Optimization Framework for Recovery from Railway Freight Network Disruptions

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joint work with:
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Nader Azad, Saint Mary’s University
Change in Management Philosophy?

- Japan’s Tsunami in March 2011
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- Japan’s Tsunami in March 2011
- Just-in-time to Just-in-case
Railroad Freight Networks and Disruptions

- Railroads shipped over 1600 million tons of goods in the United States (DOT, 2013) and 337 million tons in Canada (TC, 2013).
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- Disruptions to railroad operations, are not infrequent. For example, 61 disruptions were registered for just the Seattle-Vancouver Amtrak operation between 2009 and 2013.
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  - *Example*: Re-routing strategy
Assumptions

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- Non-disrupted portion of the train (i.e., railcars with contents intact) could still be used to meet a portion of the overall demand.
Research Goals

- Develop a methodology to aid decision makers in both pre- and post-disruption periods
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  - Identifying critical service legs in the network
  - Developing appropriate mitigation and recovery strategies
Research Methodology

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- **Predictive model to identify critical service legs**
Research Methodology

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- Consider four distinct recovery strategies: re-routing from the point of disruption, re-sending from the origin nodes, repairing the disrupted rail segments, and using third party services
- Predictive model to identify critical service legs
  - Prescriptive model to find optimal recovery strategy with the least cost
Flowchart

Start

Step 1: Calculate base-case (normal network) cost

Step 2: Conduct what-if disruption scenarios for each service leg and calculate related costs

Step 3: Identify base-case significant explanatory variables to predict disruption costs. Calculate estimation errors.

Step 4: Is the estimation error significant?

No

Step 5: Add it to the list of critical service legs and apply mitigation

Yes

Step 6: Update the network structure.

Step 7: Collect data and solve post-disruption model and apply recovery strategies.

End
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Pre-Disruption Period

No
Flowchart

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Post-Disruption Period

Step 7: Collect data and feedback.
Flowchart

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End
Pre-disruption:
100 railcars have to be sent every week from yard A to yard E. The time to delivery before disruption is seven days. The current network has two itineraries: A-B-E; and, A-B-C-D-E. We assume that the itinerary A-B-E is being used before disruption.
Disruption:
A disruption occurs for a train service passing the service leg B-E with capacity of 100 railcars. The disruption occurs at site K on the third day of the week, and results in the loss of 40% of railcars.
Post-disruption:
Add the disruption point K as a virtual node to the network whose capacity is equal to the 60 undamaged railcars. The time to delivery post-disruption is only 4 days. The available itineraries are: A-B-E, A-B-C-D-E (existing itineraries from pre-disruption), K-B-C-D-E (re-routing strategy) and K-E (repair strategy). Capacity for KB and KE is 60 railcars.
Case Study: Railroad Network in the Midwest United States

The yards are connected by thirty-one train services, which amongst them share 53 service legs.
Case Study: Railroad Network in the Midwest United States

- 25 yards in the network, and each is both a supply and demand point for the others.
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Case Study: Predictive Model Results

- We run the pre-disruption model (Step 1) and for each service leg the post-disruption model is implemented (Step 2).
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- Run a multiple regression model where the optimal volume of shipment (i.e., X1) and the ratio of itineraries (i.e., X2) using a service leg before disruption are used to predict the post-disruption cost (i.e., Y) associated with a service leg.

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Case Study: ABC Analysis

Plot Residuals (cost from post-disruption model  cost from predictive model)
Case Study: ABC Analysis

Plot Residuals (cost from post-disruption model vs. cost from predictive model)
Case Study: ABC Analysis
Case Study: Mitigation Strategy

Mitigation strategy for critical service legs: Add new itineraries by renting the tracks owned by competing railroad operators
Case Study: Mitigation Strategy
Case Study: Results
The mitigation strategy implementation results in significant enhancement to the railroad transportation resiliency with minimal changes to the existing infrastructure and insignificant increase in the pre-disruption transportation costs.