Northeastern University
College of Professional Studies

ALY6980: Optimization of Wholesaler Shipping at Brewer

Group Project Report Submitted in Partial Fulfillment for the
ALY 6980 Capstone

Submitted by: Team Cheers

Course Number (CRN): 20396

Term and Year: Winter 2025

Team Members: Rahat Khan, Cenyu Chi, Yash Gokhale,
Yumin Chen, Goutham Yerramada, Mohit Dhamija

Abstract

This report details the capstone project undertaken by Team Cheers for ALY6980 in collaboration with Allagash Brewery. The primary objective of this project was to analyze and optimize Allagash Brewery's logistics and supply chain efficiency by leveraging data-driven insights. The team developed an interactive Power BI dashboard to visualize key performance indicators such as total cost, cost per mile, shipment efficiency, and potential cost savings.

The analysis incorporated historical shipment data, cost structures, and carrier efficiency metrics to identify cost-saving opportunities. Key insights revealed that many shipments were classified as "sub-optimized," leading to higher operational costs. By implementing route optimization and truck-type switching strategies, the team projected a potential cost reduction of approximately 8.9%. Fuel and line-haul cost analysis highlighted areas where expenses could be minimized further.

The report presents recommendations for optimizing pallet utilization, improving carrier efficiency, and reducing transportation costs through data-driven decision-making. These insights aim to enhance Allagash Brewery's supply chain performance and provide a scalable framework for future operational improvements.

Introduction

Allagash is currently dealing with high annual freight expenses of around $2 million, with at least 10% efficiency recognized as a primary objective. To address this issue, a thorough data analysis was performed utilizing advanced tools such as Power BI and Python to identify cost distribution patterns, regional variances, and important impacting factors such as shipment weight and weather conditions. The investigation resulted in creating an intelligent truck-type recommendation model and focused cost-reduction methods. The initiative is expected to provide considerable benefits by improving truck selection and resolving regional and weather-related inefficiencies, including annual cost savings of at least $0.19 million. Beyond immediate financial savings, these solutions lay the groundwork for long-term operational efficiency and sustained logistics optimization, ensuring Allagash's shipping competitiveness.

The analysis utilized two comprehensive datasets made available to us by the sponsor. One of the datasets was directly through the sponsor company, while the other was from CH Robinson, Allagash's trusted shipping partner. The data captures detailed shipment records across US distribution points, including but not limited to freight costs, mileage, Drop States and Cities, and Weather conditions. These columns facilitated geographical and seasonal analyses. The data from CH Robinson highlights the mode of transportation of beer, lanes, and weight distributions, laying a solid foundation for identifying cost drivers and optimization opportunities.

Exploratory Data Analysis for Datasets

Analysis Approach

To understand key cost drivers and evaluate shipment efficiency, we performed comprehensive exploratory data analysis (EDA) on the available logistics datasets. This process involved identifying data quality issues, uncovering patterns and trends, and generating descriptive statistics and visualizations. By analyzing factors such as weight distribution, shipment routes, cost components, and seasonal variations, we aimed to extract actionable insights that could inform cost optimization strategies and support data-driven decision-making.

Key libraries and tools used in the analysis included:

- 'pandas' and 'numpy' for data cleaning, aggregation, and feature engineering.
- 'meteostat' to retrieve weather data by geolocation and date.
- 'matplotlib' and 'seaborn' for creating high-quality visualizations.
- 'geopy' for location coordinate and distance

Results & Discussion

Shipment Weight Analysis

Observation:

Most shipments are about 40,000 pounds, indicating a common weight threshold, while a considerable portion falls between 10,000 and 30,000 pounds, showing inefficient trailer utilization. Furthermore, the presence of severe outliers may influence cost and capacity planning.

Insights:

Consolidating smaller shipments increases trailer capacity and lowers freight costs, while optimizing load planning reduces underused trailers. Furthermore, dynamic routing can increase weight distribution and overall efficiency.

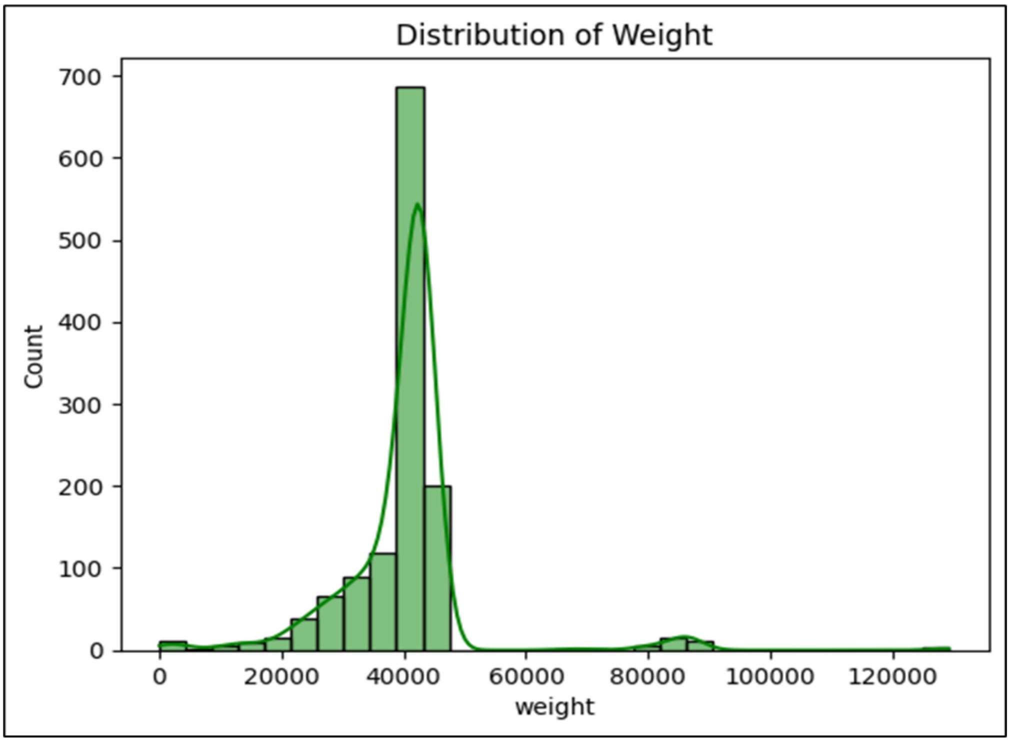

Figure 1. *Distribution of Weight*

Trends in Monthly Average Linehaul Costs:

Observations:

Linehaul prices peaked at $1,900 in January 2023, fell to $1,200 by October 2023, and fluctuated during 2024 before rising again to $1,800 in January 2025. The data shows seasonal oscillations, with peaks in the beginning of each year, most likely caused by increased demand or operational inefficiencies.

Insights:

Optimizing operations during high-cost months such as January and late Q4 can assist to reduce costs, while evaluating the big cost drop in October 2023 may reveal ideas worth duplicating. Leveraging this data to foresee high-cost seasons and carefully plan shipments during low-cost months can result in significant cost reductions.

