Traffic Complexity and the Performance of Railway Classification Yards

C. Tyler Dick, P.E.

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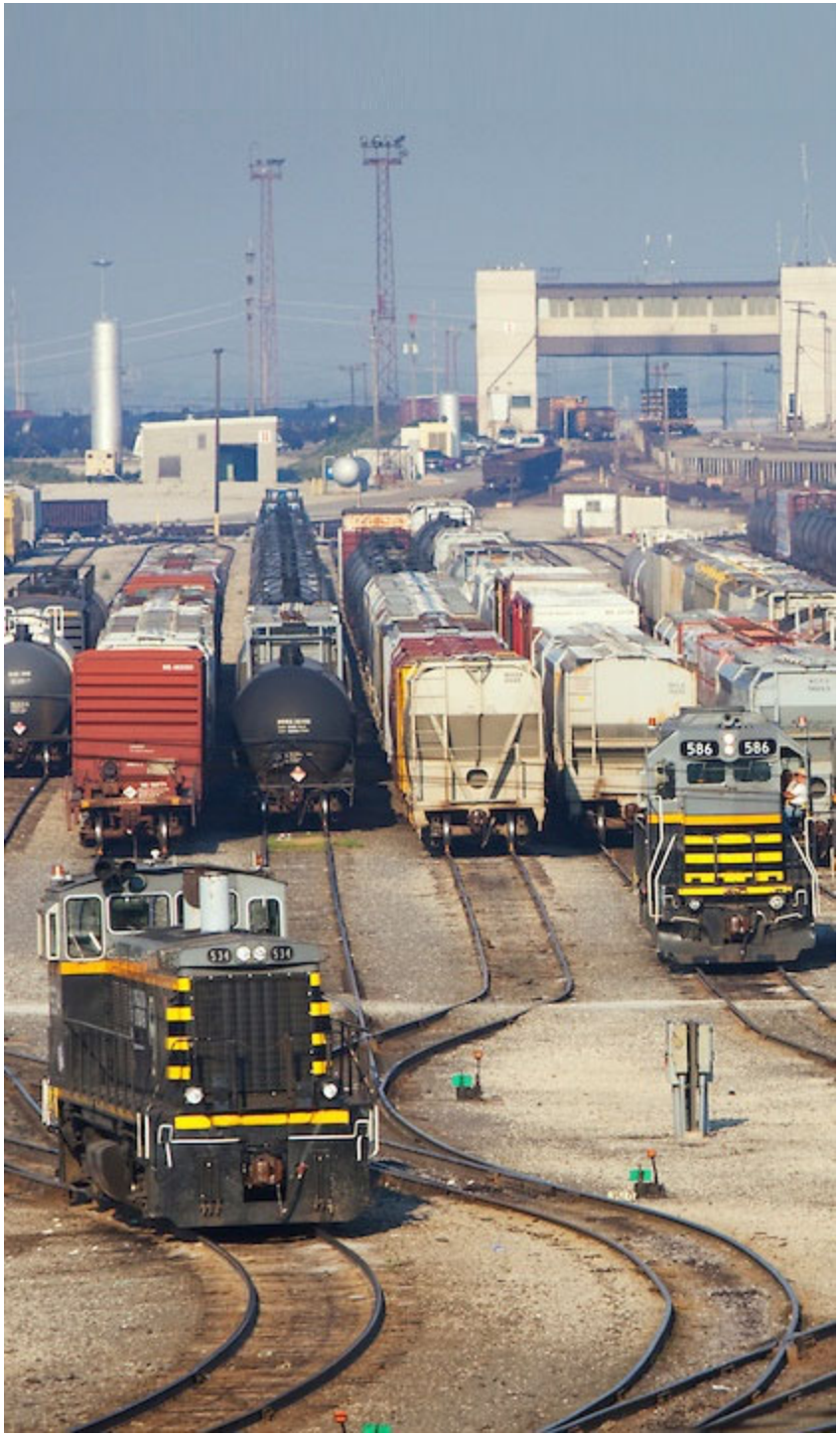


Background and Problem

- Manifest train plans must satisfy contradictory design criteria:

