Interaction Between Yard and Mainline Capacity in Railway Network Performance

C. Tyler Dick, P.E.

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RAILTEC
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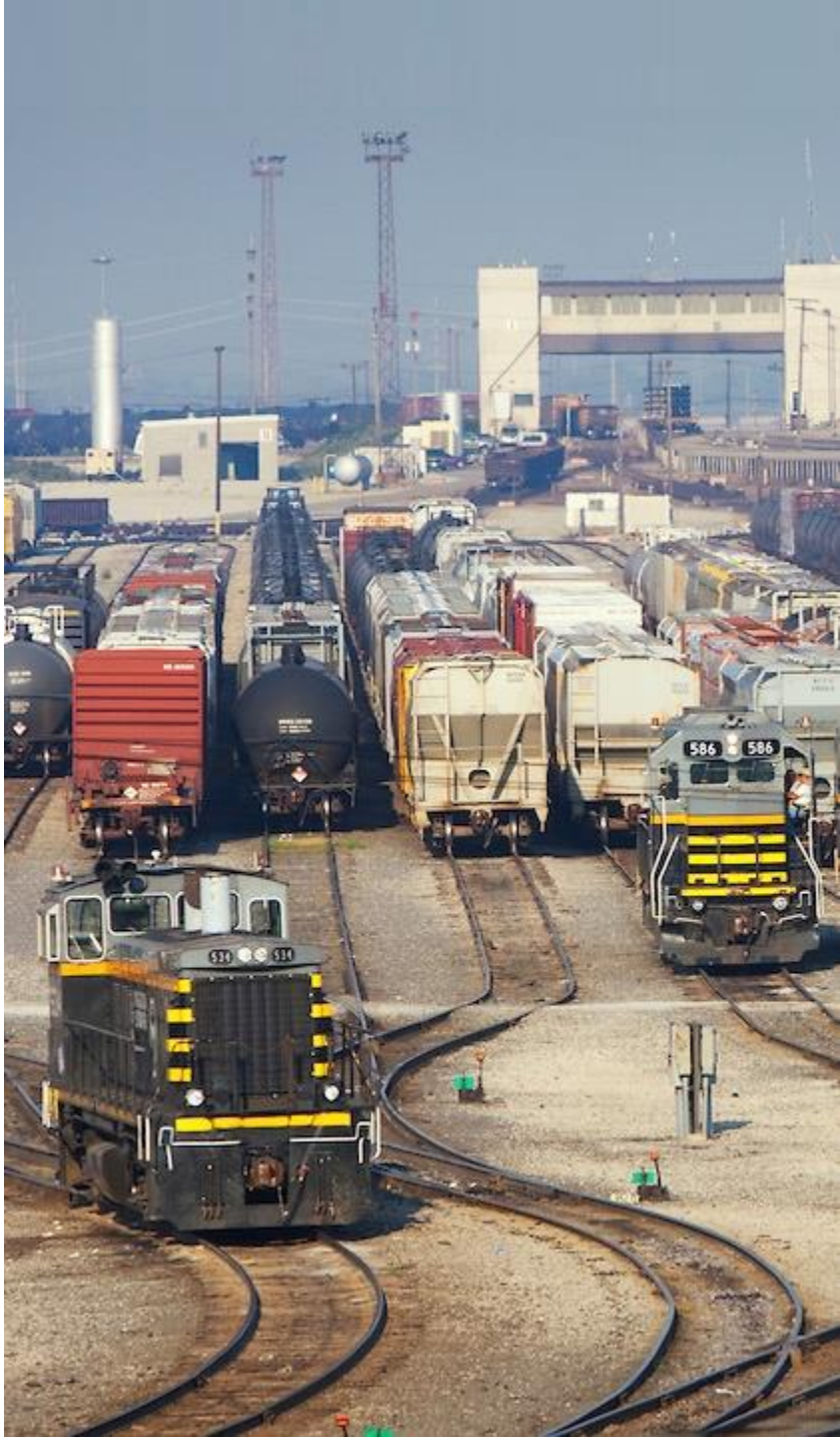


Freight Rail Transportation Network

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

- Strong financial incentive to match network capacity to demand

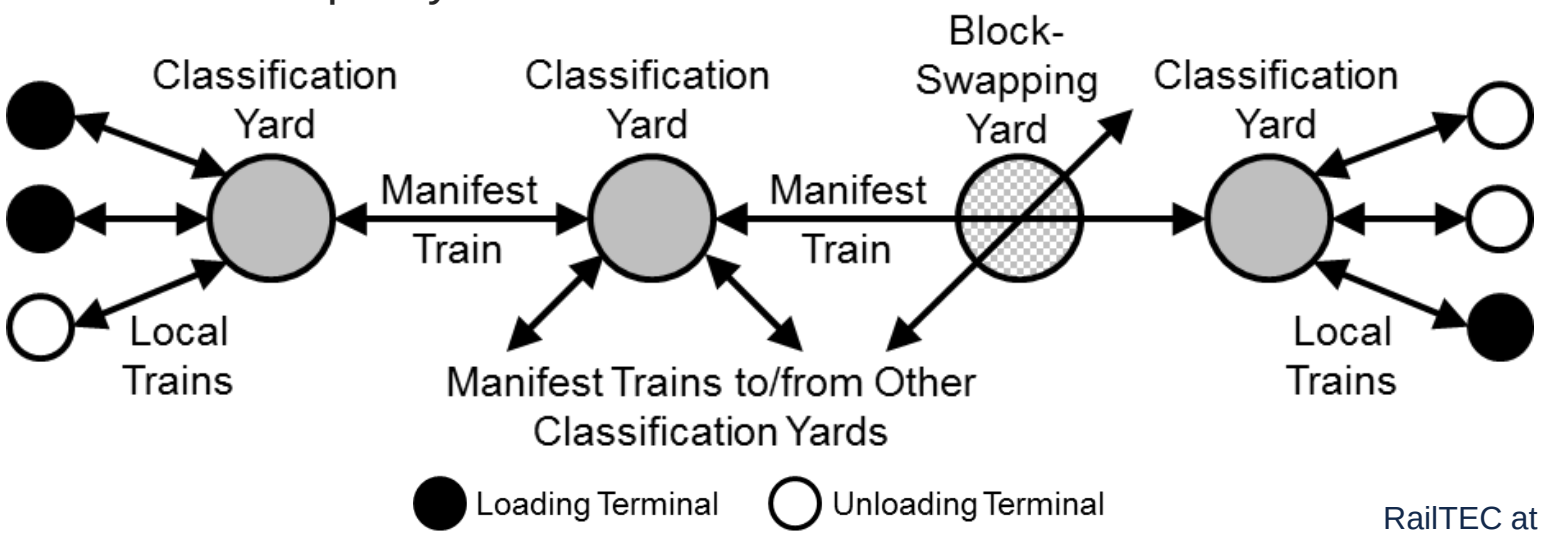
- Freight rail network is an integrated system
  - Links: 161,000 miles of track on 94,000 miles of mainline routes
  - Nodes: hundreds of yards, terminals and junctions

1.5 million railcars + 29,000 locomotives $\xleftrightarrow{\text{Yards \& Terminals}}$ 5,000 trains per day

