Interaction Between Yard and Mainline Capacity in Railway Network Performance

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Freight Rail Transportation Network

► In 2015, US Class 1 Railroads transported 1.7 billion tons of freight

► Strong financial incentive to match network capacity to demand

► Freight rail network is an integrated system
  • Links: 161,000 miles of track on 94,000 miles of mainline routes
  • Nodes: hundreds of yards, terminals and junctions

1.5 million railcars + 29,000 locomotives ←→ 5,000 trains per day

► Defining the capacity of this network is a challenge
Transporting Carload Shipments

► 2015 Class 1 carload traffic: 43% of revenue, 26% of tonnage

► Reliable and cost-effective carload service requires:
  • Network of manifest freight trains
  • Efficient classification yards
  • Train plan with timely connections between trains

► Mainline, yard and terminal performance all influence:
  • Quality of railway service
  • Network capacity
Mainline and Yard Interactions

- Majority of railway industry and academic analytical effort focused on mainline capacity and performance
- Lack of yard capacity knowledge; little research since 1983
- Less academic study of yards and how mainlines and yards interact despite observed interactions
  - Network efficiency cycle (adapted from Dirnberger, 2006)
Network Cycle: CN Performance Metrics

Average Train Speed

Terminal Dwell

Week (4/14/2017 – 4/13/2018)

Average Train Speed (mph) or Terminal Dwell (hours)

\[ y = -0.58x + 34.6 \]

\[ R^2 = 0.9007 \]
Yard Capacity and Network Disruptions

► Yard and terminal capacity has been the cause of several major network-scale railway service disruptions over the past 20 years

► Union Pacific (1997)
  • Overestimated capacity of consolidated yards in Houston

► CSX (1999)
  • Overestimated capacity of existing classification yards to support new operating plan after Conrail acquisition

► CSX (2017)
  • Overestimated capacity of remaining yards to support new operating plan after closure of multiple major classification yards

► Continuing recurrence of railway network service disruptions reinforces the need for improved understanding of
  • Mainline and yard capacity interactions
  • How delay and schedule flexibility propagates through the network
Research Question 1

What is the relationship between variability in train departure times and the performance and capacity of a given mainline?
Structured and Flexible Operations

► International research on capacity of “structured operations”
  • Fixed timetable with resolved train conflicts
  • Capacity calculated by UIC Compression Method
  • Predominantly multiple-track mainlines and passenger trains

► Difficult to apply to “flexible operations” in North America
  • Predominantly single-track mainline and freight trains
  • Train plan with target departure times and “schedule flexibility”
Mainline Performance and Capacity

► Mainline Performance Metrics
  • Train Delay = Actual Train Run Time – Minimum Free Run Time

  • Average Train Speed = Total Train-miles / Total Train-hours (excluding all time in yards and terminals)

► Line capacity is the maximum volume that results in acceptable level of service (LOS) measured by delay or average train speed.
Mainline Simulations

- Study two representative 240-mile single-track routes with Rail Traffic Controller (RTC) simulation software

- Initial structured schedule
  - Trains depart at even intervals, meets planned at sidings

- Introduce schedule flexibility to depart trains within window
  - Increment schedule flexibility from +/-0 minutes (fixed) up to +/-720 minutes (fully flexible within each day)

![Diagram showing Initial Structured Schedule and Flexible Schedule]
Train Delay and Schedule Flexibility

Sparse Single Track
+0 sidings
+4 sidings
+18 sidings

Dense Single Track
19% double track
100% double track
Delay-Volume Curves

75% Flexible Trains

40-minute LOS

Schedule Flexibility (+/- min.)
Variability in train departures decreases mainline capacity

What is the impact of these arrival delays on yards?
Research Question 2

What is the relationship between inbound train arrival variation (i.e. mainline schedule flexibility) and hump classification yard performance and capacity?
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
Belt Railway of Chicago granted access to their YardSYM model of Clearing Yard

- Simulates the classification process and movement of trains, switch engines and railcars
- Specify multiple operating and traffic parameters
- Detailed output data with yard animation
Flexible Arrivals and Yard Performance

- Average Railcar Dwell (hours)
  - Arrival Flexibility (+/- minutes)

- Railcar Connections Achieved (%)
  - Arrival Flexibility (+/- minutes)

1440 railcars/day
32 blocks
Research Question 3

Can railroads build their way out of this cycle through more investments in track capacity?
Increasingly difficult to sustain capacity through investments in expanded track infrastructure alone

- "Easy" projects but low return
- Big return but expensive and difficult to permit
A Different Approach

Decreasing schedule flexibility can be equivalent to gaining mainline capacity by adding track infrastructure.

- Reduce Schedule Flexibility
- Expand Infrastructure

Required LOS

*+/- 720 minutes schedule flexibility

8 Scheduled, 34 Flexible, 19% DT

42 Scheduled, 0 Flexible, 19% DT

8 Scheduled, 34 Flexible, 59% DT

Delay per 100 train-miles (minutes)

Amount of Double Track (%)
Summary

► Railway capacity is a network concept
  • Mainlines and yards interact to propagate congestion and poor LOS throughout the network

► Sustaining railway capacity under growing traffic does not just require mainline investments, but also in yards and terminals

► Combination of infrastructure investments and operational changes can be more sustainable than adding track alone

► Ongoing research:
  • How does traffic volume and yard capacity combine to amplify or dampen schedule flexibility and poor LOS?
  • Can moving and virtual blocks be a more sustainable approach to increase capacity compared to adding track infrastructure?
Thank you for your attention!

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