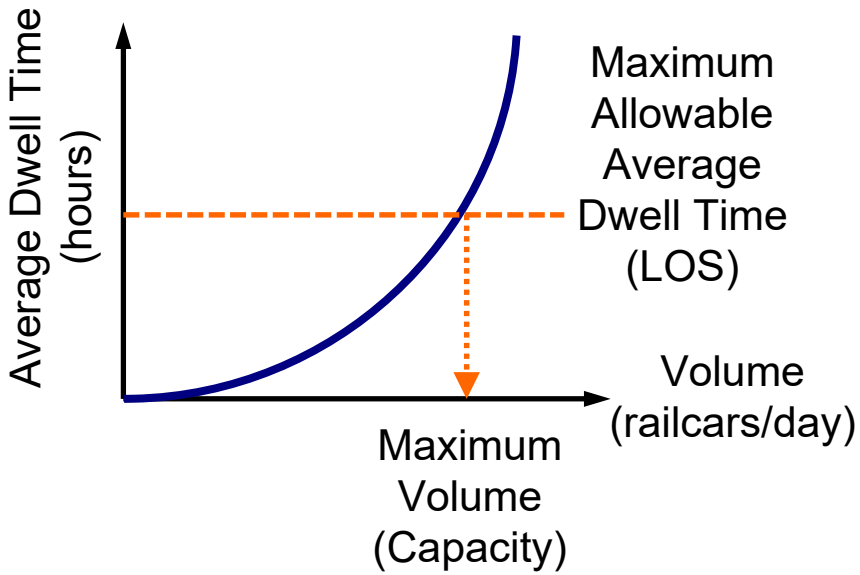
Line-Haul Perspective	Classification Yard Perspective
Fewer trains reduce costs	More frequent trains reduce dwell
Larger number of small blocks to increase routing options	Gain economies by making fewer, larger blocks
Multi-block trains reduce costs	Single-block trains reduce yard handling costs
Bunch trains at yards to reduce connection times	Evenly distribute traffic to better utilize resources and avoid queues
Vary train length to match peak demand cycles	Consistency in daily train and block sizes

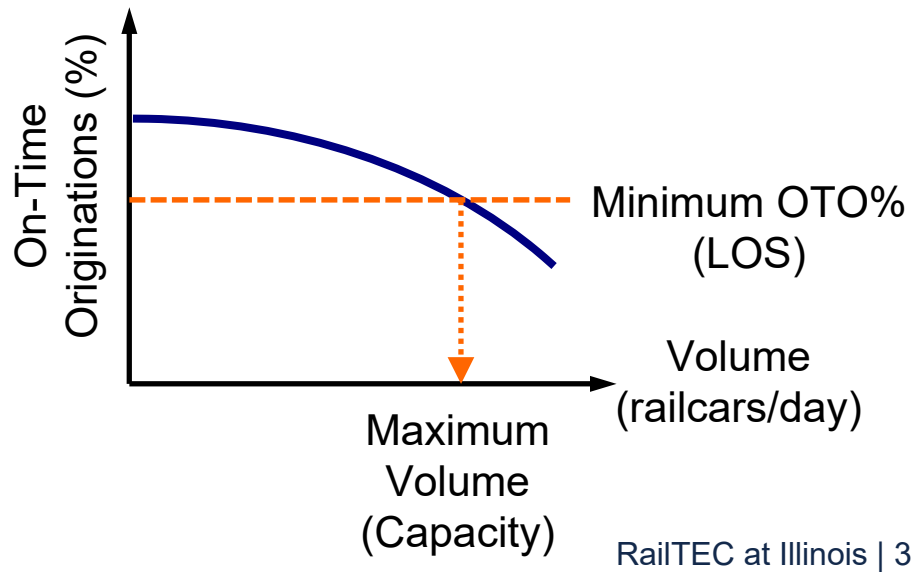
- Objective: investigate and quantify fundamental classification yard capacity relationships between traffic volume, traffic complexity and yard performance using a simulation model

Yard Performance and Capacity

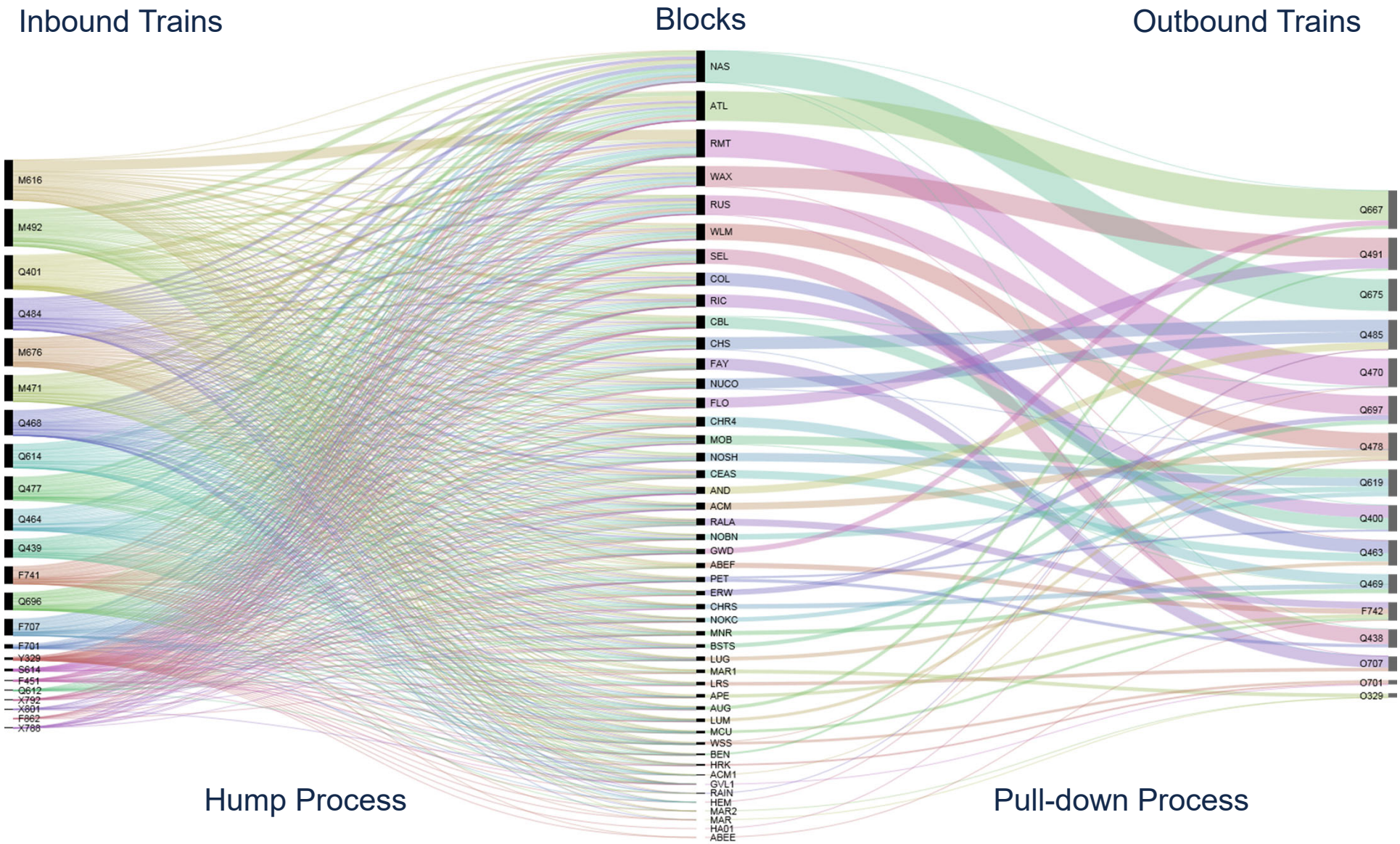
- Yard Performance Metrics
  - Average Railcar Dwell = average time from railcar arrival to departure
  - Connections Achieved = fraction of railcars departing on intended train
  - On-Time Originations = fraction of trains that depart at planned time