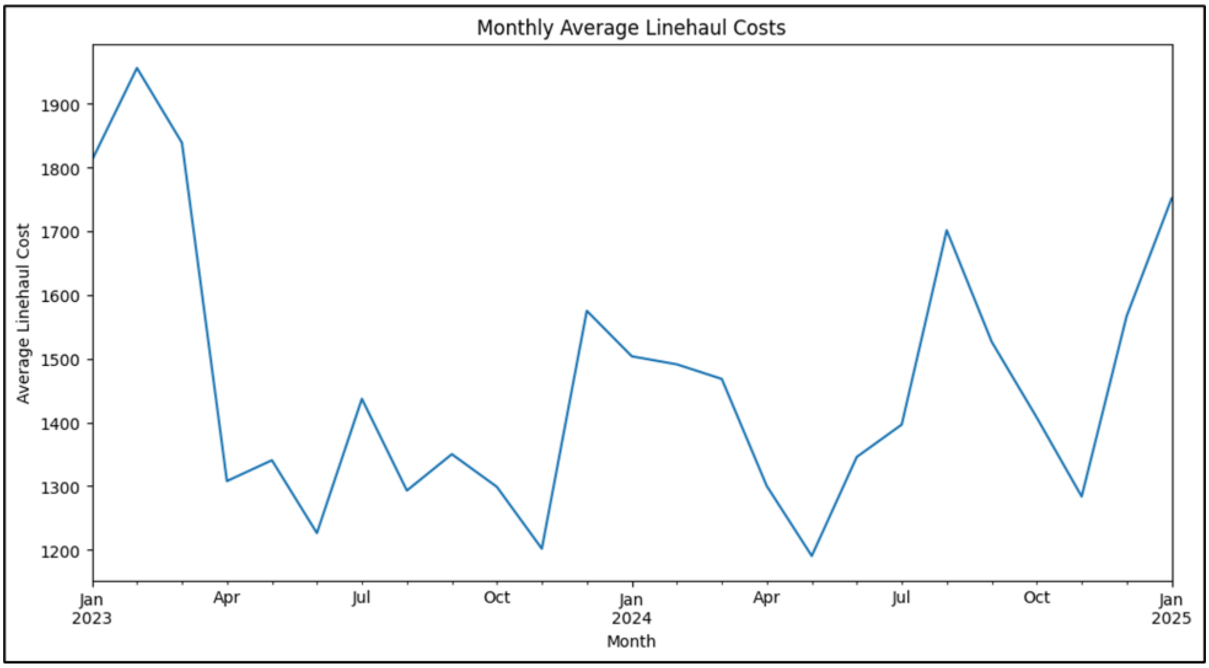

Figure 2. *Monthly Average Linehaul Costs*

Cost Analysis:

Observation:

The Pareto graphic shows that a few state pairs account for most shipping expenditures, with ME to CA having the greatest expenses, followed by ME to NJ, ME to IL, and ME to PA. The cumulative cost curve demonstrates that after the highest-cost routes, new state pairs contribute minimally to total expenses, reinforcing the Pareto principle.

Insights:

Focusing on high-cost routes can result in significant savings, particularly from Maine to California and Maine to New Jersey. Shipment consolidation, route optimization, and carrier agreements are all effective cost-cutting strategies. Investigating cost-effective options for important lanes may improve overall freight efficiency.

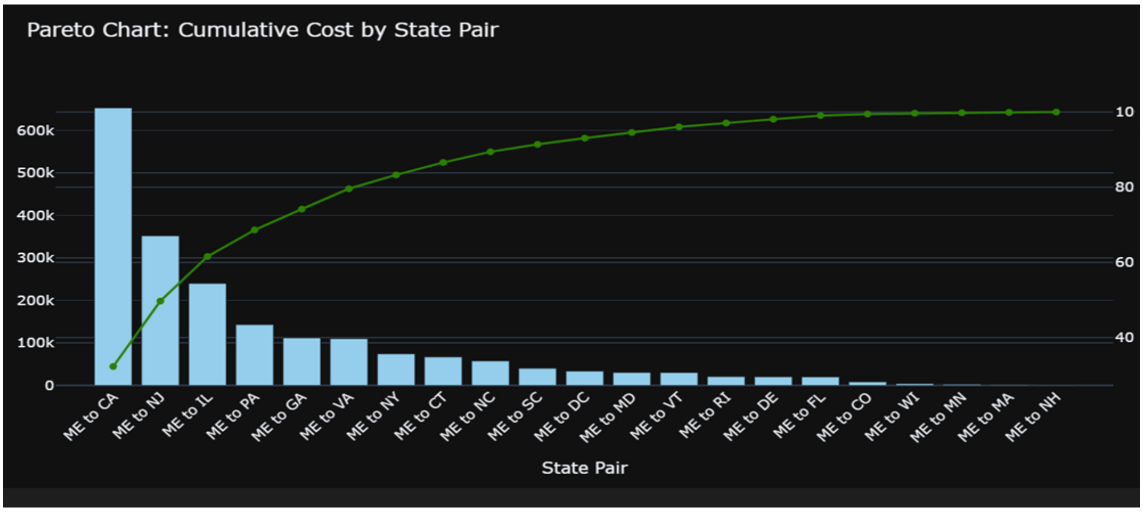

Figure 3. *Cumulative Cost by State Pair*

Temperature vs. Linehaul Shipment Cost

Observation:

A scatter plot revealed that while linehaul shipment costs fluctuate, they tend to be higher at extreme temperatures (both low and high). The relationship isn't strictly linear but does suggest a trend.

Insight:

Extreme temperatures might require special handling (e.g., insulated trucks, delay buffers), leading to increased operational costs

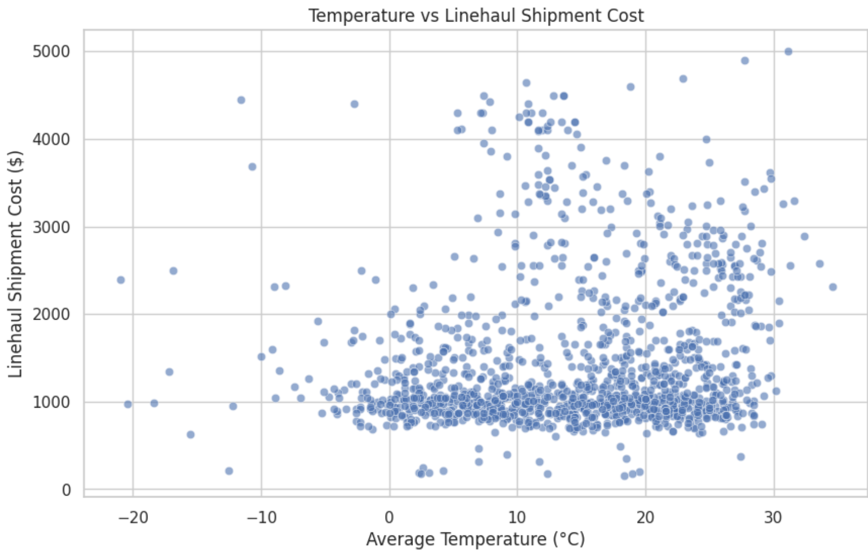

Figure 4. *Temperature vs. Linehaul Shipment Cost*

Average Linehaul Shipment Cost by Temperature Range

Observation:

When grouped by temperature bins, the data showed that average linehaul costs were lowest in the moderate range (-10°C to 20°C) and higher at both extremes.

