Analysis of Demand Variability and Robustness in Strategic Transportation Planning

May 25, 2010
Cambridge, MA

Ahmedali Lokhandwala
Candidate for M.S. in Transportation & M.Eng. in Logistics and Supply Chain Management, 2010

Thesis Advisor: Dr. Chris Caplice

Overview

Trucking Industry
- Trucking is the largest mode of commercial freight transportation in the US, contributing $660 billion in revenue and hauling 68.9% of all freight
- All carriers in the industry need to develop a strategic transportation policy to anticipate and satisfy customer requirements at lowest costs and with high service quality

Criticality of Transportation Planning
- Most traditional off-the-shelf planning software packages use “average demand per week” occurring on transportation lanes as the basis for planning
- Supply/demand/geographical variability over the transportation network results in sub-optimal execution of the plans

Need of the Hour
- Planning mechanisms need to incorporate variability
- Robust planning methods must be easy to execute at an operational level
Planning versus Execution

Long Term Planning
- Fleet Acquisition
- Allocation of fleet capacity
- Capital investments
- Hiring Drivers
- Relationships with For-Hire Carriers

Gap
- Demand Variability
- Complexities in execution

Short-term Planning
- Allocating fleet capacity locally to optimal routes
- Emergency shipments of unmet requirements

Freight Network Optimization Tool (FNOT)

- FNOT is a Large-Scale Linear Optimization Model created by the MIT-CTL Freight Lab team

- FNOT uses stochastic methods for allocating weekly demand over a transportation lane to an optimal mix of private fleet and for-hire carriers

- FNOT also creates optimal tour routes for hauling demand on the private fleet

- Thus, FNOT creates a planning strategy by optimizing load movements over the distribution network
Need for Simulations

- FNOT is a steady state model
- Real-time application of the model requires operational flexibility to re-optimize the network on a weekly basis – this adds a lot of complexity during execution
- Important to simulate weekly demand scenarios over the network for a year, and test the plan created by FNOT to see if it is robust
Planning Hierarchy

FNOT Planning Model

Methodology for creating Plans
- Stochastic Plan
- Deterministic Plan

Operational Flexibility in Annual Plans
- Complete Operational Flexibility
- Zero Operational Flexibility
  (Not Addressed in this Thesis)

Variations in Annual Plan through Heuristics
- Minimum Volume Assignment
- Maximum Volume Assignment

Plan of Action

Complete Flexibility
- Volume allocation re-optimized every week
- Best-case scenario

Zero Flexibility
- Volume allocated to stochastic plan tours only
- Excess demand goes to for-hire
Metrics used for Analysis

Network Level
- Costs, Volume Allocation, Average Cost per Load, Average Cost per mile

Facility Level
- Costs, Volume, Distance, Loaded miles, Tour details, Driver utilization

Tour Level
- Tour Occurrence, Tour Fickleness, Demand Statistics

Lane Level
- Lane Fickleness, Demand Statistics

Network & Facility Level Results

- Minimum Volume Assignment scenario is within 6% of Total Costs for Complete Flexibility Scenario

- Standard Deviations for metrics in the Min. Vol. Assignmnt. case is lower – indicating tighter bounds on weekly operations

- Facility Level metrics mirror the results observed at the Network Level – indicating no loss of generality in behavior of metrics
Tour Level Analysis

Histogram & CDF of All Tours in Complete Flexibility Operational Plan

Consistent Tours!

Histogram & CDF of Stochastic Plan Tours

Greater Percentage of Consistent Tours!!
Tour Level Analysis

Break-down of the No. of weekly generated tours that consist of Stochastic Plan Tours

Operational Plan Simulation Week

- No. of tours generated, that were part of the Annual Plan (71%)
- "Ad-hoc" tours generated, that were not part of the Annual Plan (29%)

Lane Level Analysis

Lane Volume Assignment to Private Fleet

- 81% of these lanes are Outbound (DC-S) Lanes
- 86% of these lanes are Inbound (V-DC) Lanes
Lane Level Analysis

Conclusions

- The Stochastic Plan created by FNOT is operationally viable using the Minimum Volume Assignment scenario
  - It handles 71% of Demand Variability
  - It is within 6% of the Optimal Cost Solution
  - It is easy to execute, since it requires zero operational flexibility on a weekly basis
  - It reduces the chances of sub-optimal local decision-making and maintains the network at close to system-optimal levels
  - It reduces the gap between planning v/s execution
THANK YOU

QUESTIONS?