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

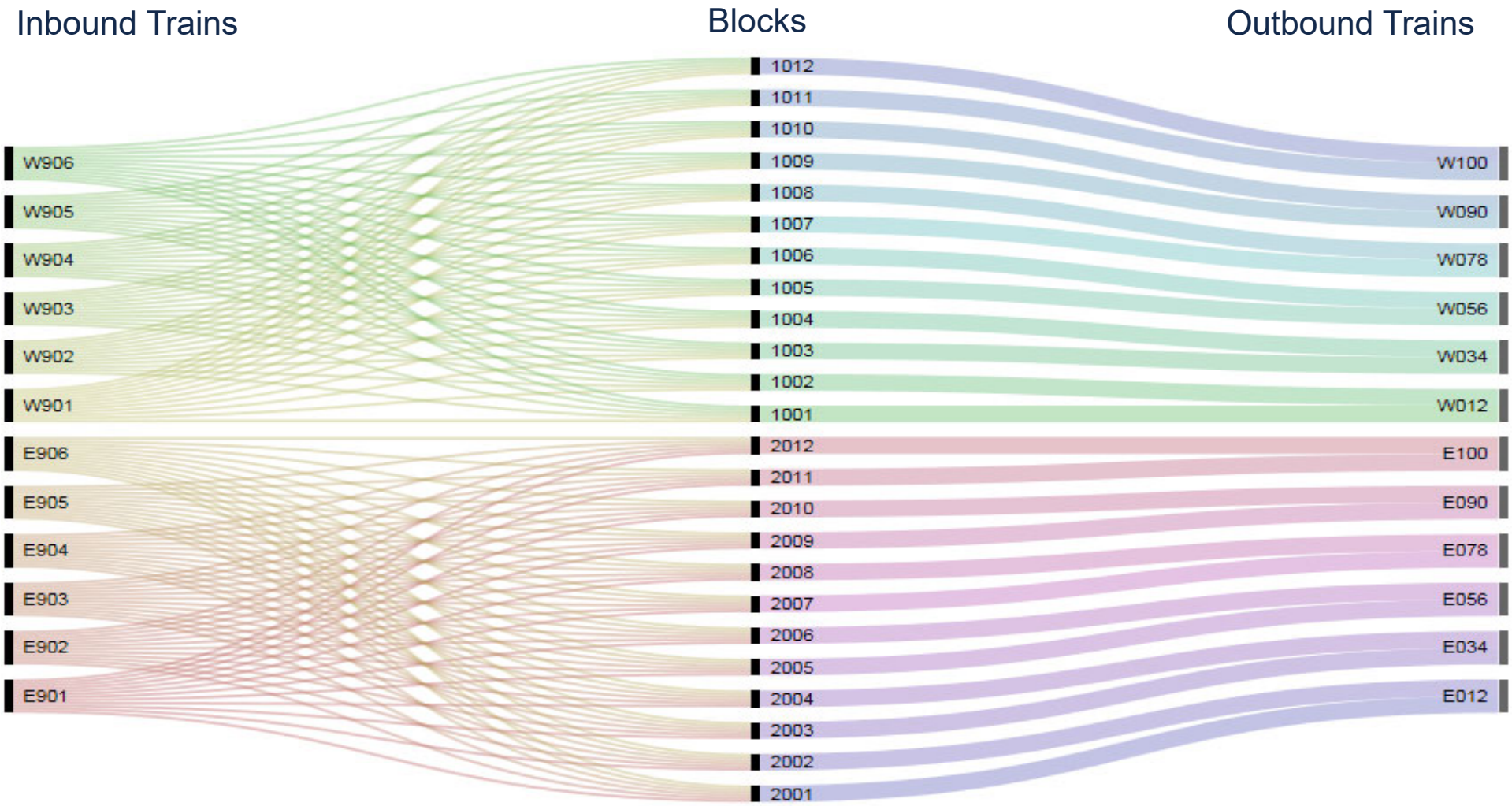




Complexity of Yard Traffic Flow



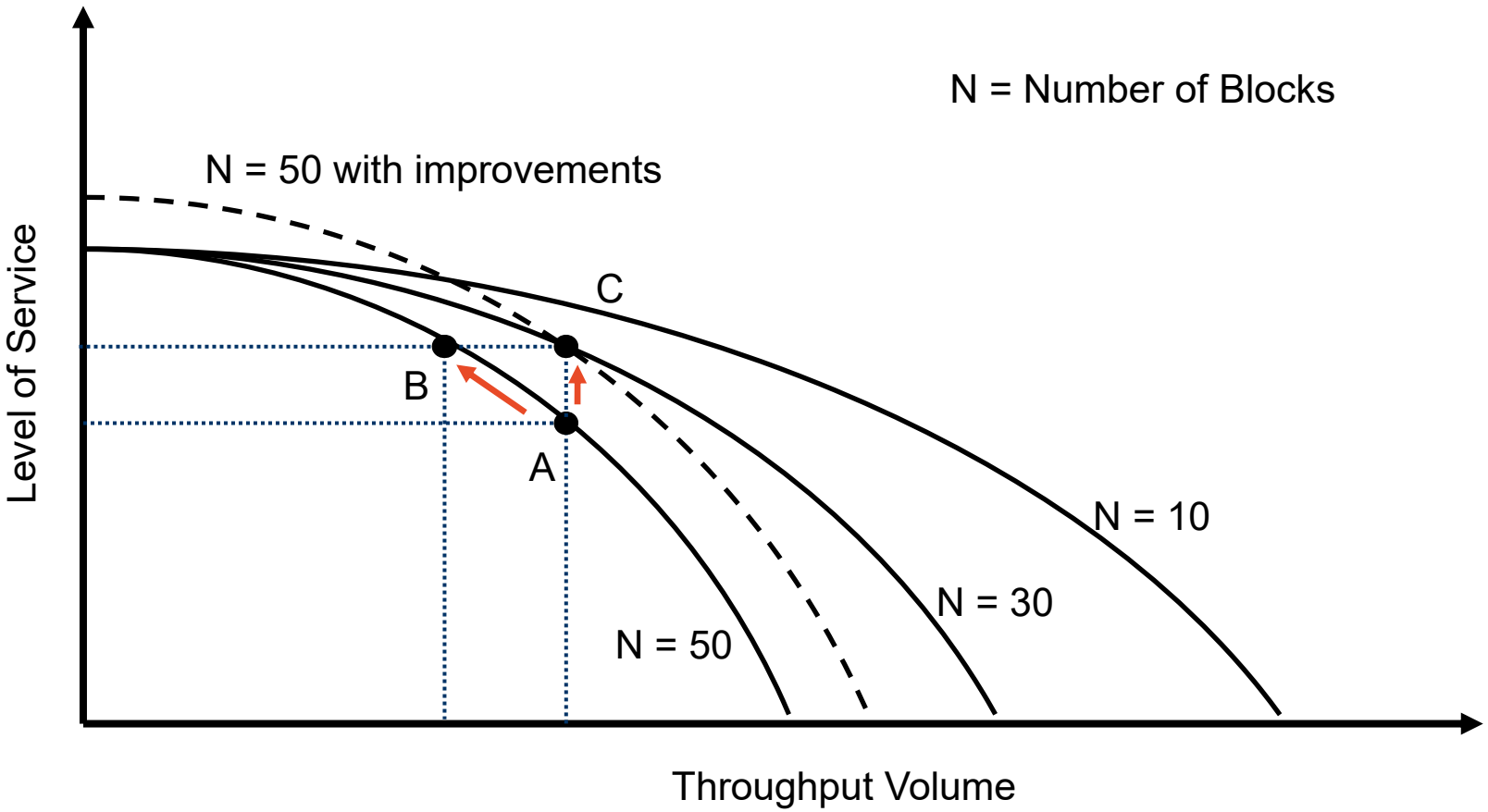
Less Complex Yard Traffic Flow



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