Insight:

This supports the theory that moderate weather conditions are more favorable for efficient logistics operations, while extreme temperatures drive costs up

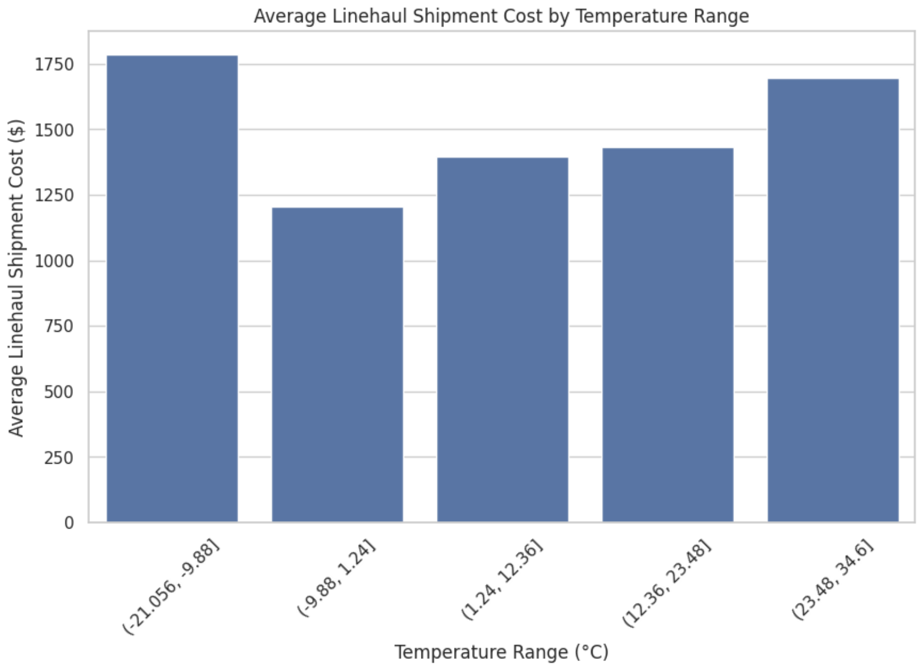

Figure 5. *Average Linehaul Shipment Cost by Temperature Range*

Temperature vs. Fuel Shipment Cost

Observation:

Fuel shipment costs also displayed an upward trend at higher temperatures, with some outliers showing cost spikes around 10–20°C.

Insight:

This may be due to reduced fuel efficiency or added cooling demands (e.g., air conditioning in summer), although the temperature-cost correlation remains weak overall

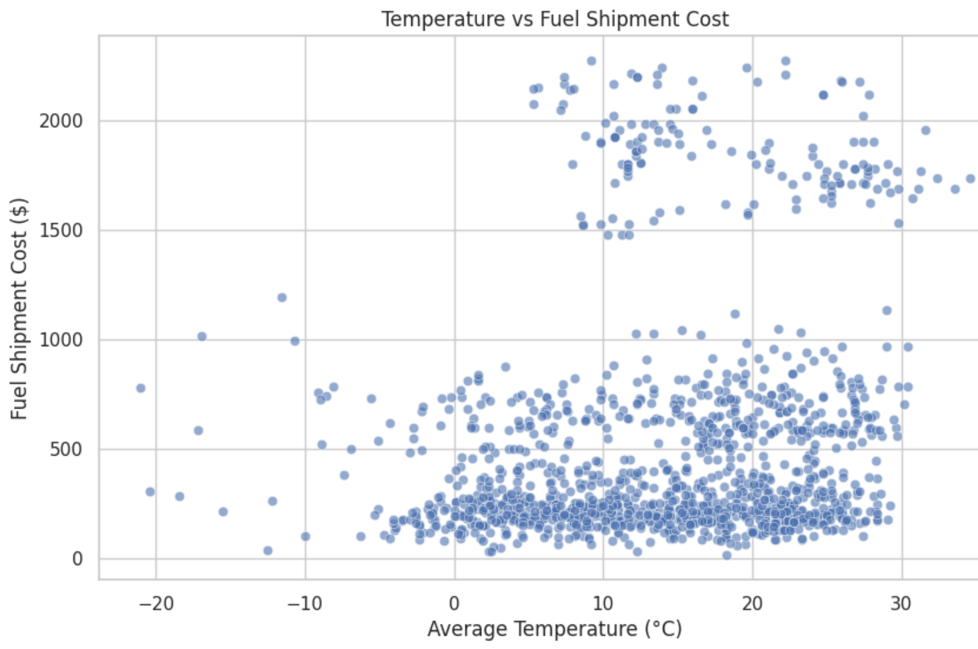

Figure 6. *Temperature vs. Fuel Shipment Cost*

Average Fuel Shipment Cost by Temperature Range

Observation:

Average fuel shipment cost increased significantly in the highest temperature range (above 23°C). The lowest costs occurred between -10°C and 10°C.

Insight:

Hot weather may stress vehicle performance and fuel efficiency, while moderate conditions are optimal for minimizing fuel expenses.

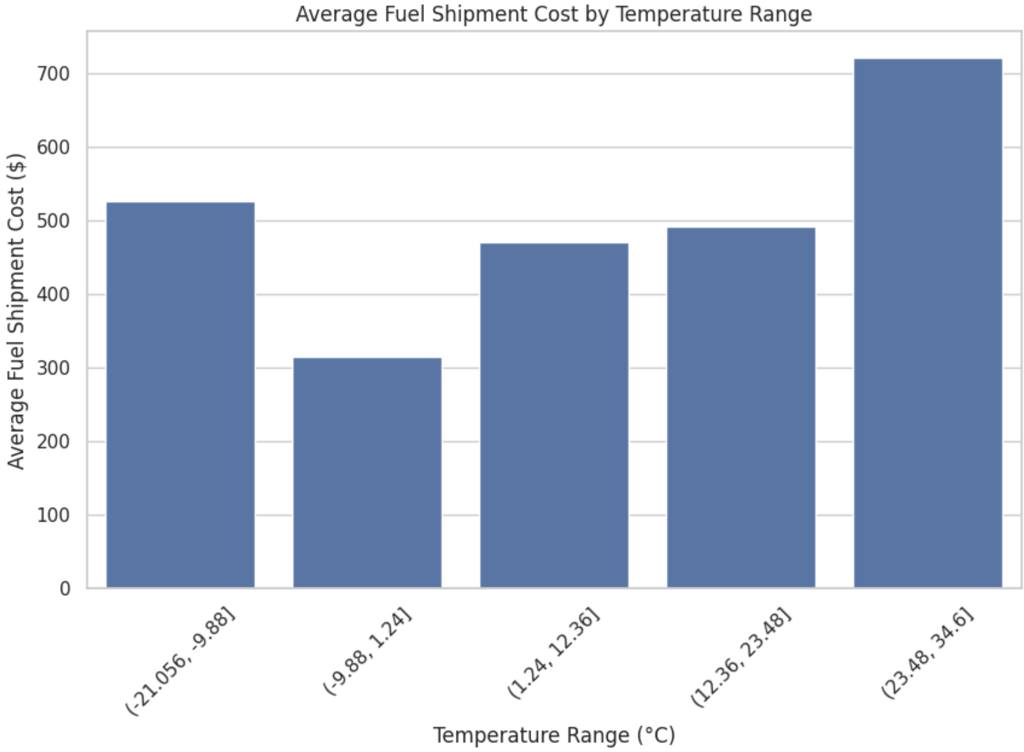

Figure 7. *Average Fuel Shipment Cost by Temperature Range*

Feature Engineering

Apart from the already available columns, it was important to engineer a few columns which would help us to get nearer to our target of obtaining the 10% cost reduction. Below mentioned are a few columns that we engineered into the datasets through python code.