- Defining the capacity of this network is a challenge

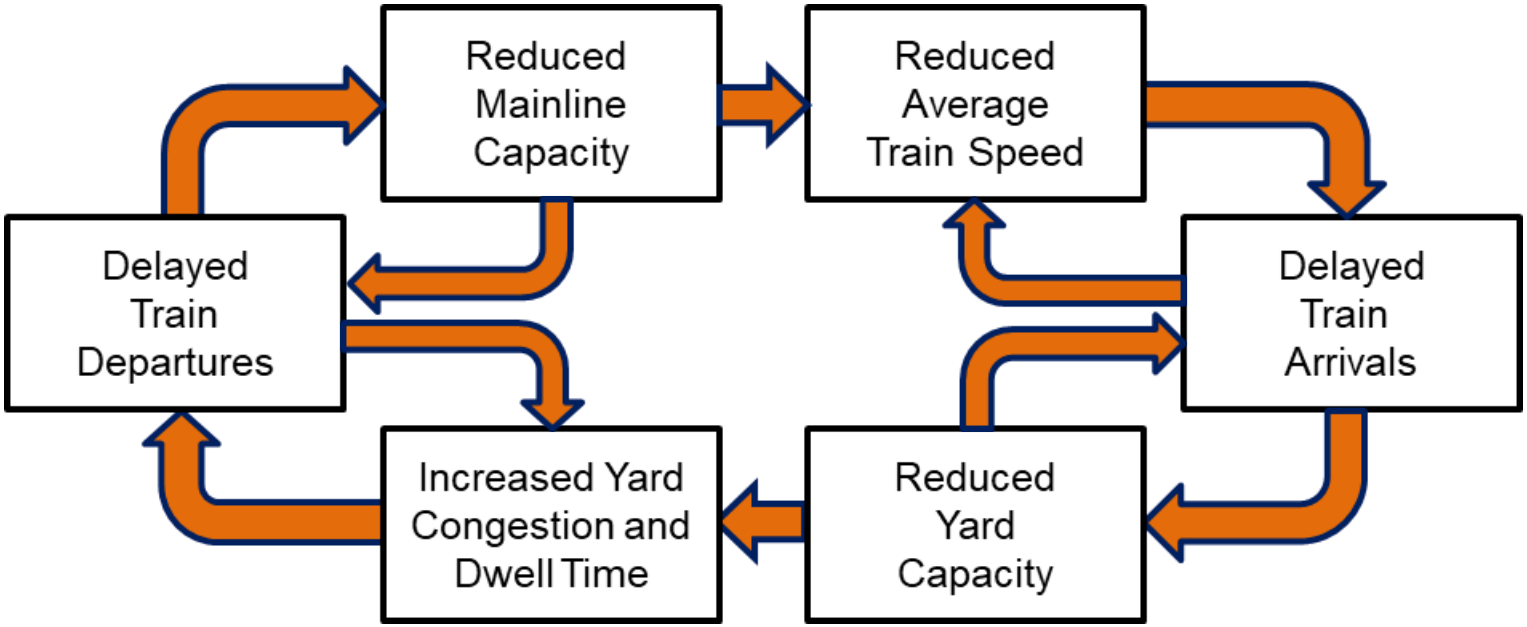
Transporting Carload Shipments

- 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

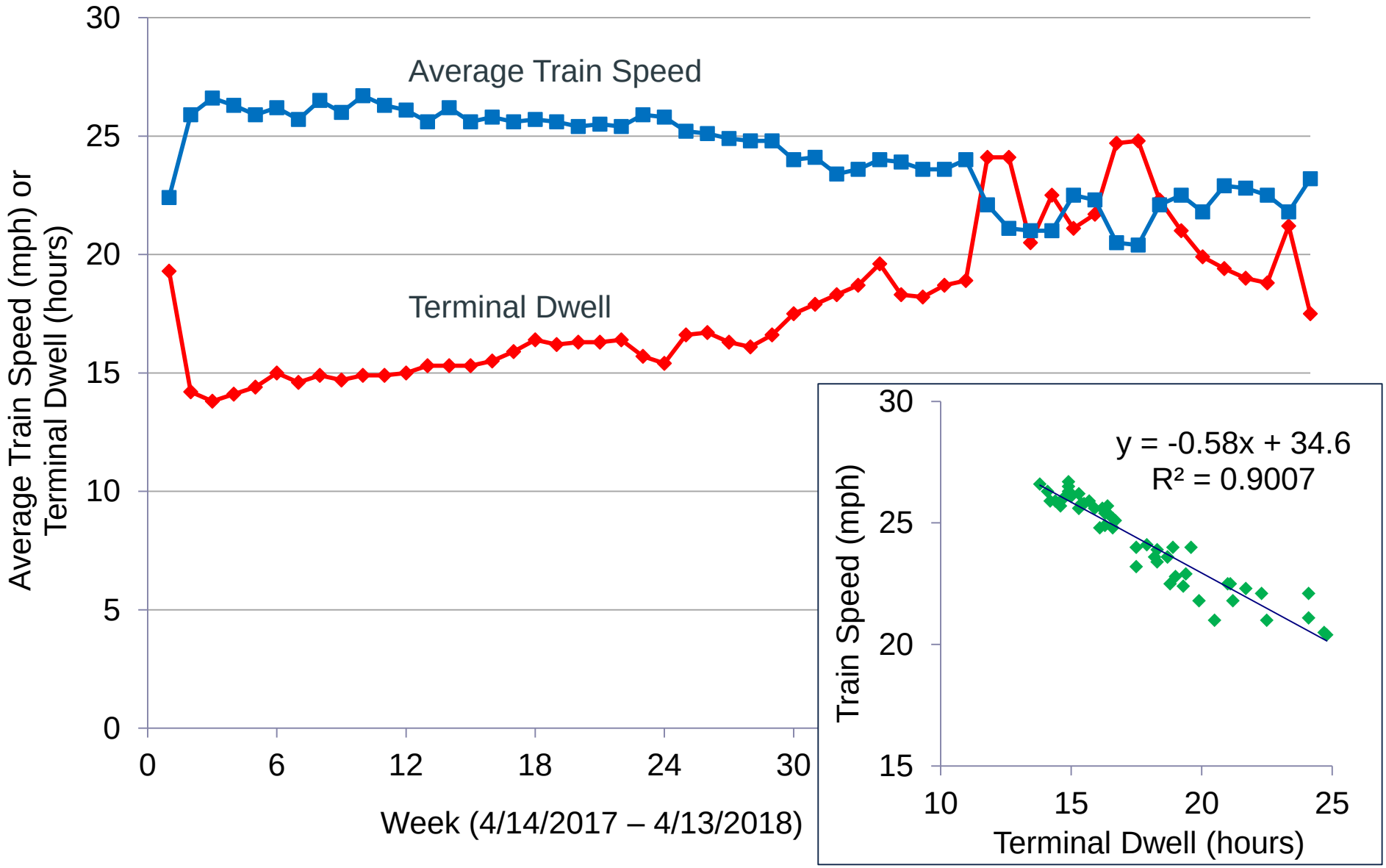


Mainline and Yard Interactions

- 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



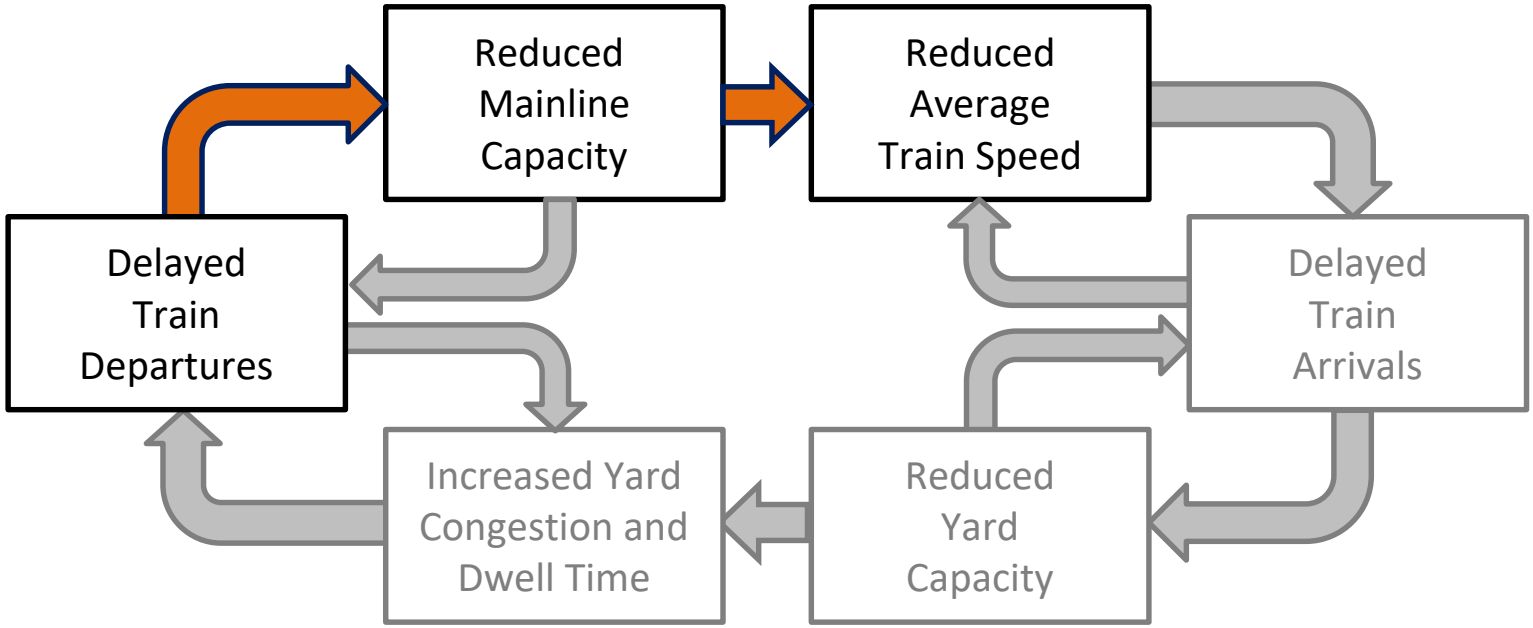
