Simulating the Impact of Higher Speed Rail on North American Freight Railroads

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Outline

- Introduction
- Shared corridor stringline analysis
- Simulation methodology
- Single Track
- Double Track
- Future work
More Demands on U.S. Freight Network

- Freight Growth
- Reliability
- Intercity Passenger Trains
- Environment
- Commuter Service
- Low Cost Transportation
Introduction

- **Theoretical capacity** is the maximum amount of flow on a mainline per unit time
  - Trains per day
  - Annual million gross tons
- **Practical capacity** is the maximum flow on a mainline while maintaining a specified level of service
- **Heterogeneous delays** due to multiple train types interfering with each other on the same mainline
- **Minimum Run Time** the fastest time a train can traverse across the mainline without interference from other trains
Intermodal & Bulk Trains

- Previous work at the University of Illinois simulated the interactions between intermodal and bulk trains in single track configuration (Dingler et al. 2010)
- Both train types experienced higher delays in heterogeneous traffic mixtures
- The cause of these extra delays was linked to the dispatching priorities and the performance of trains accelerating out of passing sidings
50 MPH Freight Line
110 MPH Passenger Line

X4 Conflicts
Running One 110 MPH Train in a 50 MPH Network

![Graph showing train conflicts](image-url)
Key Concepts

- In Homogeneous traffic, faster speeds will have fewer conflicts with other trains.
  - Infinitely fast trains cause no conflicts
  - A stopped train will cause conflicts to other moving trains

- When a faster train is present in a slow network, it will experience less meets, but:
  - Introduce heterogeneous conflicts
  - Meet resolutions become more complicated
Rail Traffic Controller

- Developed by Eric Wilson from Berkeley Simulation Software
- Emulates a dispatcher controlling train movements across a network based on train priority
- Integrated train performance calculator
- Inputs: track, signals, trains, and schedule
- Output: delay, average velocity, on time performance
Routes Analyzed

1. Single track with 15 miles between siding centers
2. Double track with 15 miles between universal crossovers

- 260 miles long
- 2.6 miles between signals
- 2-block, 3-aspect signaling
- 1 Origin-Destination Pair
- 0% grade & curvature
### Train Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Unit Freight Train</th>
<th>Passenger Train</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td>x3 SD70 Locomotives</td>
<td>x2 P42 Locomotives</td>
</tr>
<tr>
<td><strong>No. of Cars</strong></td>
<td>115 hopper cars</td>
<td>11 Articulated Talgo Cars</td>
</tr>
<tr>
<td><strong>Length (ft.)</strong></td>
<td>6,325</td>
<td>500</td>
</tr>
<tr>
<td><strong>Weight (tons)</strong></td>
<td>16,445</td>
<td>500</td>
</tr>
<tr>
<td><strong>Maximum Speed (mph)</strong></td>
<td>50</td>
<td>79,90,110</td>
</tr>
<tr>
<td></td>
<td>±20 minutes departure time</td>
<td>32.4 miles between stops</td>
</tr>
</tbody>
</table>

![Train Simulation Diagram]
Methodology

- The track is simplified to facilitate comparison between key variables:
  - Traffic mix
  - Passenger train speed (79 mph – 110 mph)
- All trains are scheduled evenly throughout the day in each direction
  - At 24 trains per day, a train leaves each terminal every two hours
  - Passenger trains are scheduled to start within daylight hours: 7am – 8pm
- The simulation analyzes three days worth of traffic
- Each traffic mix simulation is repeated 4 times.
How Train Delay is Calculated

- Two standard derivations
  - Difference between *minimum* run time and actual run time
    - Related to run time and average speed
  - Difference between *scheduled* run time and actual run time
    - Related to reliability and on-time performance
- Normalized over 100 train miles
Delay Increases Due to Heterogeneity in Train Type

36 Trains Per Day

- Freight Train Delays
- Average Train Delay
- Passenger Train Delays

Heterogeneity (% Freight Trains)

Delay Per 100 Train Miles

- 0% Passenger
- 100% Freight
Experiment Design

1. **Base Case**: Homogenous freight only line

2. **Passenger Case**: Determine the impact to the freight trains by adding additional passenger trains to the base case

3. **Compare** the results of an increase in passenger traffic to an increase in freight traffic for each base case scenario

4. **Change** the speed of the passenger trains
Distribution of Delays

Average Delay Per 100 Train Miles (min)