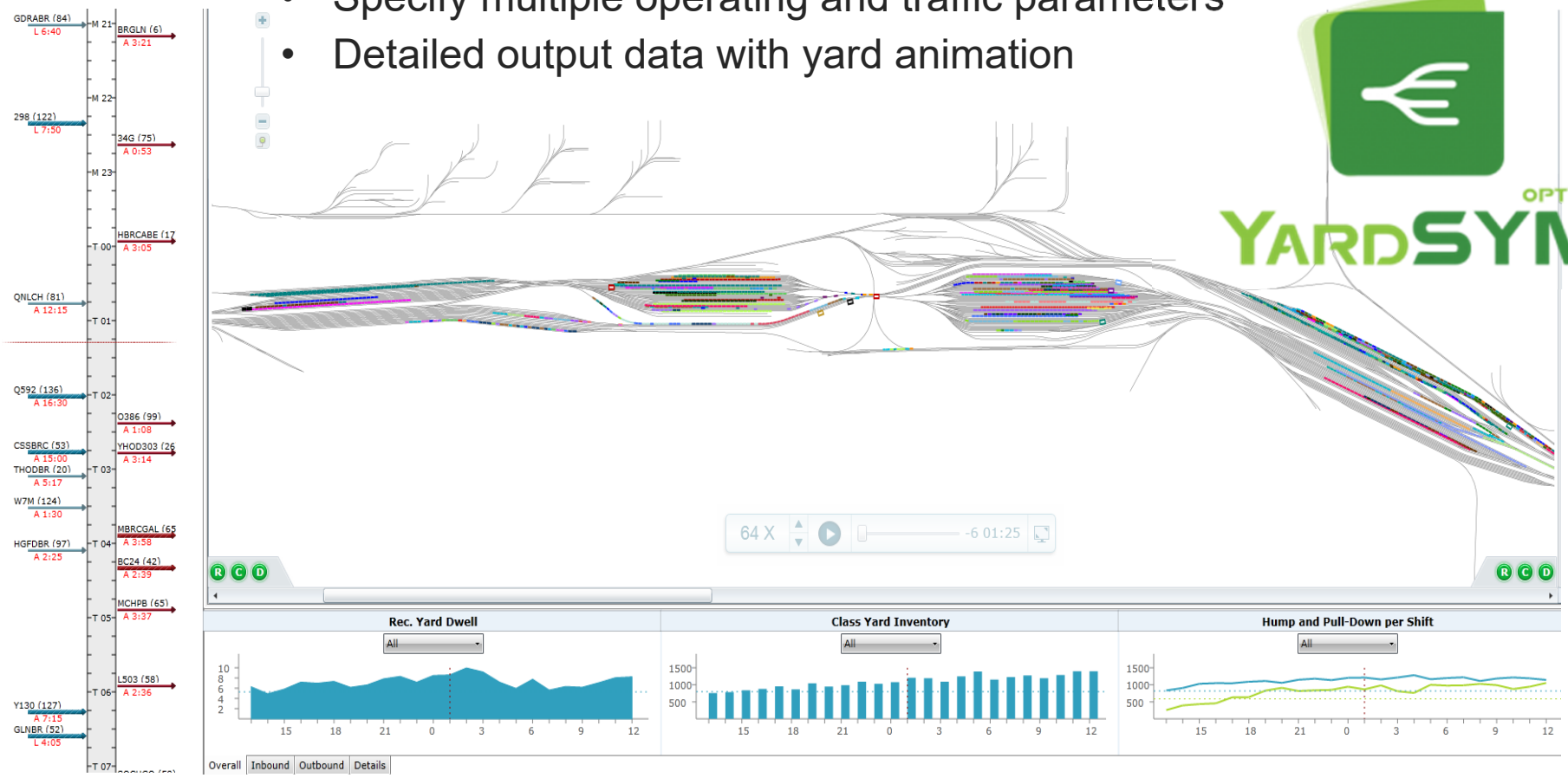


Yard Capacity Models: State-of-the-Art

- 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

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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