Yard Capacity and Network Disruptions

- 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

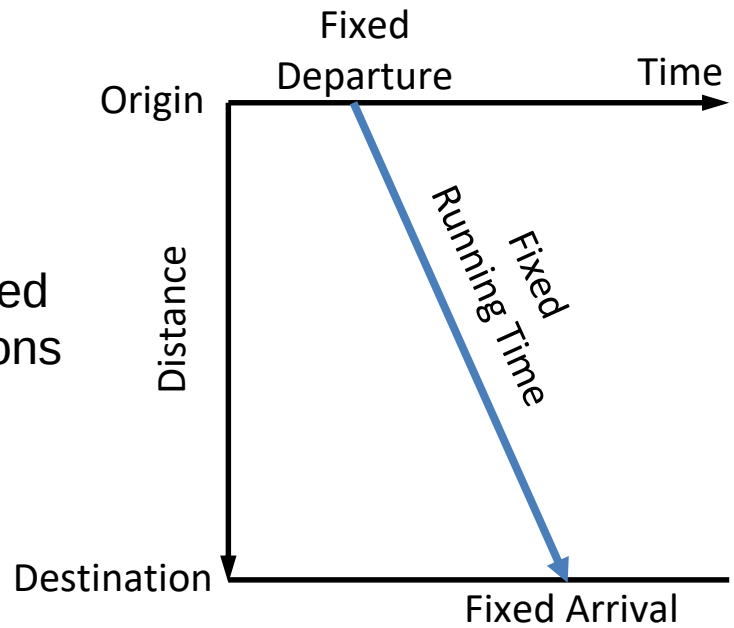


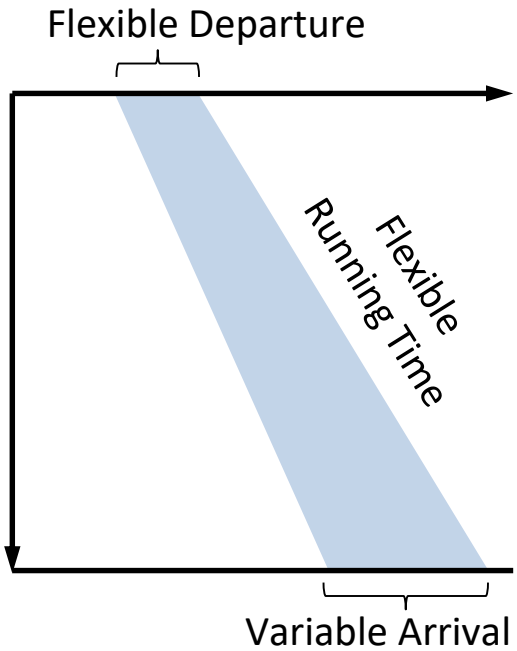
- What is the relationship between variability in train departure times and the performance and capacity of a given mainline?

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"