Frequency

0% 5% 10% 15% 20%

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 More

24 Freight Trains
Distribution of Delays

Average Delay Per 100 Train Miles (min)

Frequency

0% 5% 10% 15% 20%

0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 More

24 Freight Trains

24 Freight Trains + 8 Passenger Trains
Variation of Freight Train Delay

Adding Freight Trains

Adding 110 MPH Passenger Trains

Total Trains Per Day

Delay Per 100 Freight Trains Miles (min)

Freight Trains Per Day

- 100%
- 80%
- 60%
- 50%
- 40%
- 20%
- 0%
The Effect of Passenger Speed on Freight Delay

- Adding 50 MPH Freight Trains
- Adding 110 MPH Passenger Trains
- Adding 90 MPH Passenger Trains
- Adding 79 MPH Passenger Trains

Graphs showing the delay per 100 freight train miles (min) against the total trains per day, with different passenger speeds and their effects on freight delay.
Additional Delays to Freight Trains Caused by Passenger Trains

Passenger Train Speeds
- 79 mph
- 90 mph
- 110 mph

Additional Delay Per 100 Freight Train Miles (min)

Additional Passenger Trains Added to 24 Freight Trains Per Day:
- +2
- +4
- +6
- +8
- +10
- +12
- +14
- +16

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## Weak Relationship Between Delay and Speed

### Average Train Delay Per 100 Train Miles

<table>
<thead>
<tr>
<th>No. of Freight Trains</th>
<th>No. of Passenger Trains</th>
<th>50 MPH</th>
<th>79 MPH</th>
<th>90 MPH</th>
<th>110 MPH</th>
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<tr>
<td>24</td>
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<tr>
<td>0</td>
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### 90th Percentile of Train Delay Per 100 Train Miles

<table>
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<th>79 MPH</th>
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Effect of Speed on Passenger Train Run Time

Time to Travel 100 miles (min)

Additional Passenger Trains Added to 24 Freight Trains Per Day

- 79 mph
- 90 mph
- 110 mph
Double Track Analysis
Double Track Assumptions

- An idealized double track line should behave similarly to a conveyer belt
- Speed differentials are the cause of most of the delays
- 2nd Track Utilization:
  - **Low Capacity Case:** The track in the opposing direction is used for overtake maneuvers
  - **High Capacity Case:** There are no overtakes. The faster trains will trail behind slower trains
Overtakes Consume Capacity (1)
Overtakes Consume Capacity (2)

The amount of 2nd track capacity consumed by the overtake depends on crossover spacing, and the speed difference between trains.
Adding Passenger Trains in Double Track

Adding 79 MPH Passenger Trains

Adding 90 MPH Passenger Trains

Adding 110 MPH Passenger Trains

Adding Passenger Trains in Double Track
Delays at 64 Trains Per Day in Double Track

- 110 mph
- 90 mph
- 79 mph

Average Delay Per 100 Train Miles (Min)

Heterogeneity (% Freight Trains)
Passenger Train Performance in Double Track

- 79 mph
- 90 mph
- 110 mph

Time to Travel 100 Miles (min)

Heterogeneity (% Freight Trains)
Distribution of Freight Delays on Single & Double Track

Cumulative Frequency

Double Track

Single Track

- 79 mph (1)
- 90 mph (1)
- 110 mph (1)
- 79 mph (2)
- 90 mph (2)
- 110 mph (2)

(1) 28 Freight + 8 Passenger
(2) 40 Freight + 24 Passenger
Distributions of Passenger Travel Times on Single & Double Track

Double Track

Single Track

(1) 28 Freight + 8 Passenger

(2) 40 Freight + 24 Passenger

Time To Travel 100 Miles (min)
Summary

- Faster trains require shorter time windows to traverse the network.
- Faster trains will introduce more complex meets and pass scenarios.
- The effect of passenger train speed is smaller compared to the effect of dispatching priority.
- The speed differential between train types may be more pronounced on double track over single track.
- Increased passenger speeds will have faster travel times.
Potential Delay Mitigation Strategies

- Time separate the train types
- Decrease the speed differential
- Look for opportunities to replace multiple trains with a longer train
- Remove dispatching priorities
- Add track:
  - Longer yard leads
  - Sidings
  - Sections of 2 main track
Future Work

- Evaluate delay mitigation strategies
- Simulate mainlines that contain single & double track components
- Determine equivalence between train types
- Determine how other sources of variation affect capacity
- Yard & mainline interaction
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Questions?

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