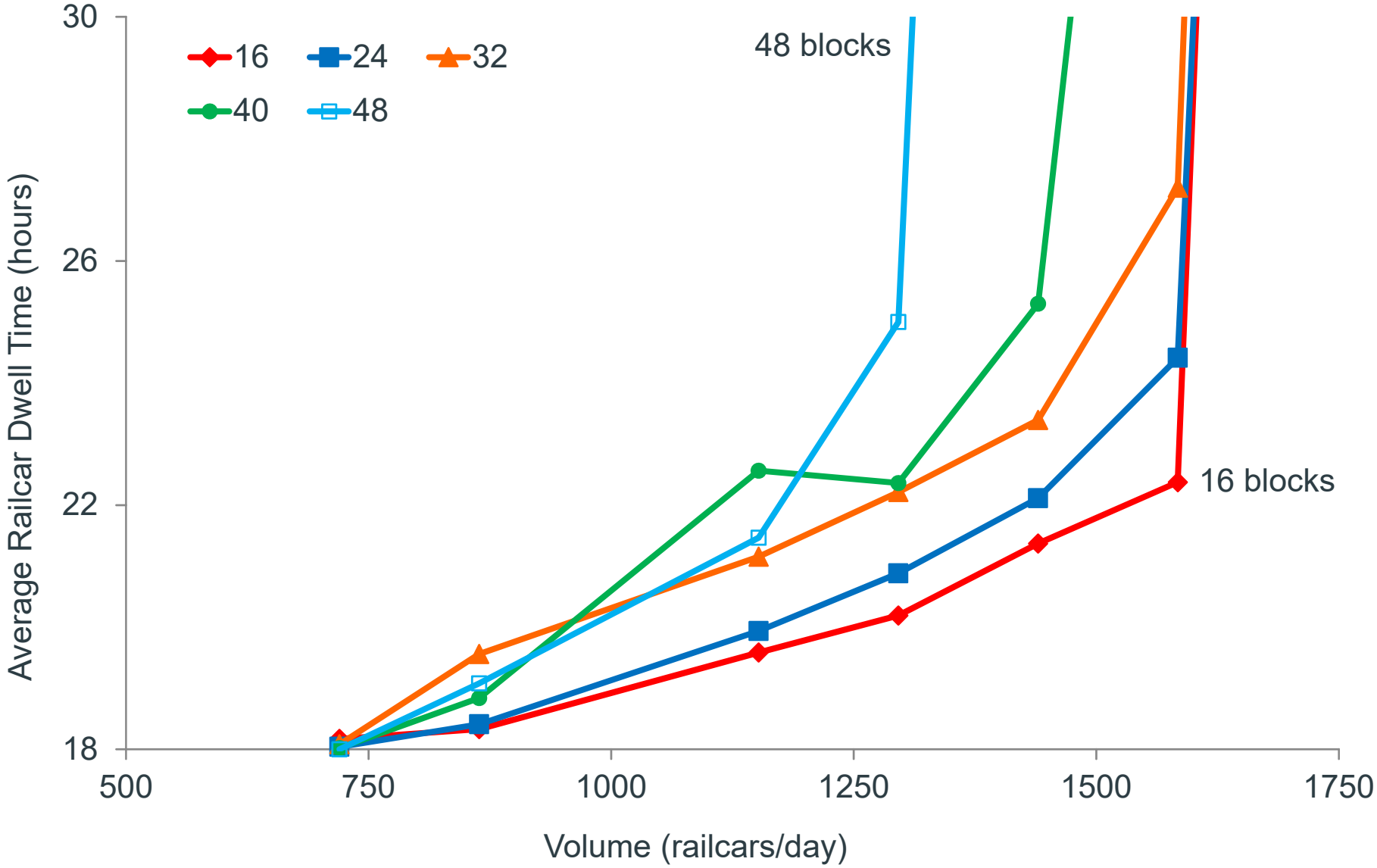
- Steady state conditions
  - Same traffic pattern every day
  - Subsequent experiments will introduce volume and schedule flexibility as additional experimental factors

Experiment 1: Volume and Blocks

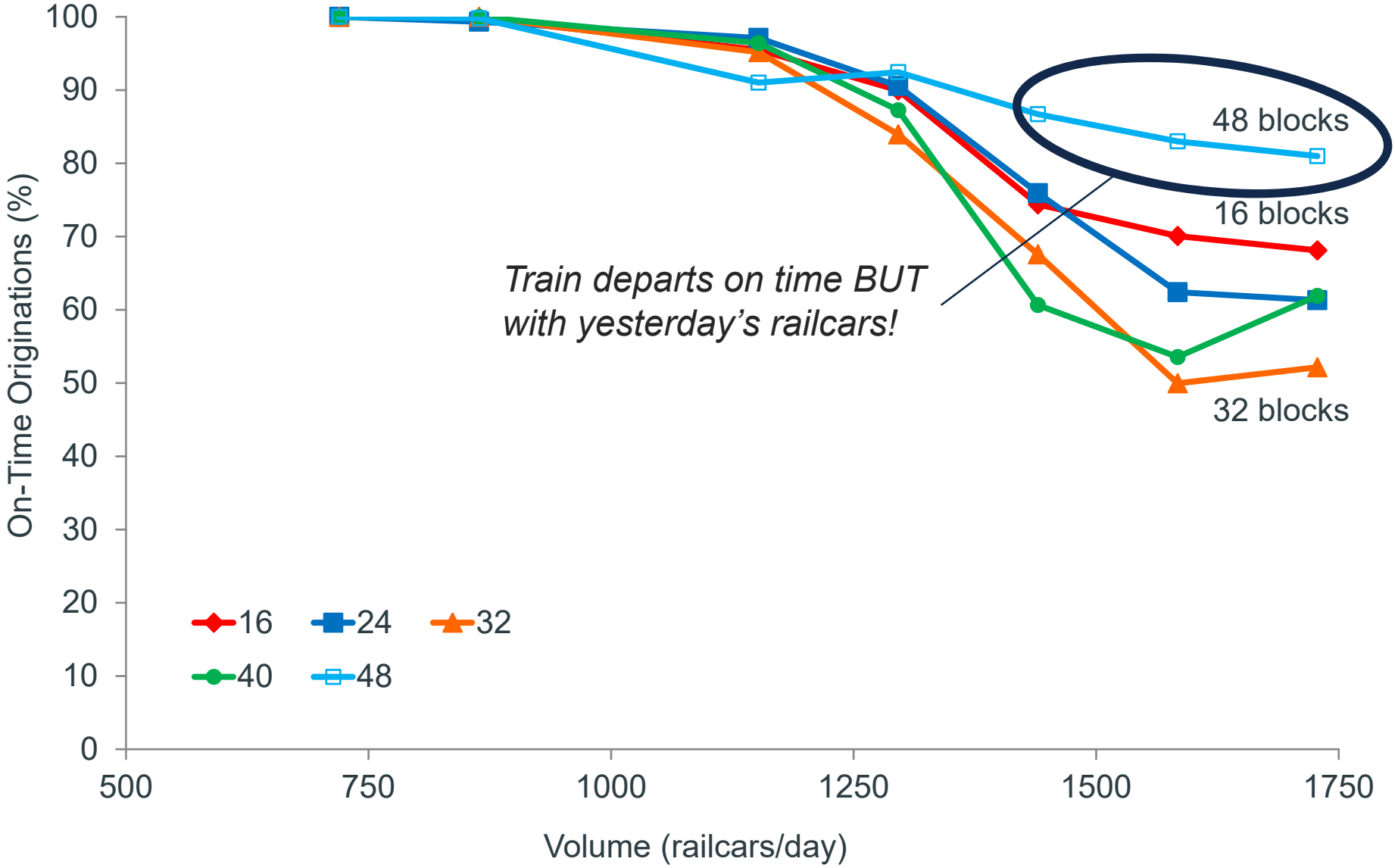
- Factors
  - Railcar volume: 720 to 1728 railcars per day
  - Number of blocks: 16 to 48 blocks per day
    - Block size, train length and blocks per train varies accordingly
- Fixed 18 inbound 16 outbound trains per day distributed evenly
- All inbound trains connect to every outbound train
- Example: blocking scenarios for 1,152 railcars per day