Structured Operations



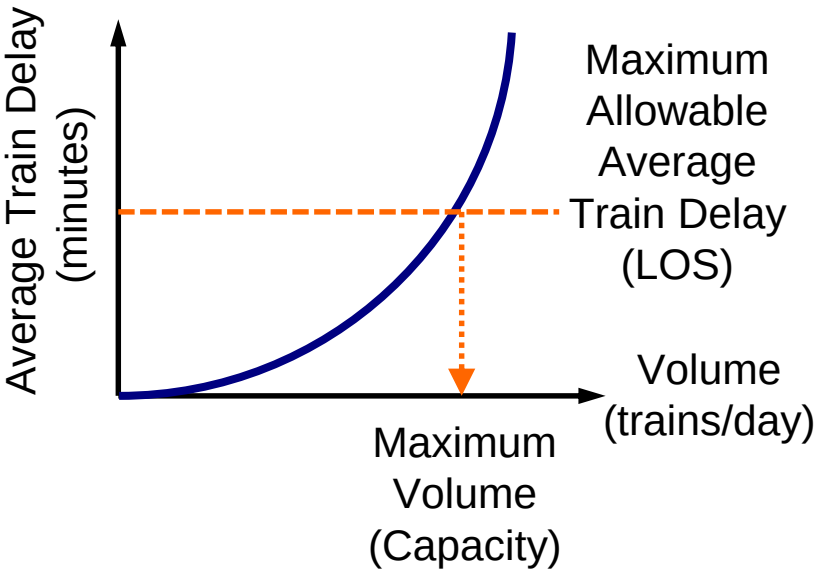


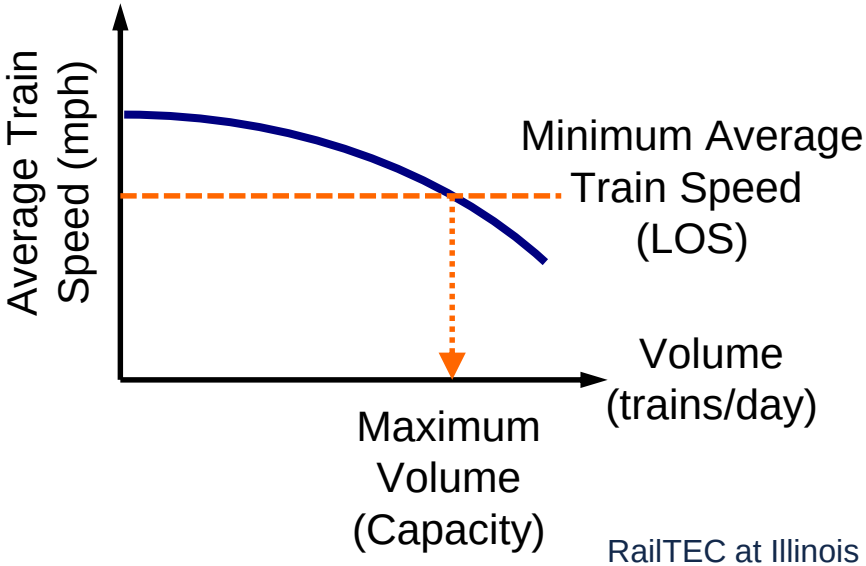
Flexible Operations

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



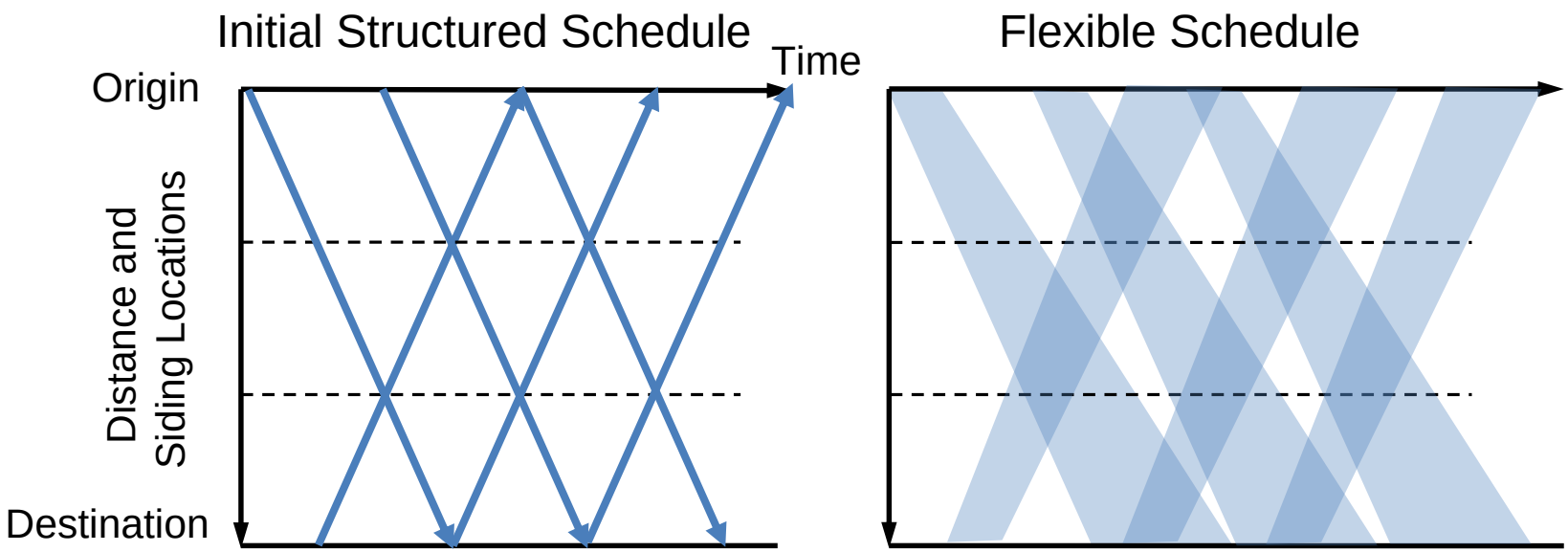


Mainline Simulations

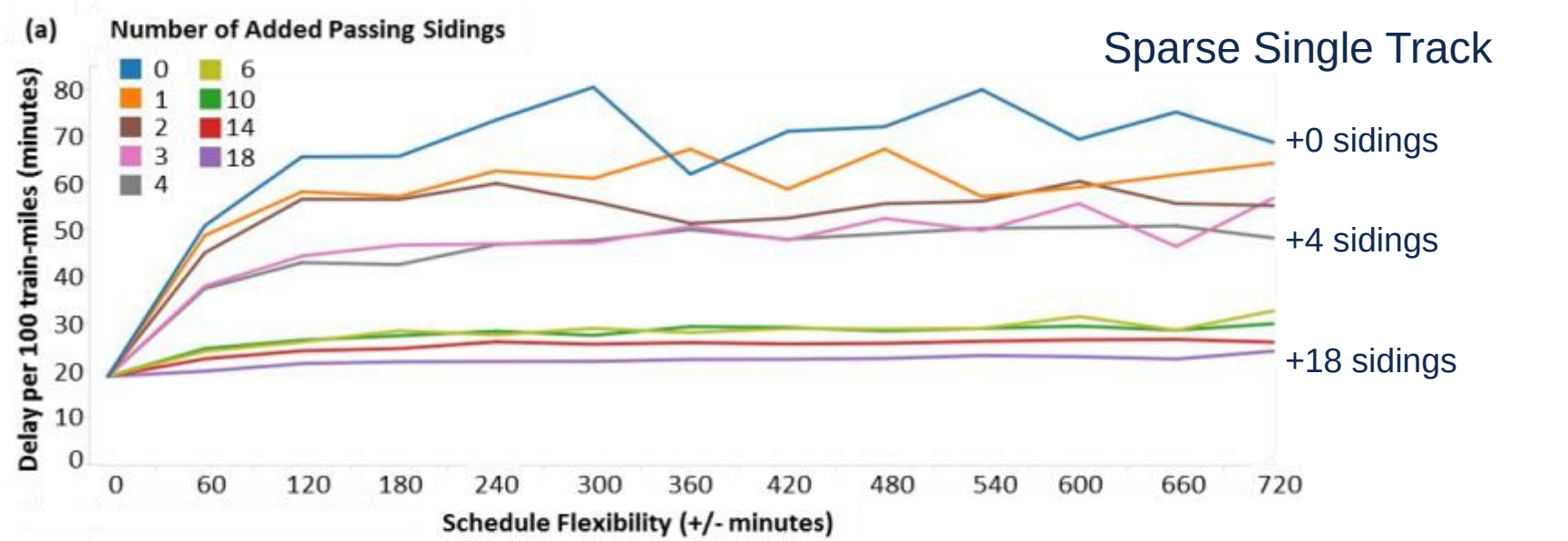
- Study two representative 240-mile single-track routes with Rail Traffic Controller (RTC) simulation software

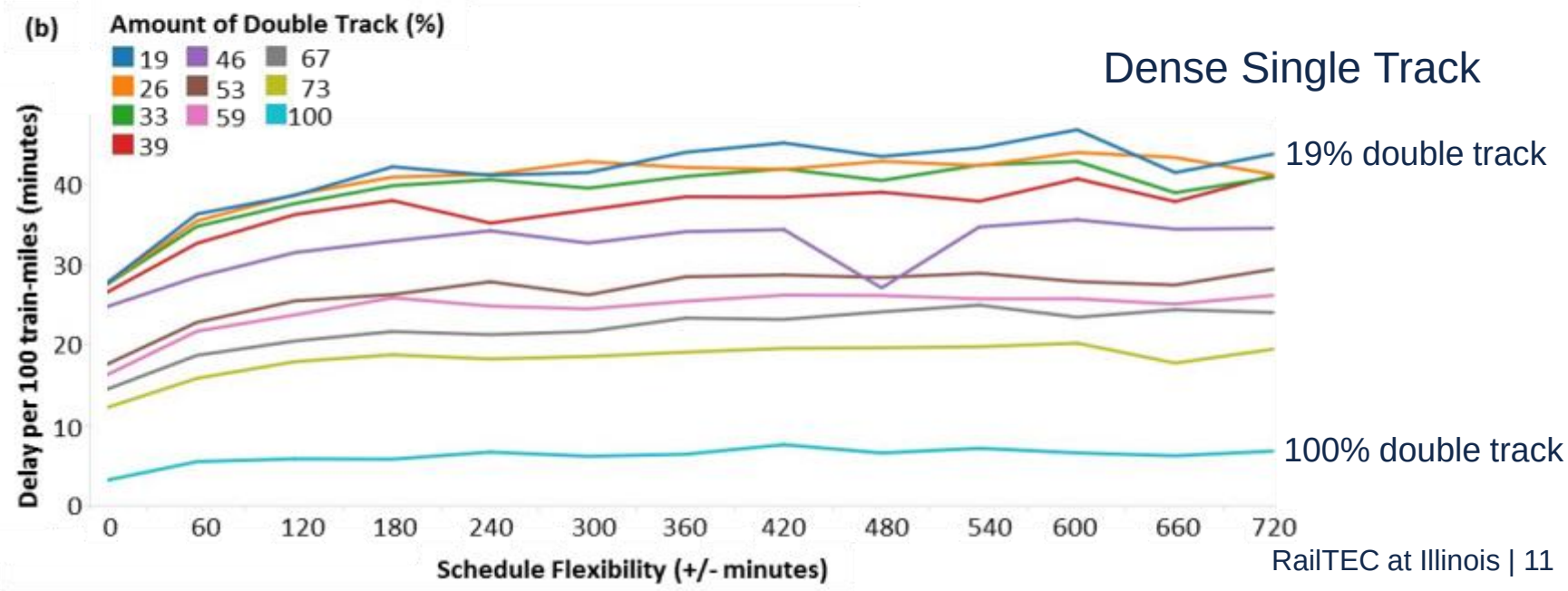
Rail Traffic Controller™

- 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)

