Optimal Railroad Routing for Shipping Containers

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Who is CMA CGM?

- **3rd largest** container shipping company in the world
- Primarily a maritime shipping company! They own a fleet consisting of **566 vessels**
- Presence in **160 countries**
- Operate at **420/521 of the world's commercial ports**

Problem Structure

A network problem with demand forecasted between origin/destination pairs. In this problem, we attempt to minimize the total cost of transporting shipping containers along rail lines while meeting demand. Beyond transportation costs, we also consider **penalties and incentives** that are defined in contracts between CMA CGM and rail carriers.

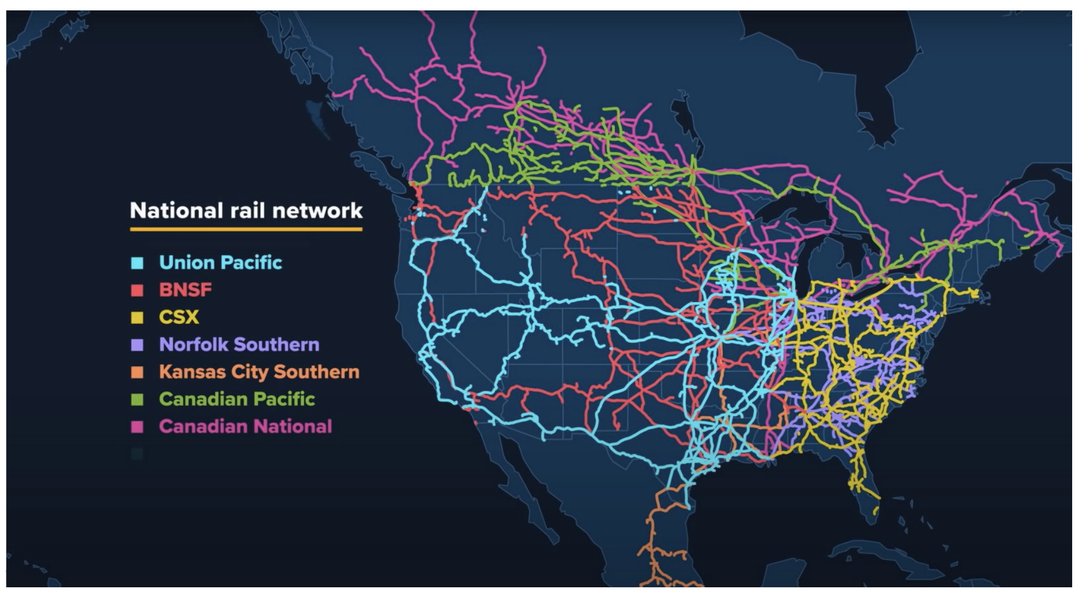


Figure 1:North American Railroad Network and Major Carriers

Penalties and Incentives

Penalties

- ✓ MAG Penalties
- ✓ Balance Penalties
- ✓ GRI Penalties
- ✓ CSX Lane Commitment Penalty

Incentives

- ✓ Quick Pay Incentives
- ✓ BNSF Inland Intermodal Incentives
- ✓ Growth Volume Incentives
- ✓ Balance Incentives

Figure 2:Types of penalties and incentives included in railroad carrier contracts

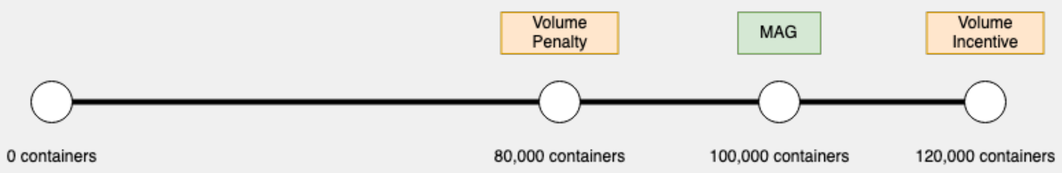


Figure 3:CMA CGM is penalized when volume is below the MAG threshold and incentived when volume is above it

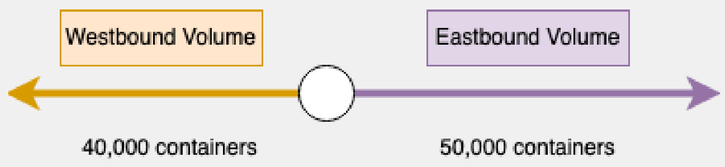


Figure 4:Railroad carriers penalize imbalanced eastward/westward flows and incentive balanced

Sliding Contract Windows

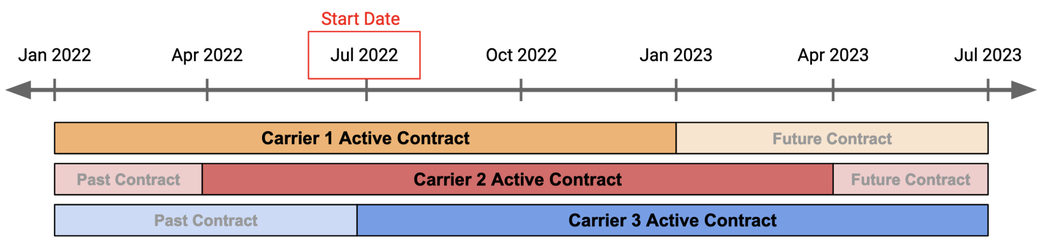


Figure 5:Our model seamlessly accounts for sliding contract windows between carriers