<u>Drop Latitude and Drop Longitude:</u>

Based on the column "Drop Zip" and using the python library "geopy" the Latitudes and Longitudes columns were created. These columns were then further used not just in visualizations but also for engineering another column.

<u>Mileage:</u>

"Geopy.distance" libraray was used to create the "Mileage" column which helped us to in turn compute a few more features which certainly helped us in the analysis.

<u>Total Cost, Cost per Mile, Cost per Pallet and Cost per Weight:</u>

Total cost was a simple addition of "Linehaul costs" and "Fuel Costs". A simple division of Mileage, Weights and Pallets with Total Cost helped us to have these columns which contributed in EDA as well as in dashboarding.

Lanes:

A column coded through the columns of “Pickup City” and “Drop City” This column was particularly helpful when it came to analyze the costs based on the lanes and thus brainstorm the optimization strategies.

Year, Month, Day, Year-Quarter:

Using the inbuilt panda's library, the column “Ship Date” was used to get the columns Year, Month, Day and Year-Quarter which helped us in date wise analyses.

We also engineered features such as:

- Temperature deviation (from mean),
- Weather Condition,
- Cost-per-weight ratios for both linehaul and fuel.

Interactive Dashboard Architecture and Functionality

Page 1: Shipping Cost & Optimization Overview

To complement the statistical modeling and decision-support tools, a dynamic Power BI dashboard was developed to visualize key freight performance metrics, identify inefficiencies, and uncover actionable savings opportunities across Allagash's logistics network.

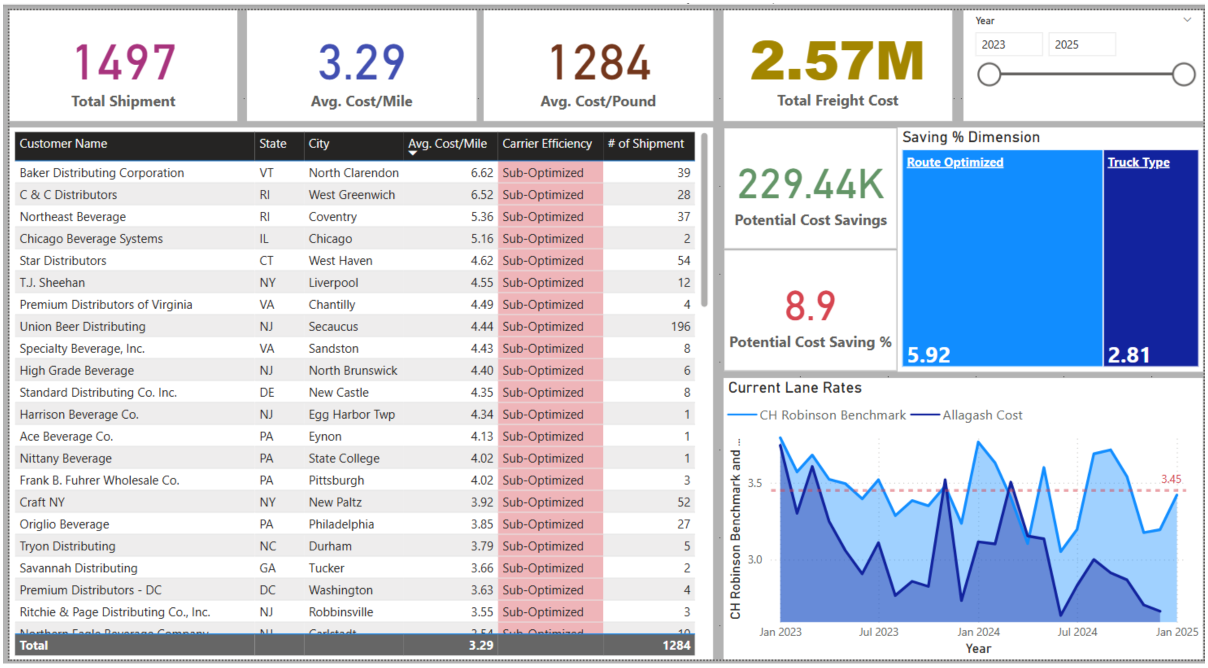

Figure 8. *Allagash Freight Analytics Dashboard:*
This dashboard provides real-time visibility into shipment volume, cost efficiency, potential savings, and carrier performance, enabling both operational monitoring and strategic planning.

Key Metrics Displayed

- Total Shipments: 1,497 completed shipments within the selected time frame (2023–2025).
- Average Cost per Mile: $3.29, indicating typical freight spend across routes.
- Average Cost per Pound: 1,284 cents/lb (or $12.84/lb), reflecting shipment density and cost structure.
- Total Freight Cost: $2.57 million over the analysis period.

Carrier Performance and Optimization Opportunities

The table on the left ranks customer shipments by:

- Average Cost per Mile
- Carrier Efficiency status (e.g., "Sub-Optimized")
- Number of Shipments

This allows stakeholders to identify high-cost routes or underperforming lanes. Notably, a large portion of shipments are flagged as "Sub-Optimized," indicating potential inefficiencies in route planning, truck type selection, or carrier choice.

Savings Potential

The dashboard highlights measurable cost-saving opportunities:

- ➢ Total Potential Savings: $229,440
- ➢ Potential Cost Saving Percentage: 8.9%
- ➢ Savings Attribution:
  - ■ 5.92% from Route Optimization
  - ■ 2.81% from Truck Type Optimization

These insights provide a roadmap for targeted interventions, such as consolidating routes, switching to dry trucks where applicable, or negotiating better carrier contracts.

Benchmarking and Trend Analysis

The bottom-right line graph compares:

- ➢ CH Robinson Benchmark Rates
- ➢ Allagash's Actual Freight Cost

The visualization shows that Allagash's costs generally track below the industry benchmark, with intermittent spikes. The most recent data (Jan 2025) shows Allagash at $3.45/mile, slightly above the benchmark—suggesting a need for strategic reevaluation of recent lane or carrier choices.

Page2: Pallet Utilization & Cost Efficiency

To complement cost-efficiency analysis, a secondary Power BI dashboard was developed to evaluate equipment utilization (dry vs. temperature-controlled trucks), revenue performance, and pallet-level shipment efficiency. This dashboard enhances strategic logistics planning by highlighting potential savings through truck-type switching and load optimization.