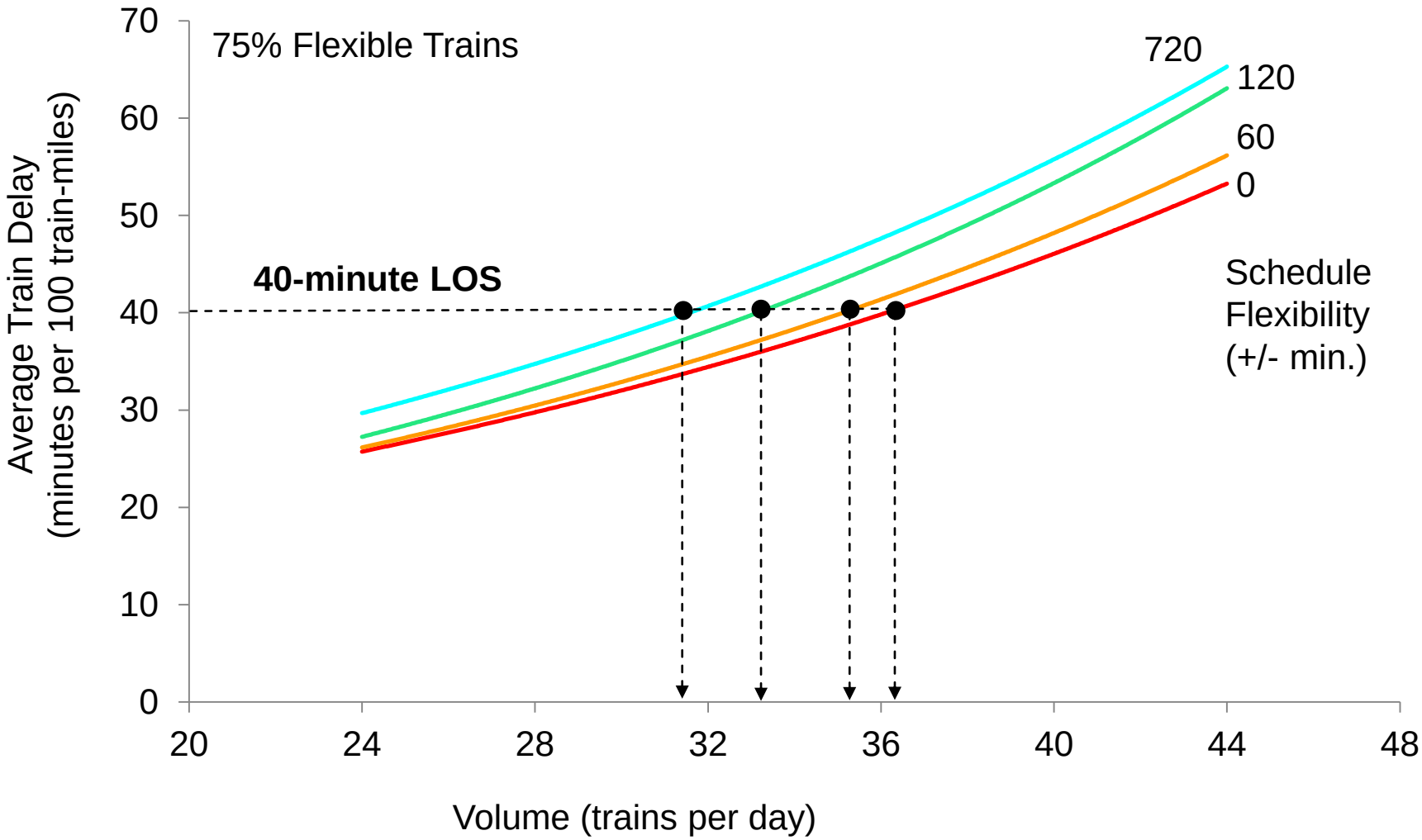


Train Delay and Schedule Flexibility

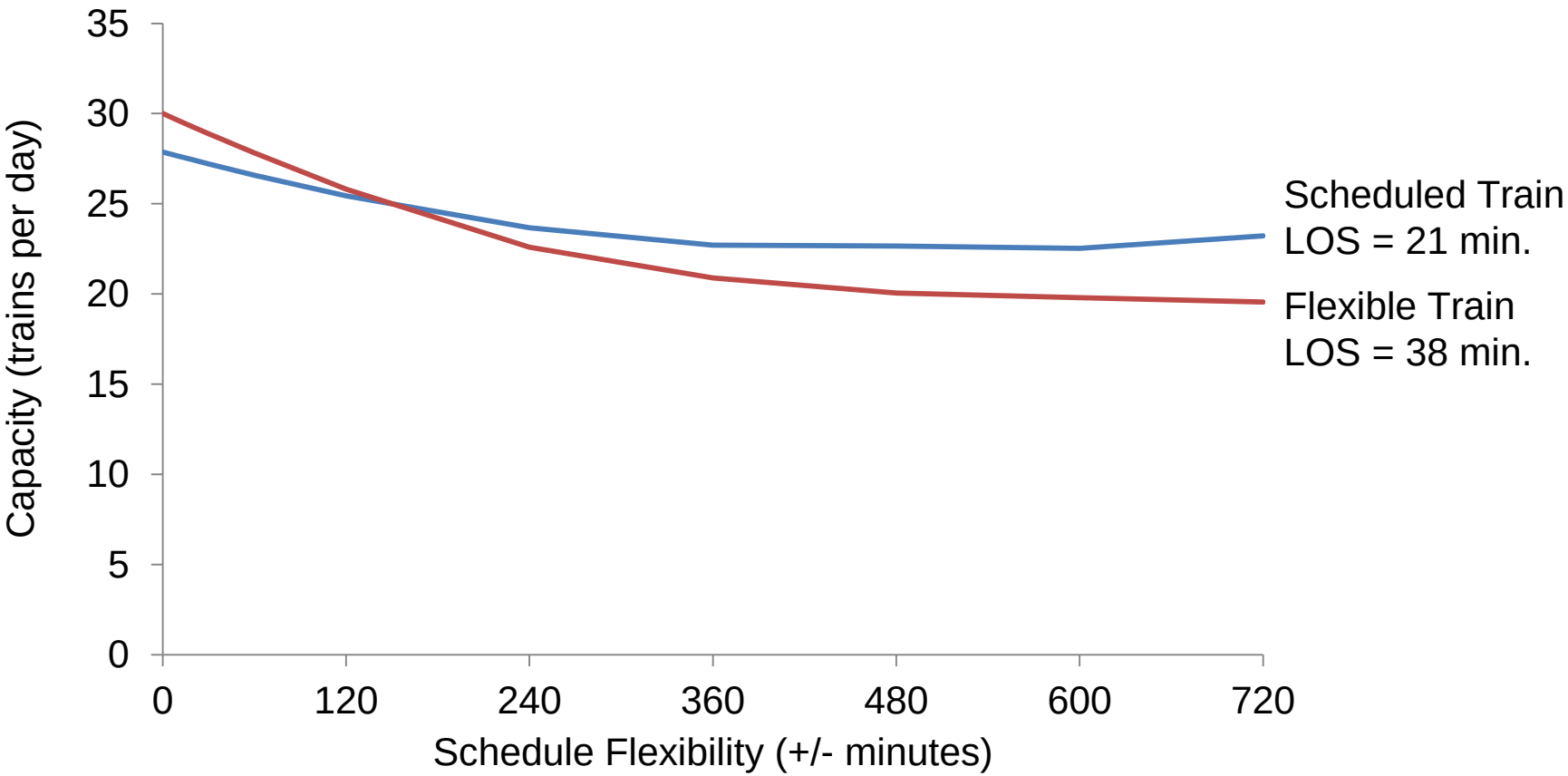




Delay-Volume Curves

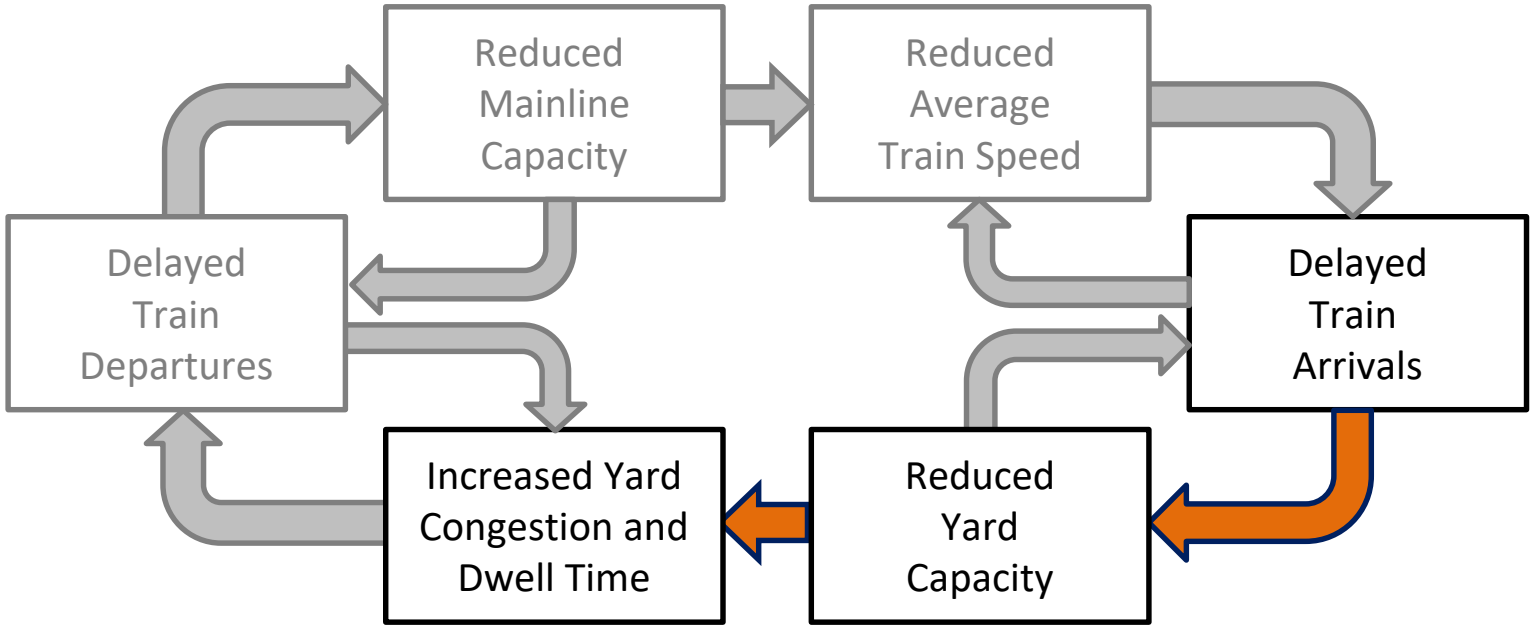


Schedule Flexibility and Capacity



- Variability in train departures decreases mainline capacity
- *What is the impact of these arrival delays on yards*?

