Automating and Standardizing the Carrier Selection Process for Managed Transportation using Multi-Objective Optimization

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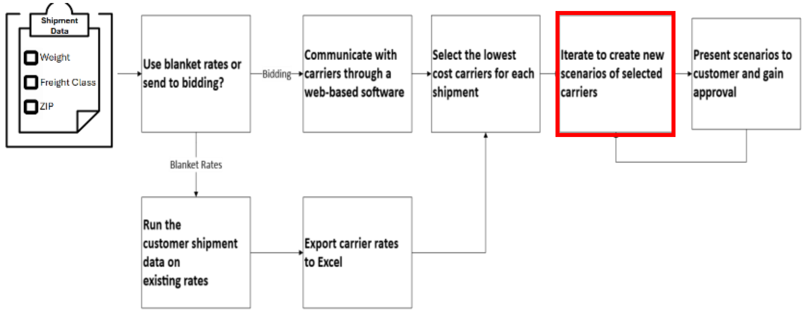
April 30, 2025

Managed Transportation Carrier Selection Process

ArcBest is a leading logistics company based in Fort Smith, AR. They aim to provide smart supply chain solutions through an extensive network of drivers and carriers. Our project focuses on ArcBest's Managed Transportation sector, which delivers comprehensive supply chain support by aligning customer needs with carrier capabilities. We partnered with Pricing and Supply Chain Engineers (PSCEs) who are contracted by Managed Transportation to handle the carrier selection process. As illustrated in the visual, PSCEs are tasked with selecting carriers for their customers, where the best carrier option might be an ArcBest provider, or it could be any other combination of providers that are not subsidiaries of ArcBest.

The carrier selection process begins by obtaining customer's historical shipment data, typically spanning 3 to 12 months. PSCEs create an initial scenario by assigning shipments to the lowest-cost carriers, then iterate to develop alternative scenarios that balance additional factors beyond cost. Once refined, these scenarios are presented for customer approval. PSCEs are concerned that the current process is ad hoc and manual, particularly when filtering carriers and accounting for customer-specific preferences during the iterate step.



Multi-Objective Optimization for Carrier Selection

To address ArcBest's concerns, we created optimization models in Python to automate the iterate step of the carrier selection process. We were provided data with 16 carriers, their retail and liftgate compliance, and their corresponding carrier metrics: carrier rates for each shipment ($), claims ratio (%), on-time delivery (%), and expected transit time (days). We normalized the data for cost, transit time, claims, and on-time delivery to fairly weigh the performance measures we are interested in. We then used Python's Pyomo framework to create three multi-objective models comparing each carrier's rate to the three other carrier metrics. By varying the weights on each of the two objectives, we use the models to create three separate sets of 11 scenarios.

Decision Variables:

- $X_{i,j}$ 1 if carrier i is assigned to shipment j
- Y_i 1 if carrier i is used in the scenario

Parameters:

- N Customer specified max number of carriers
- $C_{i,j}$ Cost of carrier i handling shipment j
- $P_{i,j}$ Transit time for carrier i handling shipment j
- D_i Claims ratio for carrier i
- M_i On-time delivery percentage for carrier i
- Z User specified minimum threshold percentage
- T_i 1 if carrier i meets the user specified minimum threshold
- $L_{i,j}$ 1 if carrier i meets the liftgate requirements of shipment j
- $R_{i,j}$ 1 if carrier i meets the retail requirements of shipment j
- E_i 0 if the customer want to exclude carrier i

Normalized Parameters:

- $C'_{i,j}$ Normalized cost of carrier i handling shipment j
- $P'_{i,j}$ Normalized transit time for carrier i handling shipment j
- D'_i Normalized claims ratio for carrier i
- $-M'_i$ Normalized on-time delivery percentage for carrier i

Constraints:

- $\sum_{i=1}^{16} X_{i,j} = 1 \quad \forall j$ Every shipment is assigned to exactly one carrier
- $\sum_{i=1}^{16} Y_i = N$ The total number of carriers used cannot exceed the customer specified maximum
- $X_{i,j} \le Y_i \quad \forall i,j$ A shipment can only be assigned to carrier i if that carrier is used
- $X_{i,j} \le C_{ij} \quad \forall i,j$ A carrier can only be assigned to a shipment if the carrier bids on the shipment
- $X_{i,j} \le L_{ij} \quad \forall i,j$ A shipment requiring a liftgate can only be assigned to a carrier with liftgate ability
- $X_{i,j} \le R_{ij} \quad \forall i,j$ A retail shipment can only be assigned to a retail-compliant carrier
- $Y_i \le T_i \quad \forall i$ Exclude carriers if they do not meet the minimum user specified threshold
- $Y_i \le E_i \quad \forall i$ Ensures that if carrier i is excluded, the carrier is not used.

Objective Functions:

$$\min \; w_c \sum_{i=1}^{I}\sum_{j=1}^{J} C'_{i,j} X_{i,j} + w_p \sum_{i=1}^{I}\sum_{j=1}^{J} P'_{i,j} X_{i,j}$$

Min total weighted normalized cost and transit time $w_c + w_p = 1$

$$\min \; w_c \sum_{i=1}^{I}\sum_{j=1}^{J} C'_{i,j} X_{i,j} + w_d \sum_{i=1}^{I} D'_i Y_i$$

Min total weighted normalized cost and claims ratio $w_c + w_d = 1$

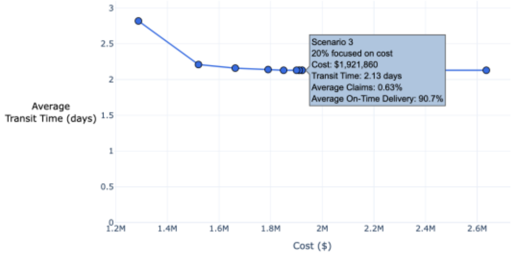
$$\min \; w_c \sum_{i=1}^{I}\sum_{j=1}^{J} C'_{i,j} X_{i,j} + w_m \sum_{i=1}^{I} -M'_i Y_i$$

Min total weighted normalized cost and on-time delivery $w_c + w_m = 1$

$w_c \in [0.0, 0.1, \ldots, 1]$

Pareto Analysis and Potential Impacts

After looping through each weighted multi-objective function a Pareto front is created to visualize trade-offs between conflicting objectives. Each dot on the front represents a different scenario. Interactive visualization is used to enhance the user's experience of viewing Pareto fronts with hover boxes, which display the scenario number, how cost focused the scenario is, the total cost, average transit time, and average on-time delivery. User interfaces are implemented within the model and in a dashboard view where users may select scenarios they wish to compare. Comparisons are be made using three tabs: the Pareto Front tab, the Scenario Summary tab, and the Scenario Assignments tab. After using the Pareto front to visualize scenario tradeoffs, details of selected scenarios are displayed in a Scenario Summary table where information about the shipment count and awarded rate assigned to each carrier is shown. If more details of a scenario are wanted, the user may view a Scenario Assignments tables which lists the individual shipments assignment to each carrier and the corresponding rate.



After surveying PSCEs on the impacts of our model and output visualization, we found that our work reduced the average iteration time by 79%, increased the average number of scenarios produced within the improved timeframe by 1400%, and improved consideration of non-cost-related variables by 45.8%. Overall, the multi-objective model and its outputs can be used to improve the carrier selection process and enhance future ArcBest business decisions.