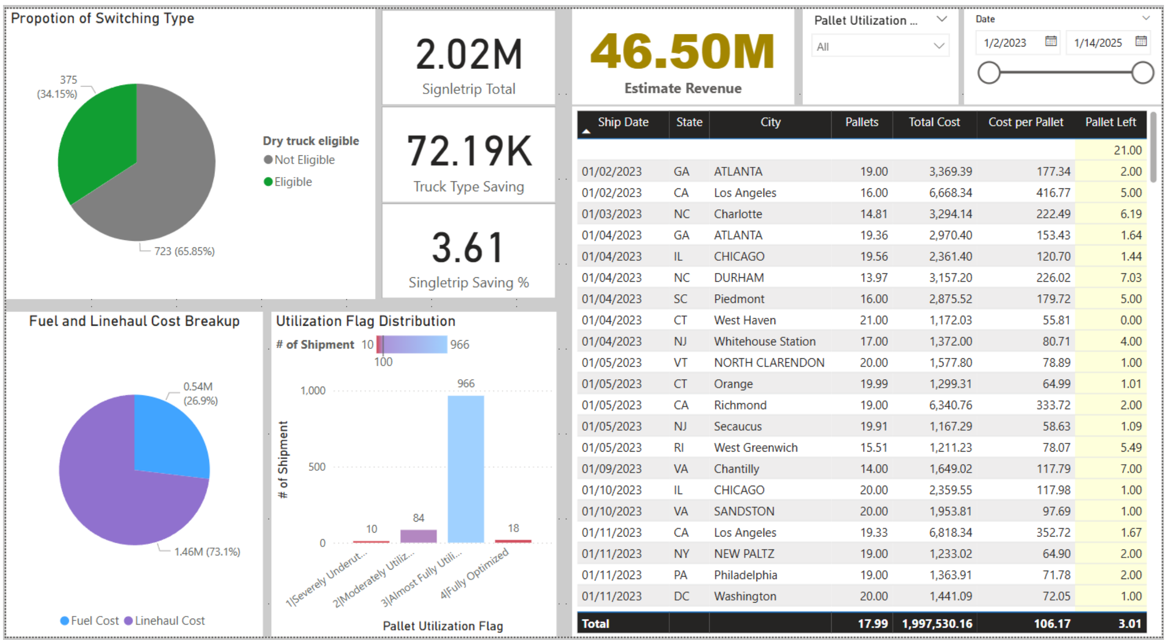

Figure 9. *Truck Type Optimization and Utilization Dashboard.*
This dashboard visualizes dry truck eligibility, fuel and linehaul cost distribution, revenue metrics, and pallet utilization per shipment to support continuous freight optimization.

Key Performance Metrics

- Estimate Revenue: $46.50 million in total revenue for the evaluated shipments (2023–2025).
- Single-Trip Freight Spend: $2.02 million, reflecting shipments not bundled or consolidated.
- Truck Type Savings Potential: $72,190 in avoidable cost identified by switching to dry trucks where feasible.
- Single-Trip Saving Percentage: 3.61%, demonstrating incremental gains through equipment optimization alone.

Truck Type Optimization

A **proportional breakdown** of shipments indicates:

- **723 shipments (65.85%)** are *not eligible* for switching to dry trucks (due to temperature requirements, duration, or ambient conditions).
- **375 shipments (34.15%)** are *eligible* for dry truck substitution, representing a significant opportunity to reduce unnecessary use of temperature-controlled equipment.

This analysis is directly supported by prior cost modeling, which showed reefer trucks are ~15% more expensive than dry trucks. These insights can inform standard operating procedures, especially in warmer months or with temperature-sensitive freight.

Cost Structure Analysis

A **Fuel and Linehaul Cost Breakdown** reveals:

- **Linehaul Cost:** $1.46 million (73.1%)
- **Fuel Cost:** $540,000 (26.9%)

This distinction is vital for understanding cost drivers. Since fuel costs are more variable (due to market pricing), efforts to reduce linehaul charges through route consolidation and equipment choice provide a more controllable path to savings.

Load Utilization Efficiency

The **Pallet Utilization Flag Distribution** provides a snapshot of how effectively each truck's pallet space is being used:

- **Fully Optimized Shipments:** 966 (majority)
- **Marginally Underutilized or Fully Underutilized:** 84 + 18 respectively
- **Severely Underutilized:** 10
- **Overloaded:** 10

Underutilized trucks present clear cost-inefficiency—moving lower volumes at full shipping rates—while overloaded cases may indicate errors in planning or violation of capacity limits. This view supports process improvement and proactive capacity planning.

Shipment-Level Insights

The right-hand **shipment table** lists:

- Origin and destination by city/state
- Total pallets shipped
- Cost per pallet
- Remaining pallet space (i.e., potential for consolidation)

For example:

- A shipment from **Atlanta, GA** on **01/02/2023** used **19 pallets**, costing $3,369.39, with **1 pallet left unused**.

- A **Los Angeles** shipment on the same day cost $6,668.34 with **6 pallets left**, indicating poor utilization.

This granularity enables freight managers to pinpoint inefficiencies at the individual shipment level, and schedule load merges or carrier reassignments accordingly.

Comparative Evaluation of Single-Stop vs. Multi-Stop Shipment

Objective

The decision interface evaluates the relative merits of individual (single stop) versus consolidated (multi-stop) shipping strategies in transportation logistics. Leveraging user-defined inputs (destination cities, weights, etc.) alongside distance and rate information quantifies potential cost savings and environmental benefits, informing decisions about bundling multiple shipments.

Data Inputs and Methodology

Number of Shipments

Users indicate how many shipments (one or two) they plan to evaluate.

Shipment Details

For each shipment, the user provides:

- Destination city and state (e.g., "Robbinsville, NJ")
- Shipment weight (e.g., in pounds)

These details allow the model to retrieve geographic distances and compute shipping costs.

Geographic Data and Distance Retrieval

When sufficient connectivity is available, the system queries an online geocoding service (e.g., Nominatim) to obtain latitude and longitude from the user's specified city and state. It then calculates any required distances—such as origin-to-destination or the legs of a multi-stop route.

- Coordinate Fetching – Translates each destination into latitude/longitude pairs.
- Distance Calculation – Employs geospatial libraries or formulas to derive driving or straight-line mileage.
- Fallback Handling – If a timeout or other issue occurs, the model defaults to approximate distance values to ensure continuity of the analysis.

Cost Calculation Framework

Separate Shipment Costs

When shipments are not combined:

$$\textit{Separate\_cost} = \textit{Cost(shipment 1)} + \textit{Cost(shipment 2)}$$

Multi-stop (Consolidated) Shipment Costs

Bundled shipments typically incur a rate structure that differs from separate shipping. For example:

$$\textit{Combined\_cost} = \textit{Base\_rate} \times (\textit{Leg1\_distance} + \textit{Leg2\_distance}) + \textit{Stop\_fee}$$

potentially augmented by weight-based or accessorial charges:

$$\textit{Combined\_cost} = \textit{Linehaul\_rate} \times (\textit{Total\_weight}/100) \times (\textit{Leg1\_distance} + \textit{Leg2\_distance}) + \textit{Additional\_fees}$$

Expected Savings

The cost difference between the two strategies is computed as:

$$\textit{Expected\_savings} = \textit{Separate\_cost} - \textit{Combined\_cost}$$

with a percentage metric:

$$\textit{Expected\_saving\_pct} = \textit{Separate\_cost}/\textit{Expected\_savings} \times 100\%$$

Decision Logic

After calculating costs, the model determines which option—single-stop or multi-stop—is more economical. It presents:

1. [Mode]: Returns 'Single-stop' if independent shipments are cheaper, or 'Multi-stop' if consolidation is preferred.
2. [Separate_cost]: The total of shipping each load separately.
3. [Combined_cost]: The total for a multi-stop run.
4. [Expected_saving] and [Expected_saving_pct]: Absolute and percentage savings if the multi-stop approach is chosen.