CMA CGM's Current Process

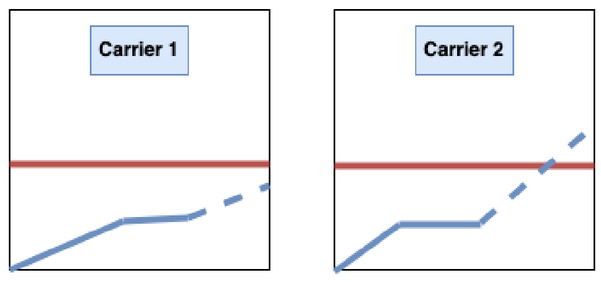


Figure 6:Manual Analysis

1. View volume projections via dashboards
2. Carrier 1 projection is below the goal. Select more routes along Carrier 1

How We Solved This

Mixed-Integer Optimization!

- Convex Formulation
- **470K** Integer Variables
- **3.5K** Binary Variables
- **570K** Total Constraints

Objective: Minimize the total cost of routing the forecasted volume over the next twelve months. This cost includes linehaul charges, surcharges, penalties, and incentives.

Decision Variables

- Which route should we select for a given Origin/Destination (OD) pair?
  - Over 1200 OD pairs in the network
- How much volume should we send along the selected route in a given month?
  - Over 1 million containers transported along rail lines annually

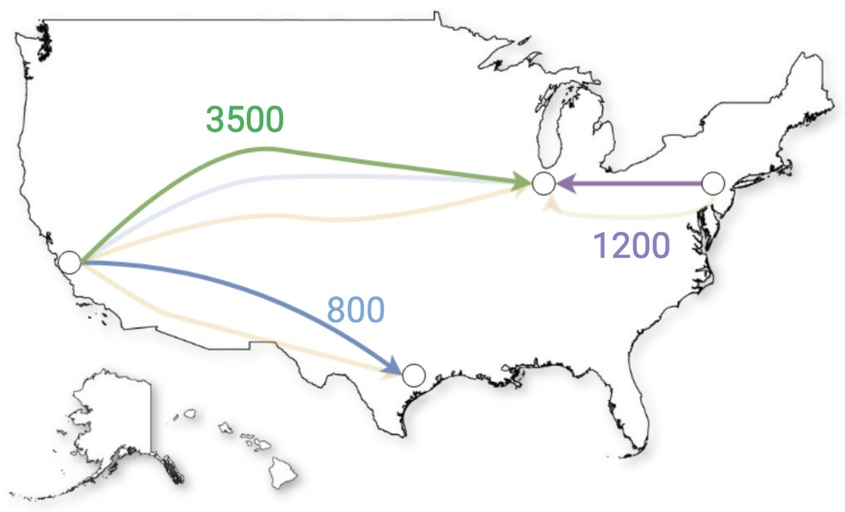
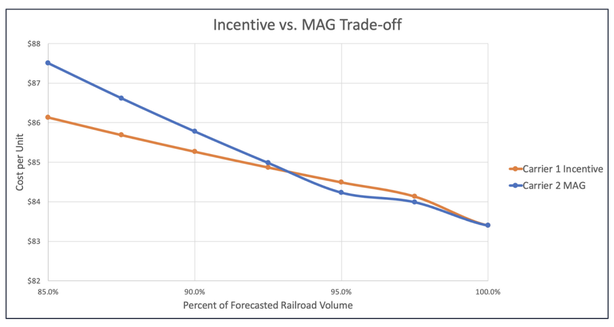


Figure 7:Select exactly one route per origin/destination pair

Interpretable Routing Strategies



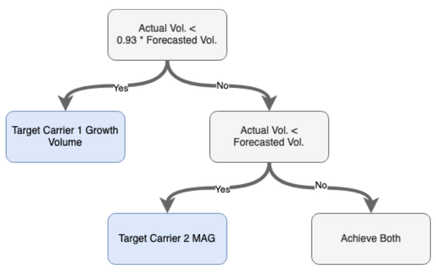


Figure 8:Example decision tree to decide which contract to prioritize

Scenario Comparisons

27 scenarios run with ignored constraints, added constraints, or changes to the demand forecast. Provided **global cost implications** of various constraints – useful for future contract negotiations!

- How much is gained by considering penalties and incentives in our model?
- How much can be saved by eliminating customer preferences?
- What savings opportunities could we potentially negotiate into future carrier contracts?

Projected Savings Opportunities

- **$17M** in immediate savings opportunities
- **Interpretable strategies** to help route planning teams decide between railroad carriers
- **Scenario-based simulations** of optimized model
  - Additional **$9M** savings opportunity in future contract negotiations
  - Global cost comparison across various demand scenarios/contract strategies