Research Question 2

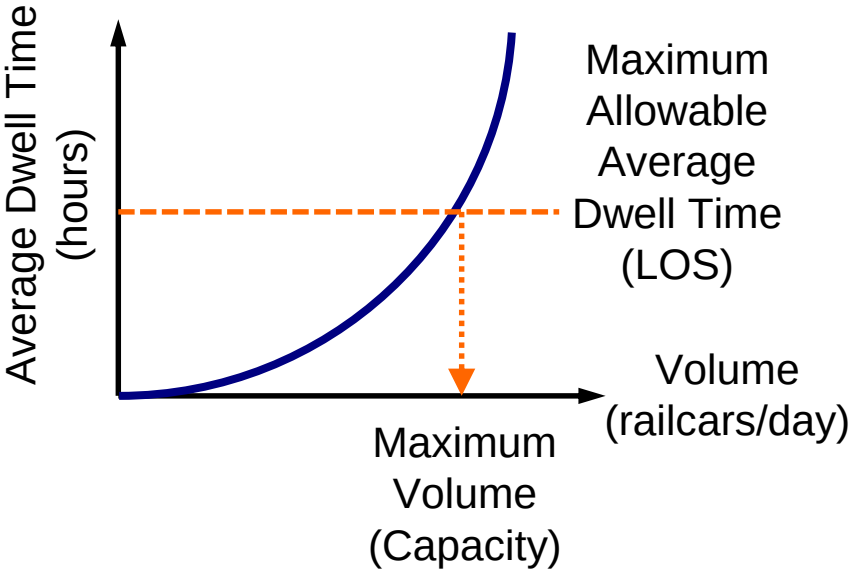


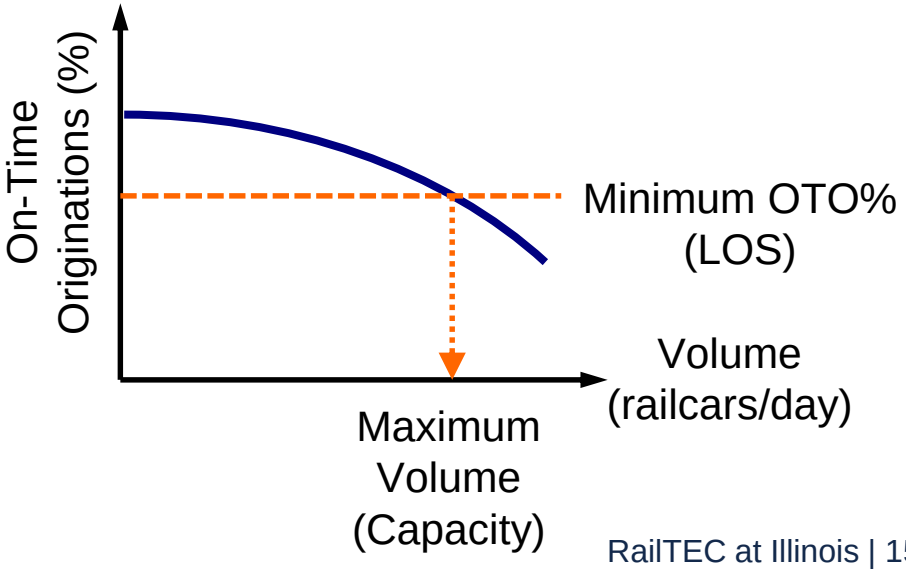
- What is the relationship between inbound train arrival variation (i.e. mainline schedule flexibility) and hump classification yard performance and capacity?

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

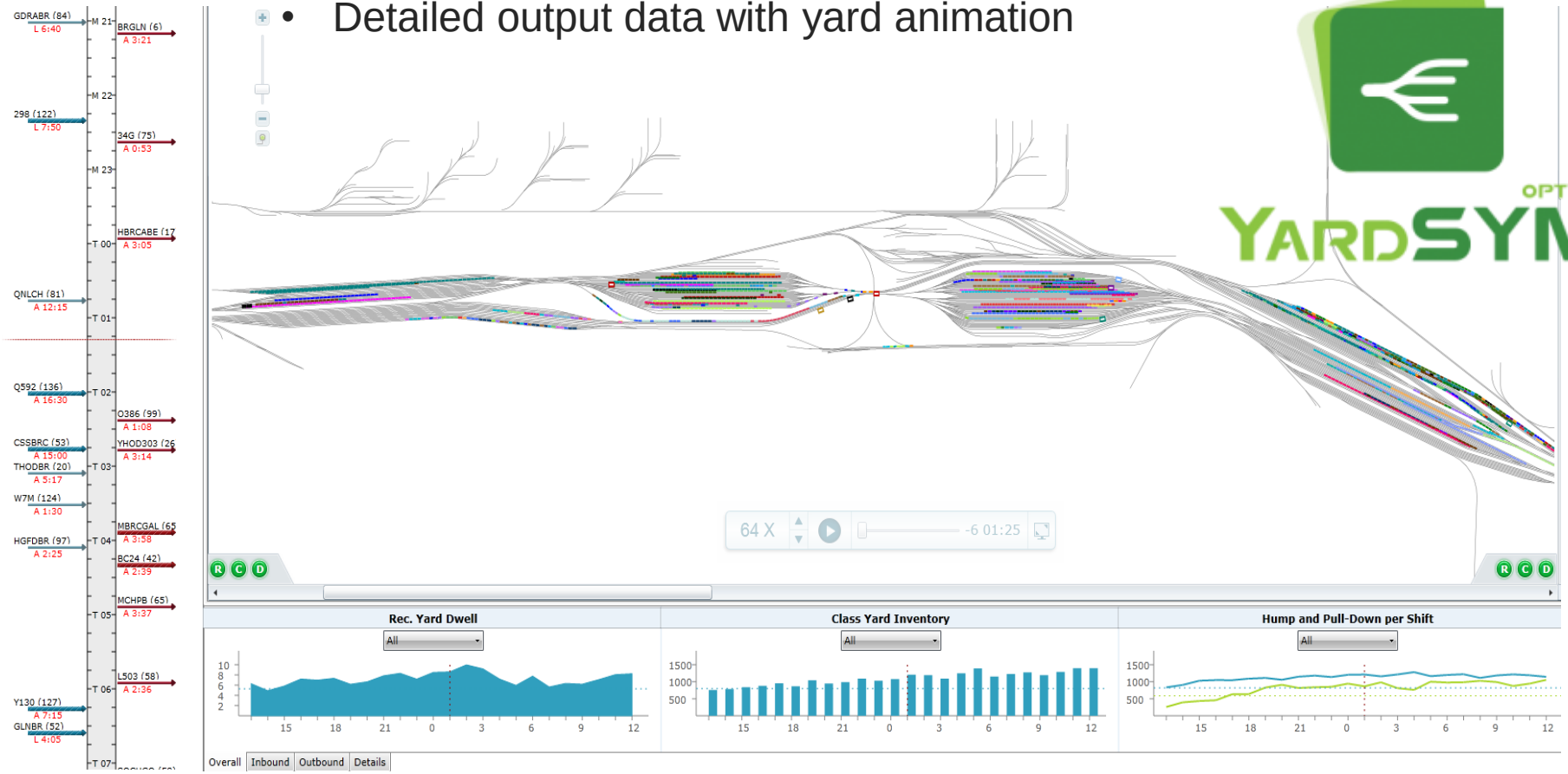
- Yard capacity defined by maximum volume that results in acceptable dwell, connections achieved or on-time originations