Model Performance

After loading 1,099 single-stop records and 233 multi-stop records (total: 1,568), the model was trained to predict single-stop shipping costs based on mileage, weight, and additional shipment features. The regression achieved:

- **RMSE (Root Mean Square Error):** 444.73
- **R^2 (Coefficient of Determination):** 0.88

These values suggest the model explains approximately 88% of the variance in single-stop costs, with an average deviation of around $445. The fitted model's primary coefficients include:

- **Mileage Coefficient:** 1.7257
- **Weight Coefficient:** 0.0004243
- **Intercept:** 611.9844

(See Figure 7, "Actual vs. Predicted Single-Stop Cost")

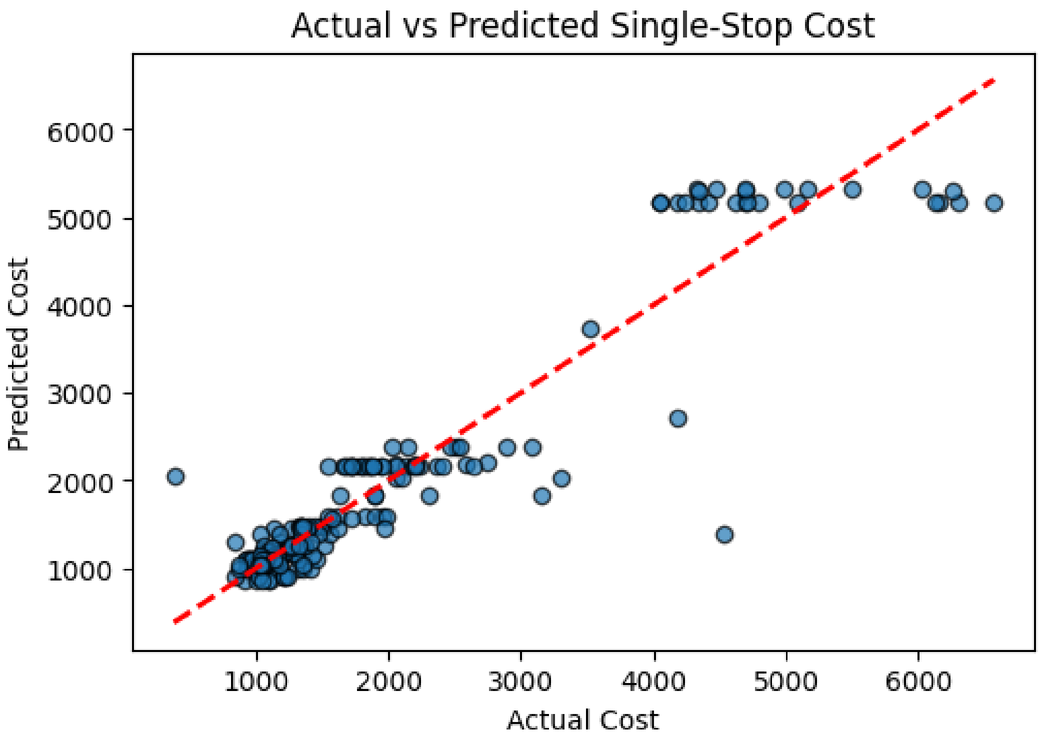

Figure 10. *Actual vs. Predicted Single-Stop Cost*

This figure reveals that most points cluster near the diagonal reference line (y=x), indicating strong alignment between the model's predictions and actual shipping costs. Some outliers exist for extremely high-cost shipments, which may reflect unusual operational nuances (e.g., special equipment fees or interstate toll differentials).

Aggregated Savings Analysis

An aggregated analysis of potential savings by consolidating multiple shipments produced the following summary:

- **Total Separate Cost:** $925,469.37
- **Total Combined Cost:** $610,972.33
- **Total Saving:** $314,497.04
- **Overall Freight Cost:** $2,657,478.4
- **Global Saving Percentage:** 11.83%

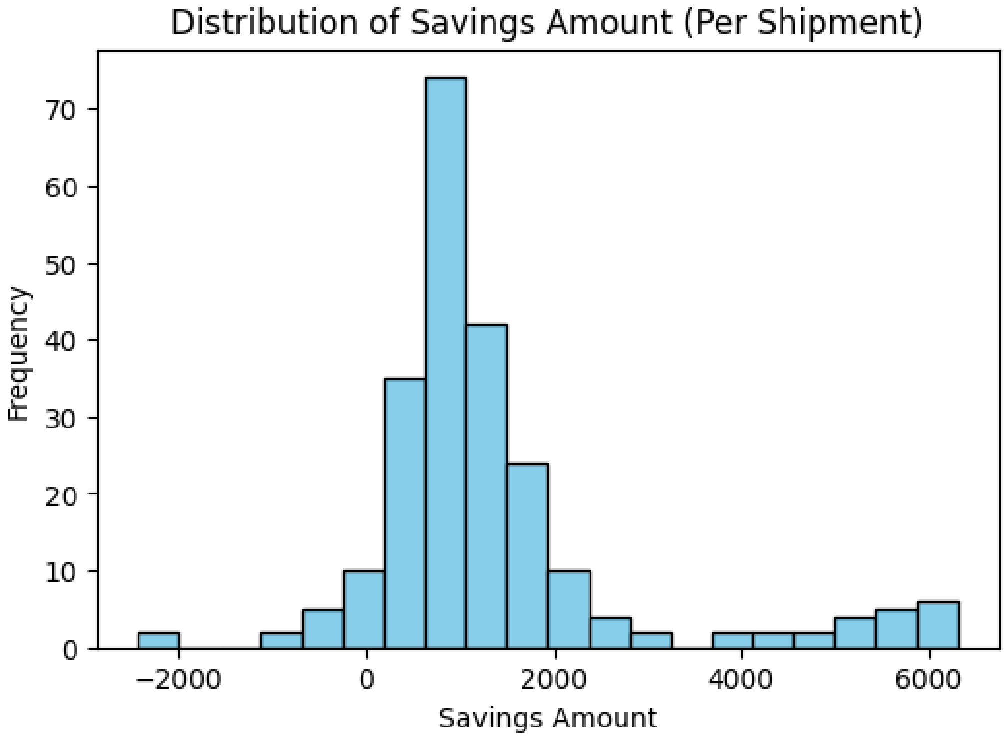

Figure 11. *Distribution of Savings Amount (Per Shipment)*

If all shipments suitable for consolidation were combined, the organization could realize an estimated 12% savings on shipping costs overall for the year of 2023-2024. The "Distribution of Savings Amount (Per Shipment)" histogram (Figure 8) shows how most shipments stand to benefit from moderate savings, with the distribution centered around $1,000–$2,000 in savings; a smaller subset experiences minimal or negative savings due to less favorable routings or additional stop fees.

