Improving Freight Transportation Reliability

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Webinar / Monday, November 16, 2015 / 1:00 – 2:00 PM ET

Moderated by James B. Martin, PE
Institute for Transportation Research and Education (ITRE) at NC State
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• Center theme is “Strategic Transportation Policies, Investments and Decisions for Economic Competitiveness”

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• During and following remarks, presenters will address as many questions as possible.

• At end of presentation, contact information will be provided for follow-up with presenters.
Webinar Presenters

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Basic Concepts

• Travel time reliability
  – Many definitions exist
  – *In principle*: times of arrival are within the desired time of arrival windows
  – *Practically*: consistency in travel times, given a context
  – Pertains mainly to single routes or paths

• Service reliability
  – Actual delivery times are within promised arrival windows
  – Captures the effects of connections
  – Pertains mainly to overall system performance
Travel Time Reliability

- Trajectory control (explicit or implicit)
- Real-time responses to system status
- Variance management

- Implicitly focuses on minimizing the disutility of travel
- Feedback loop should account for impacts on disutility for users
Best Practice

• Define success
  – Set context
  – Select metrics
  – Establish target bands
• Monitor, analyze
  – Collect data
  – Actual vs desired CDF
  – Seek explanations
• Objectives
  – Meet or exceed targets
  – Identify actions
  – Continuous improvement
Analysis

- Measure performance
- Label observations based on context
- Analyze cause-effect relationships
- Take actions to improve performance
Context is Important

• It is always important to understand the data being analyzed and the context

• Data
  – Average travel times from system sensors
  – Individual vehicle travel times from Bluetooth, tags, etc.

• Context
  – Time period(s)
  – Span of the data (month, season, year, etc.)
  – Days included (all, weekdays, workdays)
  – Non-recurring events (included? documented?)
Average Rates - Urban Freeway
Vehicles – Urban Freeway

• Bluetooth data
• Sensor 39 – Sensor 09
• Winter season
• I-5 south of Sacramento
• Southbound (PM Peak)
• Weekdays

Off Peak

PM Peak

Almost always the same

PM Peak

Incidents w/o Weather

Travel Rates

Incidents with Weather

Travel Rates

Incidents w/o Weather

Standard Deviations by Percentile

Almost always the same
Trucks vs Other Vehicles

- Travel rates can be different
  - Kinematics
  - Speed limits
  - Not travel times for general traffic flow
- For a specific company
  - Not even trucks generally
  - Specific trucks and drivers

The fact that the trucks are different might or might not be visible in the overall travel time distribution, but they are specific vehicles nonetheless.
Truck Tours – Early and Late

- Specific vehicles and drivers
- Immersed in highway flows
- CDFs, PDFs for their performance
- Individual vehicles, not averages
- Specific times of day
- Tours, not routes
- Both early and late matter
- Real-time adjustments are critical

Diagram:
- Late arrival
- Late departure
- Early arrival
- Makespan of the tour
Tour Management

- Service windows
  - Settable or imposed
  - Penalties
- Makespan constraint
- Slack times

![Tour Trajectory Graph](chart.png)

- Deviations by Stop
- Departure deviation
- Arrival deviation
- Cumulative distribution of deviations

![Cumulative Distribution Graph](chart2.png)

- Expected
- Actual
- Tolerable Early
- Tolerable Late

Arrival deviation
Departure deviation
Cumulative distribution of deviations
Vehicle Routing Management

- Pre-departure planning
  - Reliability balancing
  - Fleet size $\cong$ reliability trade-offs
- Real-time adjustment
  - Node-to-node paths
  - Node sequences
  - Pick-up reassignments
  - Delivery resequencing
Reliability Balancing / Fleet Sizing

Reliability Balancing
• Deviation performance by truck
• Balancing the deviations
• Makespan tradeoff
• Efficient frontier

Fleet Sizing
• Policy on deviations
• Limit on makespan
• Truck productivity expectations
Facility Siting

- Reliability as a factor
- Customer costs
- Fleet size cost
- Operating cost
Siting Tradeoffs

- Location choice
  - Cost, workforce, accessibility
- Delivery cost
  - Overall mileage, time
  - Reliability
Measures of Reliability

• Fraction or % “on time”, i.e. within a specified time window
• Standard deviation of arrival or delivery times
• Fraction of failures or missed deliveries
• Costs or penalties for failures
Reliability Effects

• Predictable ”just-in-time” deliveries can significantly reduce:
  – Inventory sizes and storage costs
  – Re-handling of freight
  – Queues and waiting times in terminals
  – Idling time and costs for personnel, facilities and equipment at transfer terminals and destinations