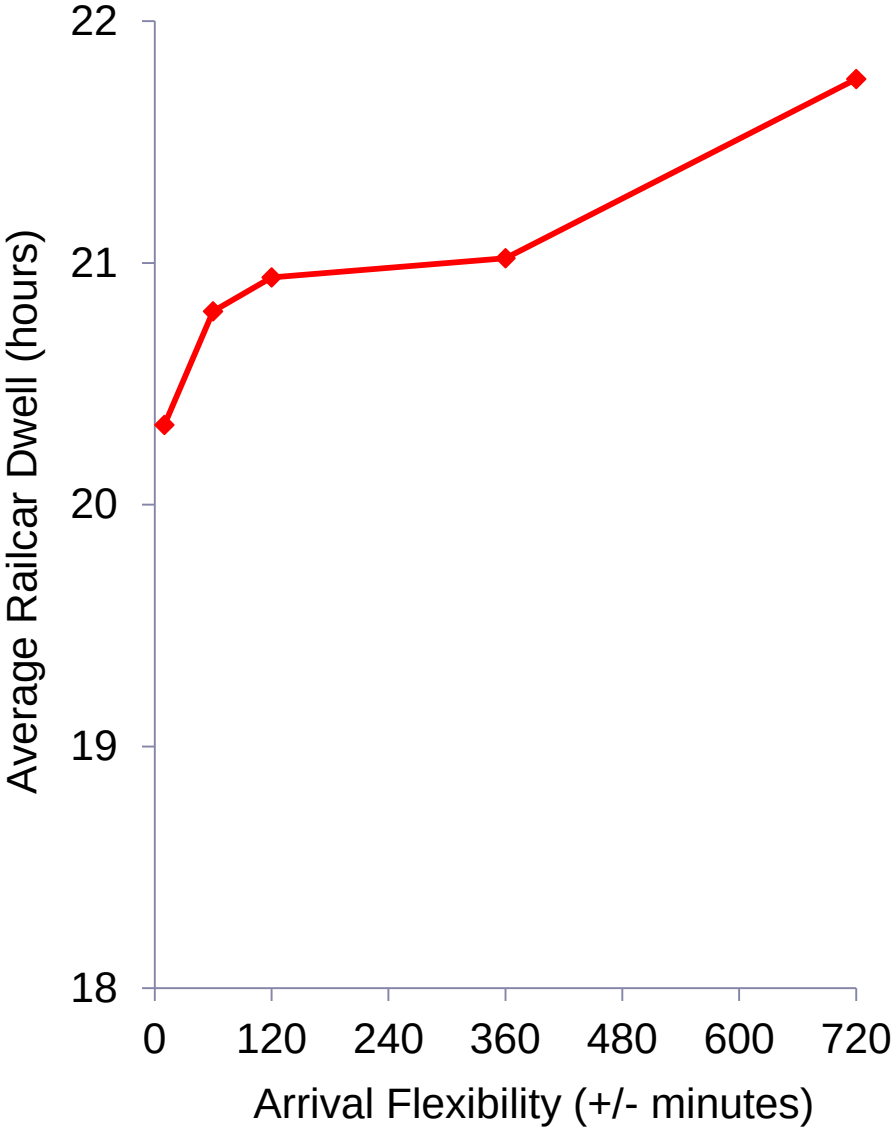


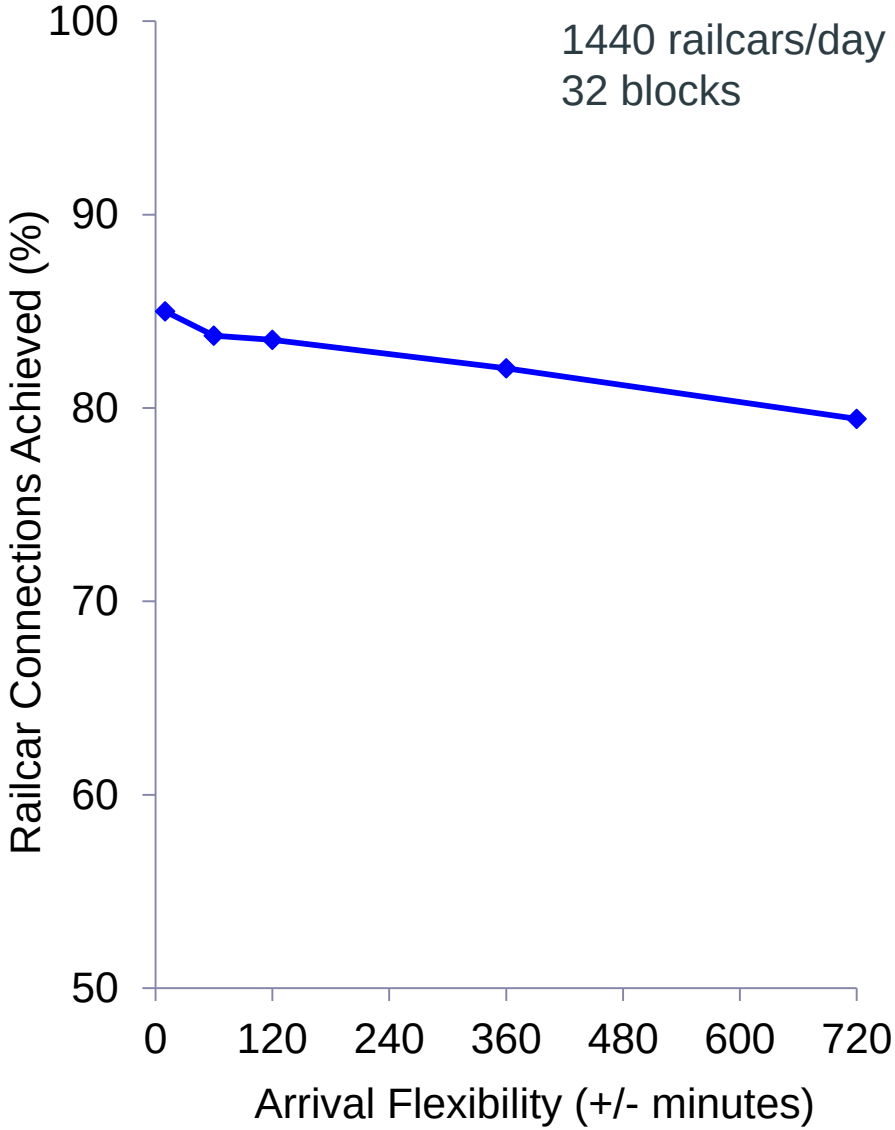
Yard Simulations

- 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

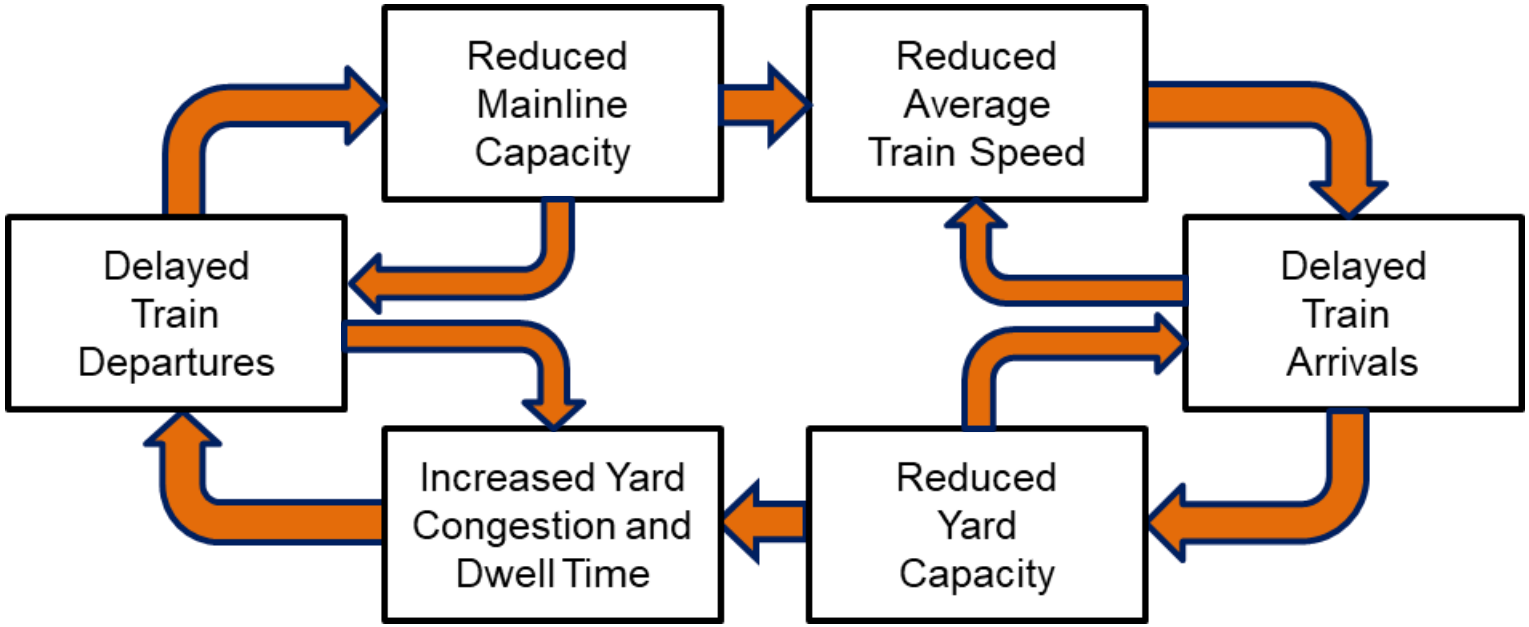


Flexible Arrivals and Yard Performance



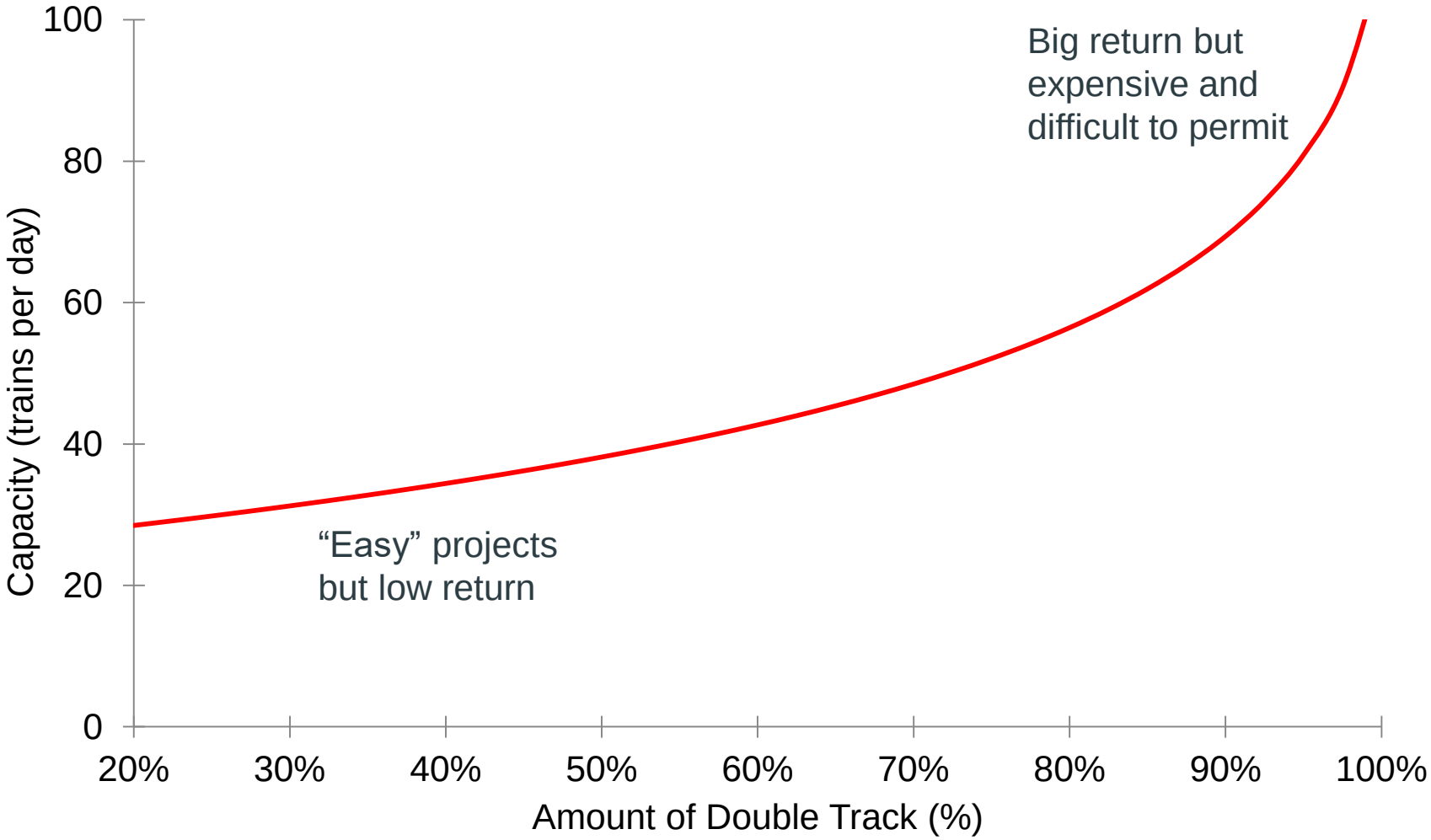


Research Question 3



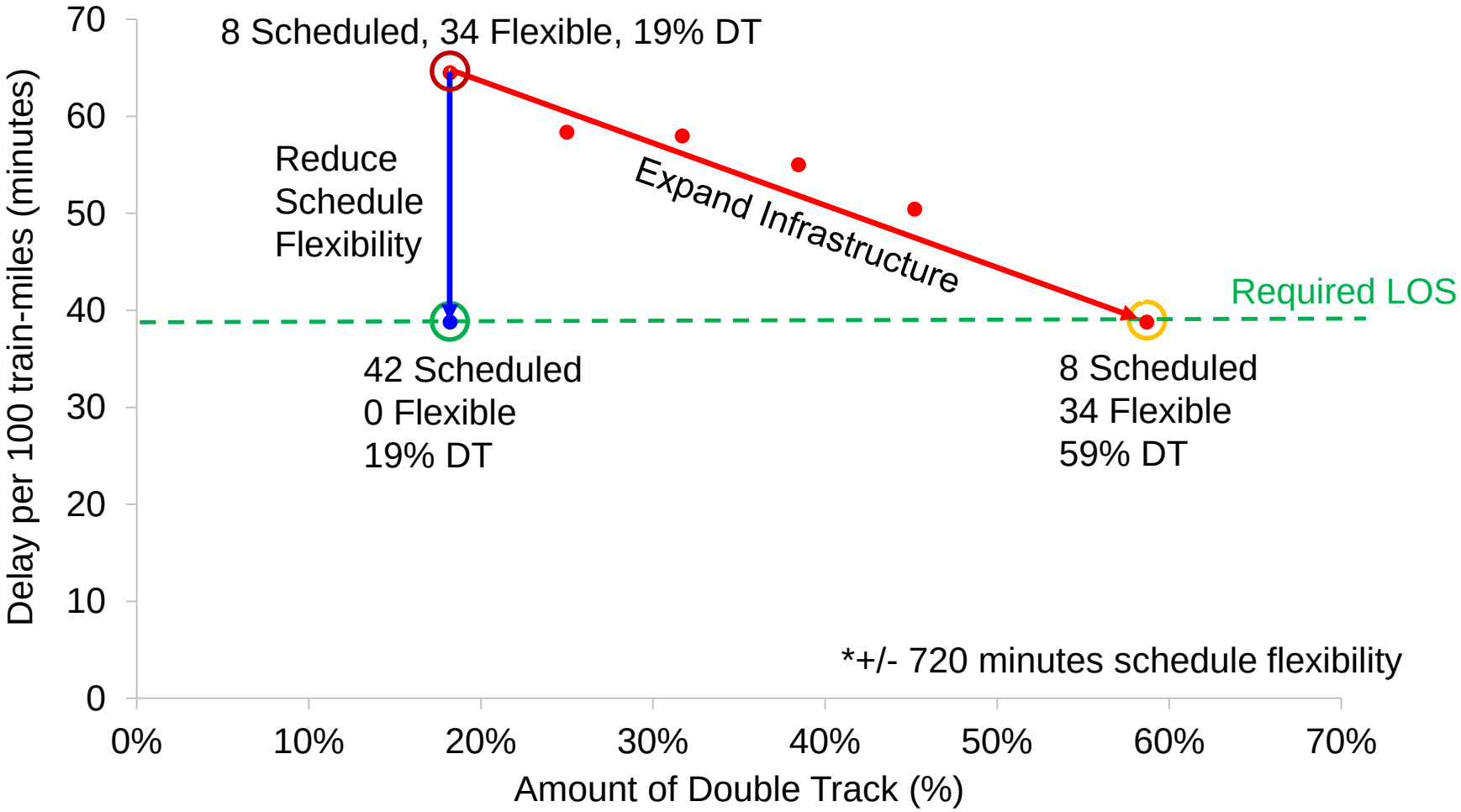
- Can railroads build their way out of this cycle through more investments in track capacity?

Capacity Return on Double Track



- Increasingly difficult to sustain capacity through investments in expanded track infrastructure alone

A Different Approach



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

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!

C. Tyler Dick, P.E.
Senior Railway Research Engineer
Rail Transportation and Engineering Center (RailTEC)
University of Illinois at Urbana-Champaign
ctdick@illinois.edu

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