Interactive Decision Interface Example

In addition to the bulk analysis, the code offers a command-line interface for daily or ad-hoc shipment inquiries. Figure 9 demonstrates a sample interaction:

1. **User Inputs:**
   a. Number of shipments (1 or 2)
   b. Destination city and state for each shipment (e.g., "Robbinsville, NJ")
   c. Corresponding weight

2. **Distance Retrieval:**
    a. The system queries a geocoding API (e.g., Nominatim).
    b. If the API times out (see "ReadTimeoutError" in Figure 3), the code uses approximate or cached distances.
3. **Output:**
    A dictionary indicating which shipping mode is more cost-effective and by how much. A typical output might read:

```
--- Decision Interface ---
Enter number of shipments to combine (1 or 2): 2

Shipment 1:
Enter destination city: Robbinsville
Enter destination state: NJ
Enter weight: 12576

Shipment 2:
Enter destination city: Nottingham
Enter destination state: MD
Enter weight: 20078
WARNING:urllib3.connectionpool:Retrying (Retry(total=1, connect=None, read=None, redirect=None, status=None)) after connection broken by 'ReadTimeoutError("HTTPSConnectionPool(host='nominatim.openstreetmap.

Decision Recommendation for New Shipments:
{'[Mode]': 'Multi-stop', '[Separate_cost]': 2555.7756973040186, '[Combined_cost]': 1569.4022942552633, '[Expected_saving]': 986.3734030487553, '[Expected_saving_pct]': 38.59389554761161}
```

Figure 12. *Decision Interface Example Output*

In this example, combining two shipments (one to Robbinsville, NJ, and another to Nottingham, MD) results in a single multi-stop route that is $986 cheaper than handling them as separate loads -- a savings of approximately 39%.

Practical Applications

Cost Efficiency

Consolidating smaller loads can lower net transportation expenses by maximizing vehicle capacity, although extra stops can introduce additional fees or complexity. The model's comparative analysis clarifies these trade-offs.

Carbon Footprint

By reducing the total number of trucks in transit, multi-stop shipping may help an organization meet sustainability goals through decreased emissions.

Lead Time Considerations

Combining shipments has potential time implications for any secondary destinations. Decision-makers can weigh extended transit times against the cost advantages of consolidation.

Streamlit Application: Truck Type Recommendation and Cost Estimation

Objective

This Streamlit application is designed to assist Allagash in making optimal logistics decisions regarding truck selection (Dry vs. Temperature-Controlled/Reefer) for shipments across various U.S. states. The goal is to recommend the most cost-effective and operationally safe truck type based on dynamic factors such as route mileage, freight weight, and ambient temperature while providing a granular breakdown (Linehaul and Fuel costs) for both truck types.

This solution complements our Power BI dashboard, which focuses on overall cost optimization and freight analytics. Thus, this Streamlit app is the decision-support component for day-to-day operational choices.

The application addresses two critical business goals:

1. **Product Quality Protection**: Ensures sensitive products are transported under appropriate temperature conditions.
2. **Cost Optimization**: Recommends dry trucks where permissible, reducing reliance on higher-cost reefers, potentially saving significant freight expenses annually

Methodology and Workflow

- **User Input Panel (Sidebar)**:
  - The user selects pickup and drop-off locations (city/state level) from dropdowns populated by historical shipment data.
  - The user inputs key shipment details such as:
    - Weight (lbs.)
    - Shipment Month
    - Shipment Week (1-4)
  - The app then automatically fetches corresponding geographical coordinates and retrieves historical weather data.
- **Geospatial Distance Calculation**:
  - Using the “geopy” library, the app calculates the straight-line mileage between the pickup and drop-off cities using latitude and longitude coordinates.
- **Weather Data Fetching**:
  - Using the “meteostat” API, the app fetches average historical temperatures (in °F) for both the pickup and drop-off cities during the selected week.
  - If temperature data is unavailable, the app allows for manual temperature input by the user to ensure flexibility.

Truck Recommendation Logic

The engine's core balances product safety (temperature sensitivity) against cost efficiency. The logic integrates industry best practices for “dry” truck usage versus “reefer” truck requirements based on ambient temperatures and shipment durations.

Temperature Range (°F)	Max Transit Time for Dry Truck	Recommendation
≤ 32	0 hours	Reefer (Freeze Protection)
32 - 40	≤ 12 hours	Dry or Reefer, depending on mileage

40 - 65	≤ 24 hours	Dry or Reefer, depending on mileage
65 - 75	≤ 18 hours	Dry or Reefer, depending on mileage
75 - 80	≤ 8 hours	Dry or Reefer, depending on mileage
> 80	0 hours	Reefer (Heat Spoilage Risk)

Table 1. *Product Logic Table*

- **Data Sources**
  - **Historical Shipment Data:** Used to build regression models for cost prediction.
  - **Geolocation API:** Calculates distances between pickup and drop-off points.
  - **Meteostat Weather API:** Retrieves historical average temperature data for selected locations.
- **Key Assumptions:**
  - Average truck speed: **50 mph**.
  - Predefined temperature bands dictate the maximum allowable transit time for dry trucks.
- **Temperature vs. Time Guidelines:**
  - The maximum allowable transit time is converted to the maximum permissible miles for a dry truck using the formula:

    $$\textit{Max Mileage} = \textit{Max Transit Time} \times 50 \textit{ mph}$$
  - If the calculated mileage exceeds this limit, a reefer truck is recommended to protect the product integrity.
- **Logic Basis** - This logic is grounded in industry best practices and internet research on transportation standards for temperature-sensitive freight (e.g., perishables, beverages, and temperature-controlled goods). While this logic provides a reliable starting point, we recommend that **Product** and **Quality Assurance teams** collaborate to:
  - Fine-tune temperature ranges based on specific cargo types and product shelf-life.
  - Introduce additional variables (e.g., humidity, seasonality, customer-specific handling protocols).

Cost Estimation Model & Model Performance

The cost model used in this application is derived from regression analysis on historical freight data. It estimates **Linehaul** and **Fuel Costs** separately for both dry and reefer trucks. The model incorporates key variables: weight, mileage, and truck type.

Formulas used:

1. **Linehaul Cost**:
   - $\textit{Linehaul Cost} = 554.53 - 0.0004 \times \textit{Weight} + 0.9826 \times \textit{Mileage} + 111.7638 \times \textit{Is\_Reefer}$
2. **Fuel Cost**:
   - $\textit{Fuel Cost} = -124.03 + 0.0013 \times \textit{Weight} + 0.7073 \times \textit{Mileage} + 70.0032 \times \textit{Is\_Reefer}$

Where **Is Reefer** = 0 for dry truck and 1 for reefer truck.

3. **Total Cost**:
   - $\textit{Total Cost} = \textit{Linehaul Cost} + \textit{Fuel Cost}$

These formulas allow for a cost comparison between truck types under varying shipment weight and mileage conditions.