• Costs of transportation

• Customer satisfaction and resulting sales
Reliability Improvement Options

• Carrier-based options
  – Facility location
  – Facility design and capacity
  – Facility operation & maintenance
  – Vehicle design characteristics
  – Vehicle operation & maintenance
  – Fleet selection
  – Workforce recruitment & training
  – Workforce management
Reliability Improvement Options

• Carrier-based options (continued)
  – Market selection & development
  – Route planning
  – Scheduling
  – Real-time control, including dispatching, routing, and re-assignment
  – Contingency planning and real-time decision-making
  – Response to major disruptions
  – Exploiting information technology
Reliability Improvement Options

• Public sector options
  – Infrastructure development
  – Infrastructure management
  – Traffic management
  – Information services for carriers and users
  – Regulation
  – Inspection & enforcement
Cost Trade-offs

• The pursuit of reliability can increase some costs while decreasing others.
• Reserve factors (in vehicle sizes, fleet sizes, workforce, facilities, equipment, and schedules) are costly but reduce the expected costs of delays, failures and penalties. The right balance may be found through economic analysis and optimization.
Advantages of Relying on Transfers

Numbers of routes, vehicle miles, economies of scale and concentration, service frequencies, some infrastructure requirements.

Without transfers
\[ n(n-1) \text{ routes} \]

With transfers at hub
\[ 2n \text{ directional routes} \]
Transfer Coordination =

Minimization of transfer costs through appropriate planning, scheduling and control. This may involve:

- Network design
- Location and design of transfer terminals
- Fleet selection
- Vehicle and crew scheduling
- Design and control of transfer operations within terminals
- Monitoring operations
- Predicting vehicle movements
- Vehicle dispatching
- Controlling delay propagation
Disadvantages of Relying on Transfers

• Circuity
• Transfer handling time and costs
• Capacity requirements at transfer terminals
• Congestion and delays at transfer terminals
• Managerial complexity
Costs Associated with Transfers

- Vehicle delay
- On-board user delay
- Downstream user delay
- Delay propagation
- Missed connections
Transfer coordination *may* be desirable for *some* vehicle pairs at transfer terminals, depending on route characteristics, expected wait times at transfer terminals and elsewhere, variability of travel times, slack times needed in schedules, information on vehicle locations and their expected arrival times, connecting freight and freight waiting downstream, and effects induced elsewhere in the system.
Coordination Options

Deterministic coordination of routes at hub terminal: may use (a) equal headways, (b) integer-multiple headways, or (c) uncoordinated headways
Deterministic Coordination in Multiple-hub Network
Transfer Coordination under Uncertain Conditions

Routine (rather than major) Schedule Disruptions

\[ f(t) \]

- Expected ready time
- Scheduled departure

Slack

Time
Cost vs. Slack Time, with Uncertain Travel Times
Lost Revenue, with Limited Vehicle Capacity
Profit vs. Vehicle Capacity, with Uncertain Demand

![Graph showing profit vs. vehicle capacity](image-url)
Dispatch a ready vehicle (RA-RD) if some connecting vehicles (L1-L3) are still late?
Dispatching Decision

For each ready vehicle, the cost of waiting for additional late vehicles can be plotted. Choose the lowest local optimum.
Real-time Dispatching Model

- A real-time dispatching control model is developed to alleviate schedule disruptions.

- Disruptions may sometimes affect the system operations, and the previous optimal plan may become non-optimal or even infeasible.

- When disruptions occur, we mainly consider how to adjust or re-optimize the original plan to adapt the changing environment and how to get back on track in a timely manner while effectively using our available resources.

- The control model will determine through an optimization process which ready outbound vehicles should wait for which late inbound ones.
Network Configuration

Case 4 Large Network Configuration

Routes 1 - 13

Routes 14 - 17

Routes 18 - 30

Route 33

Routes 31 & 32
Dispatching Optimization Example

Real-Time Dispatching in Single Commodity Multi-Mode & Single Hub Network

• 9 light truck routes and 1 container train route

• All parameter settings and the network configuration are the same as in Case 1

• Assume that inbound vehicles on Routes 1, 3, 5, 6, 8, and 9 have estimated delays while the vehicle on Route 10 is ready to be dispatched.
Inbound Route Delay Information

- The optimized holding time and cost solved with the hybrid GA-SQP algorithm are 0.255 (hr) & 1272 ($).
- The results indicate that the ready vehicle should wait until the 5\textsuperscript{th} late vehicle (from Route 6) arrives.
Thank You! Questions?

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