0.80*	*0.89*	*11%*
SOU275	*534.0*	*59*	*0.82*	*0.89*	*8%*
SOU212	*694.0*	*35*	*0.90*	*0.92*	*3%*
SOU238	*217.7*	*35*	*0.95*	*0.83*	*-12%*
SOU274	*907.8*	*33*	*0.90*	*0.92*	*2%*
SOU231	*237.2*	*22*	*0.86*	*0.86*	*0%*
SOU200	*614.0*	*17*	*0.89*	*0.92*	*3%*
SOU221	*510.8*	*14*	*0.91*	*0.91*	*0%*
SOU285	*1430.0*	*13*	*0.89*	*0.96*	*8%*

SOU217	*726.8*	*8*	*0.84*	*0.91*	*8%*
SOU226	*684.5*	*8*	*0.74*	*0.91*	*22%*
SOU228	*730.0*	*7*	*0.92*	*0.92*	*0%*
SOU236	*382.3*	*6*	*0.89*	*0.89*	*0%*
SOU280	*671.4*	*5*	*0.86*	*0.87*	*1%*
SOU276	*450.6*	*4*	*0.89*	*0.83*	*-6%*
SOU219	*573.3*	*4*	*0.88*	*0.89*	*1%*
SOU273	*717.6*	*3*	*0.90*	*0.91*	*0%*
SOU223	*515.8*	*2*	*0.89*	*0.89*	*0%*
SOU284	*632.8*	*2*	*0.79*	*0.81*	*2%*
SOU286	*1634.0*	*1*	*0.86*	*0.96*	*11%*