Traffic Complexity and the Performance of Railway Classification Yards

C. Tyler Dick, P.E.

INFORMS Annual Meeting
November 5th, 2018
# Background and Problem

- Manifest train plans must satisfy contradictory design criteria:

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- Objective: investigate and quantify fundamental classification yard capacity relationships between traffic volume, traffic complexity and yard performance using a simulation model
Yard Performance and Capacity

▶ Yard Performance Metrics
  • Average Railcar Dwell = average time from railcar arrival to departure
  • Connections Achieved = fraction of railcars departing on intended train
  • On-Time Originations = fraction of trains that depart at planned time

▶ Yard capacity defined by maximum volume that results in acceptable dwell, connections achieved or on-time originations
Complexity of Yard Traffic Flow

Inbound Trains

Outbound Trains

Blocks

Hump Process

Pull-down Process
Directional traffic, fewer blocks and fewer trains → more capacity for given LOS?
Hypothetical Yard Relationships

- level of service as a function of throughput volume of railcars and number of blocks assembled in the yard

![Graph showing the level of service as a function of throughput volume for different numbers of blocks (N). The graph includes curves for N = 10, N = 30, N = 50, and N = 50 with improvements. Points A, B, and C are marked on the graph.](image-url)
Yard Capacity Models: State-of-the-Art

► Manual Simulation
  • Yard charting or paper switch

► Analytical
  • Little’s Law (1961)
  • Conceptual Equations (Newell, 1950; El-Din, 1968)
  • Queuing Theory (Petersen, 1977; Khan, 1979; Turnquist and Daskin, 1982)
  • Parametric Models (Zhang et al., 2017)

► Optimization
  • Maximize performance of yard process but may not calculate capacity

► Simulation
  • Early logic-based models (Shields, 1966)
  • USRA Yard Simulation Model (Reinschmidt, 1981)
  • FRA CAPACITY and CONFLICT (Wong et al., 1981)
  • CN Terminal Interactive Model (TRIM) (Engelberg, 1983)

► Current simulation models with advanced logic and graphics/animations
Advanced Yard Simulation Models

- Norfolk Southern YardSIM
- AnyLogic
- CSX Hump Yard Simulation System → Optym YardSYM
  - Simulates the movement of trains, switch engines and railcars
  - Specify multiple operating and traffic parameters
  - Detailed output data with yard animation
YardSYM Modeling Options

**Historical Traffic**
- Actual instances of inbound trains
- Blocking details for each railcar
- Yard operation under actual traffic and new operating parameters

**Hypothetical/Future Traffic**
- Inbound and outbound train plan
- Number of railcars by block per inbound train
- Yard operations under new traffic and actual operating parameters

- Generates output for 28 days of operations
  - Railcar dwell
  - On-time originations (OTO)
  - Connections achieved → Right-car-right-train (RCRT)
Technical Approach

► Belt Railway of Chicago granted access to their YardSYM model
► Clearing Yard model has two directional inline humps
  • Focus on eastbound classification operation
Traffic Complexity Experiments

► Specify traffic patterns of varying complexity for the eastbound classification operation

► Three experiments:
  1) Basic experiment between volume and blocks
     - Fixed number of trains and uniform block sizes
  2) Influence of the block size distribution
     - For a given volume, number of blocks, number of trains
  3) Influence of the number of outbound trains
     - For a given volume and number of blocks with uniform block size

► Steady state conditions
  • Same traffic pattern every day
  • Subsequent experiments will introduce volume and schedule flexibility as additional experimental factors
Experiment 1: Volume and Blocks

► Factors

- Railcar volume: 720 to 1728 railcars per day
- Number of blocks: 16 to 48 blocks per day
  - Block size, train length and blocks per train varies accordingly

► Fixed 18 inbound 16 outbound trains per day distributed evenly

► All inbound trains connect to every outbound train

► Example: blocking scenarios for 1,152 railcars per day

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Blocks</th>
<th>Inbound Railcars/Block/Train</th>
<th>Outbound Trains</th>
<th>Blocks/Train</th>
<th>Cars/Block</th>
<th>Average Blocks/Train</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>4</td>
<td>16</td>
<td>1</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>32</td>
<td>2</td>
<td>16</td>
<td>2</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>48</td>
<td>1.333</td>
<td>16</td>
<td>3</td>
<td>24</td>
<td>3</td>
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<td>D</td>
<td>40</td>
<td>1.333</td>
<td>8</td>
<td>3</td>
<td>24</td>
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Blocks, Volume and Railcar Dwell Time

Average Railcar Dwell Time (hours)

Volume (railcars/day)

- 16 blocks
- 24 blocks
- 32 blocks
- 40 blocks
- 48 blocks

500 750 1000 1250 1500 1750

16 blocks

48 blocks
Train departs on time BUT with yesterday’s railcars!
Blocks, Volume & PMAKE

- 1152 and 16 blocks
- 1152 and 48 blocks
- 1440 and 16 blocks
- 1440 and 48 blocks
## Experiment 4: Variability

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- Ongoing work investigates the influence of volume variation and schedule flexibility on classification yard performance and capacity.
Propagation of Variability

- Comparing inbound variation to outbound variation yields additional research questions:

- 1) Does a classification yard amplify or dampen schedule flexibility and volume variability?

- 2) Does a classification yard transform schedule flexibility into volume variability and vice-versa?
Flexible Arrivals and Yard Performance

Average Railcar Dwell (hours)

Arrival Flexibility (+/- minutes)

Railcar Connections Achieved (%)

Arrival Flexibility (+/- minutes)

1440 railcars/day
32 blocks

135 railcars/day
32 blocks
Summary of Preliminary Results

► Understanding how traffic complexity and schedule flexibility influences the capacity and performance of classification yards and mainlines is critical to understanding how the railway network responds to service disruptions and changes to rail traffic patterns

► A combination of factors describing traffic complexity can be a better predictor of yard performance than volume alone

► Increasing the number of blocks formed degrades hump yard performance at a constant railcar throughput volume

► Starting from a structured operation, small amounts of schedule flexibility rapidly degrades yard performance
Thank you for your attention!

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Technical collaboration and assistance from:

This project is supported by the National University Rail Center (NURail), a US DOT-OST Tier 1 University Transportation Center, and the Association of American Railroads