We evaluated our predictive models for **Linehaul Cost** and **Fuel Cost** using the **R² (coefficient of determination)** metric:

- **Linehaul Cost Model**: R^2 = **0.83**
  This means the model explains **83%** of the variability in linehaul costs based on input features like mileage, weight, pallets, month, and drop location.
- **Fuel Cost Model**: R^2 = **0.95**
  This indicates that **the model captures 95% of the variation in fuel costs**, making it highly reliable for prediction purposes.

Interpretation Example:

For the **Fuel Cost Model** with R^2 = **0.95**:
Suppose the actual fuel cost for a shipment is **$1,000**, and the model predicts **$950**.

- Since **the model explains 95% of the variance**, the **$50 gap** likely arises from:
  - External factors like unexpected fuel surcharges, regional pricing anomalies, or driver behavior
  - Random noise or unmeasured variables (e.g., weather conditions, traffic delays)

A similar prediction scenario for the Linehaul Model with R^2 = 0.83 would suggest more variability is left unexplained compared to the fuel model.

Output Features

1. **Recommendation Summary**:
   - Based on the logic above, the app provides a clear recommendation: either a **Dry Truck** or a **Temperature-Controlled (Reefer) Truck,** along with reasoning (e.g., temperature or mileage constraints).
2. **Cost Comparison Table**:
   - Displays a side-by-side breakdown of Total Cost, Linehaul Cost, Fuel Cost, and Mileage
   - Highlights potential cost savings when a dry truck is viable.

Recommendation and Cost Estimation

Cost Comparison Table

	S.No	Truck Type	Mileage	Weight	Linehaul Cost	Fuel Cost	Total Cost	Recommendation	Reasoning
0	1	Dry Truck	326.5 miles	42000 lbs	$858.57	$161.52	$1020.10	✅ Recommended	Temperature is within the safe range for the distance (326.5 miles). Dry truck recommended.
1	2	Temperature-Controlled Truck	326.5 miles	42000 lbs	$970.33	$231.52	$1201.80	Not Recommended	

Figure 13. *Recommendation Result Output Example*

3. **Visual Insights**:

   The **bar chart** (Figure 11) visually compares dry vs. reefer costs. bar chart compares the total shipping cost for a dry truck ($1,020.10) versus a temperature-controlled truck ($1,201.80). The additional cost for the reefer truck is $181.70, representing a 15.12% increase.

   This differential underscores the importance of deploying reefer trucks only when product integrity and ambient temperature conditions demand it. When temperature control is not strictly necessary, switching to dry trucks can yield significant operational cost savings.

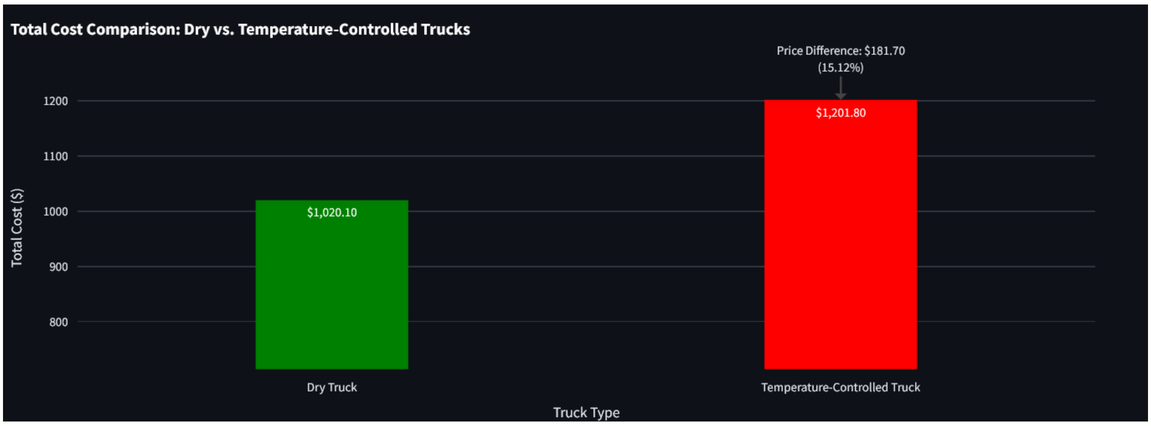

Figure 14. *Total Cost Comparison: Dry vs. Temperature-Controlled Trucks*

Business Value

- **Operational Efficiency**: The app minimizes human errors by automating truck selection and ensures compliance with temperature-sensitive product requirements.
- **Cost Savings**: It enables informed decision-making to reduce unnecessary use of expensive reefer trucks, optimizing freight spending.
- **Scalability**: The app's logic and model can easily be extended to different regions, products, and seasons.

Conclusion

Analyzing Allagash Brewery's logistics and supply chain data has provided valuable insights into cost optimization and operational efficiency. The project uncovered inefficiencies in shipment processes, carrier performance, and cost structures by leveraging Power BI for data visualization. The findings highlighted that many shipments were categorized as "sub-optimized," leading to higher transportation costs. Also, the analysis identified key areas for cost savings through route optimization, truck type switching, and improved pallet utilization.

By implementing these data-driven recommendations, Allagash Brewery can achieve a potential cost savings of 8.9% and enhance overall supply chain performance. The insights generated in this project serve as a foundation for continuous improvements in transportation efficiency, ultimately contributing to better resource allocation and increased profitability.

Further Recommendations

To build on the findings of this report, the following recommendations are proposed for Allagash Brewery:

1. **Enhance Route Optimization:**
    a. Implement dynamic routing algorithms to identify cost-effective delivery paths.
    b. Leverage real-time GPS tracking and predictive analytics to adjust routes dynamically.
2. **Improve Carrier Efficiency:**
    a. Collaborate with carriers to ensure optimal truckload utilization and minimize empty miles.
    b. Negotiate contracts based on data insights to secure better rates for optimized routes.
3. **Optimize Pallet Utilization:**
    a. Increase shipment consolidation strategies to maximize pallet capacity.
    b. Implement a tiered palletization system to improve load distribution.
4. **Reduce Fuel and Line-haul Costs:**
    a. Invest in fuel-efficient transportation options or consider alternative fuel sources.
    b. Evaluate and adjust the cost-to-mile ratio to enhance fuel expenditure management.
5. **Expand Data Analytics Capabilities:**
    a. Integrate AI and machine learning techniques to predict shipment delays and cost fluctuations.
    b. Develop an automated alert system to identify cost inefficiencies in real time.
6. **Continuous Monitoring and Benchmarking:**
    a. Establish a KPI-driven performance tracking system to monitor logistics efficiency.
    b. Benchmark Allagash's logistics costs against industry standards to maintain competitiveness.

References

1. "North America Truckload Freight Market Update: December 2024." *North America Truckload Freight Market Update: December 2024*, www.chrobinson.com/en-us/resources/insights-and-advisories/north-america-freight-insights/dec-2024-freight-market-update/key-freight-service-updates/na-truckload/. Accessed 24 Mar. 2025.

2. Make Beer Storage Simple With The 3-30-300 Rule https://www.yahoo.com/lifestyle/beer-storage-simple-3-30-002539135.html