Scenario	Blocks	Inbound Railcars/Block/Train	Outbound Trains	Blocks/ Train	Cars/ Block	Average Blocks/Train
A	16	4	16	1	72	1
B	32	2	16	2	36	2
C	48	1.333	16	3	24	3
D	40	1.333	8	3	24	2.5
		2	8	2	36	
E	24	2	8	2	36	1.5
		4	8	1	72	

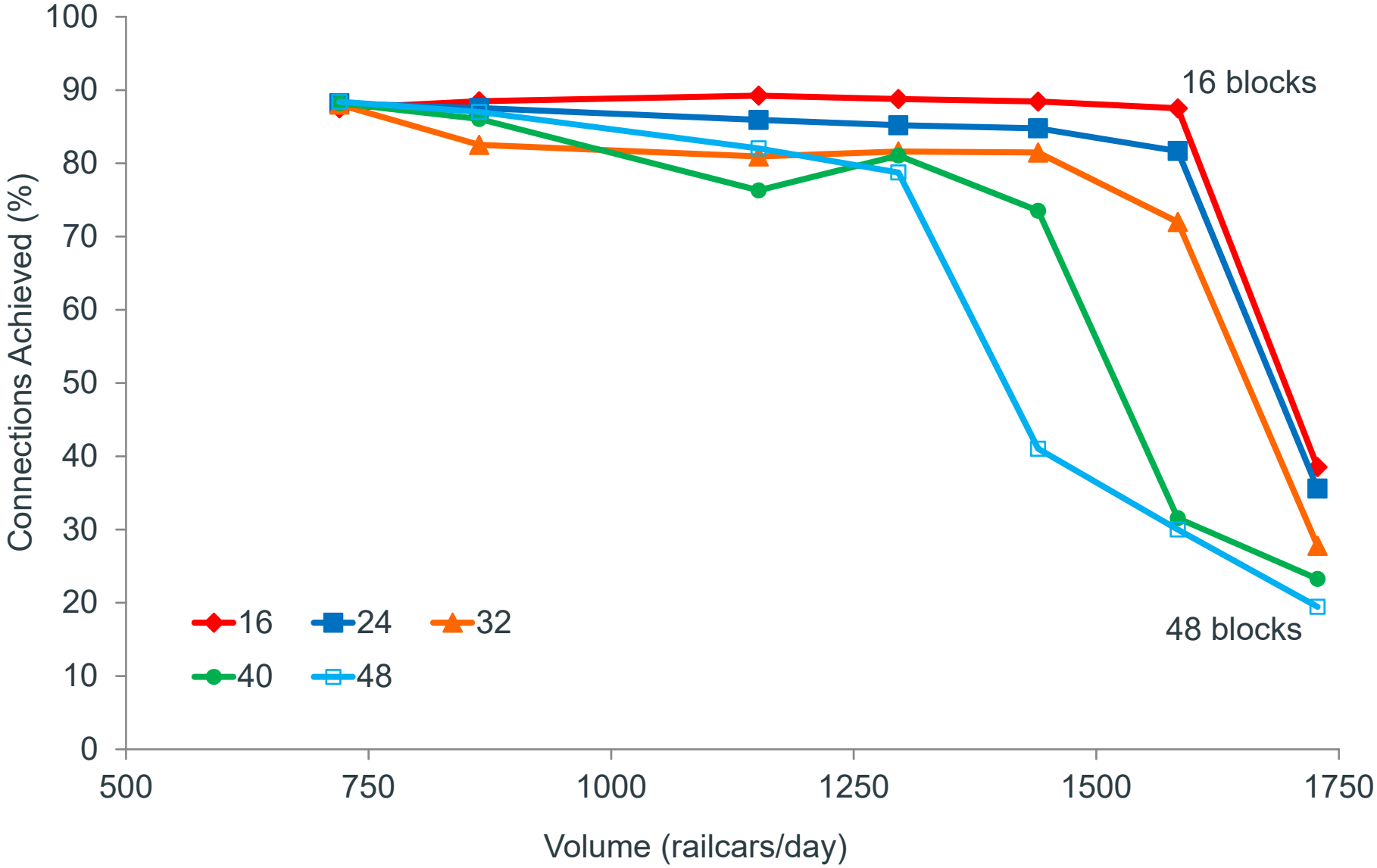
Blocks, Volume and Railcar Dwell Time



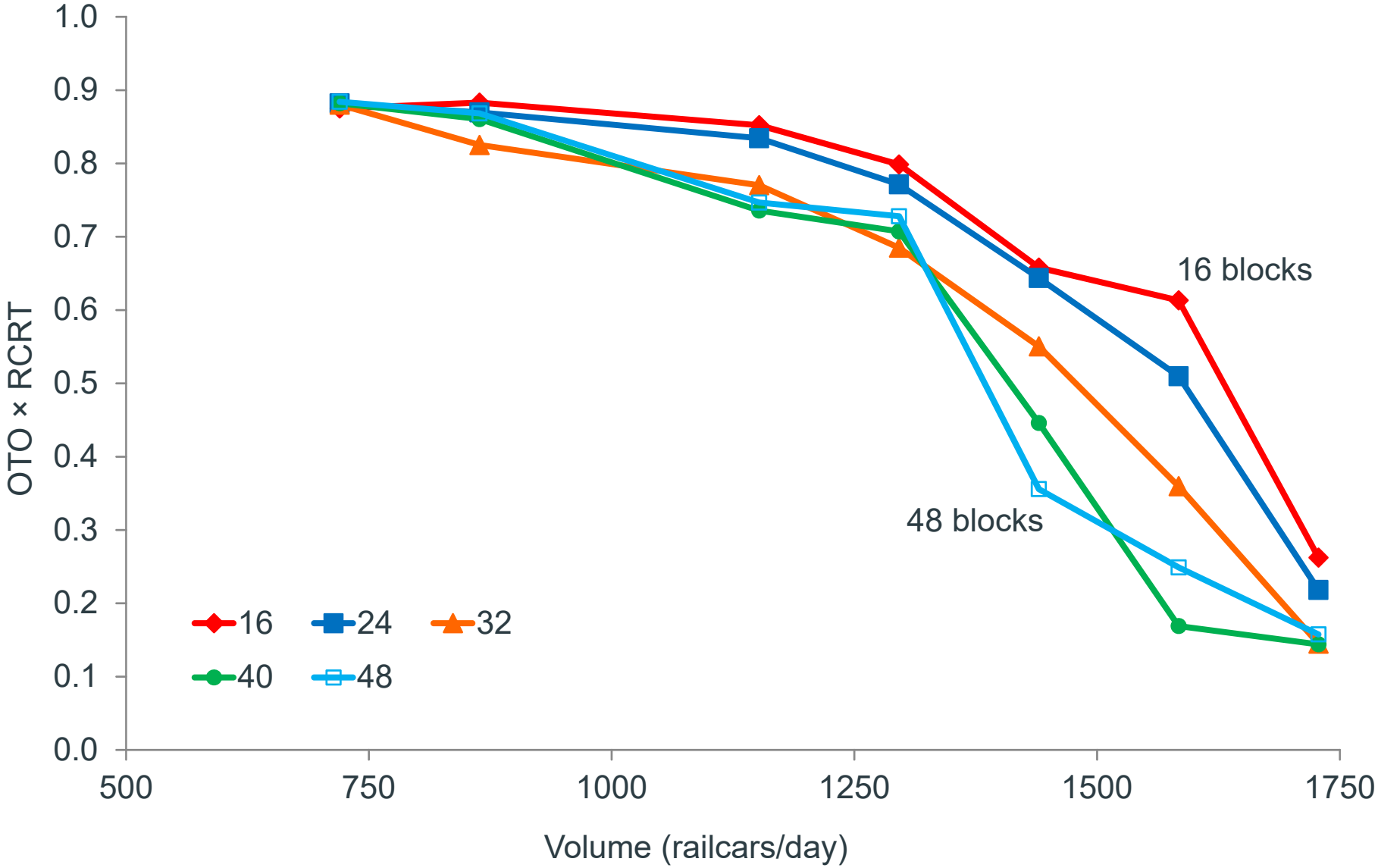
Blocks, Volume & On-Time Originations



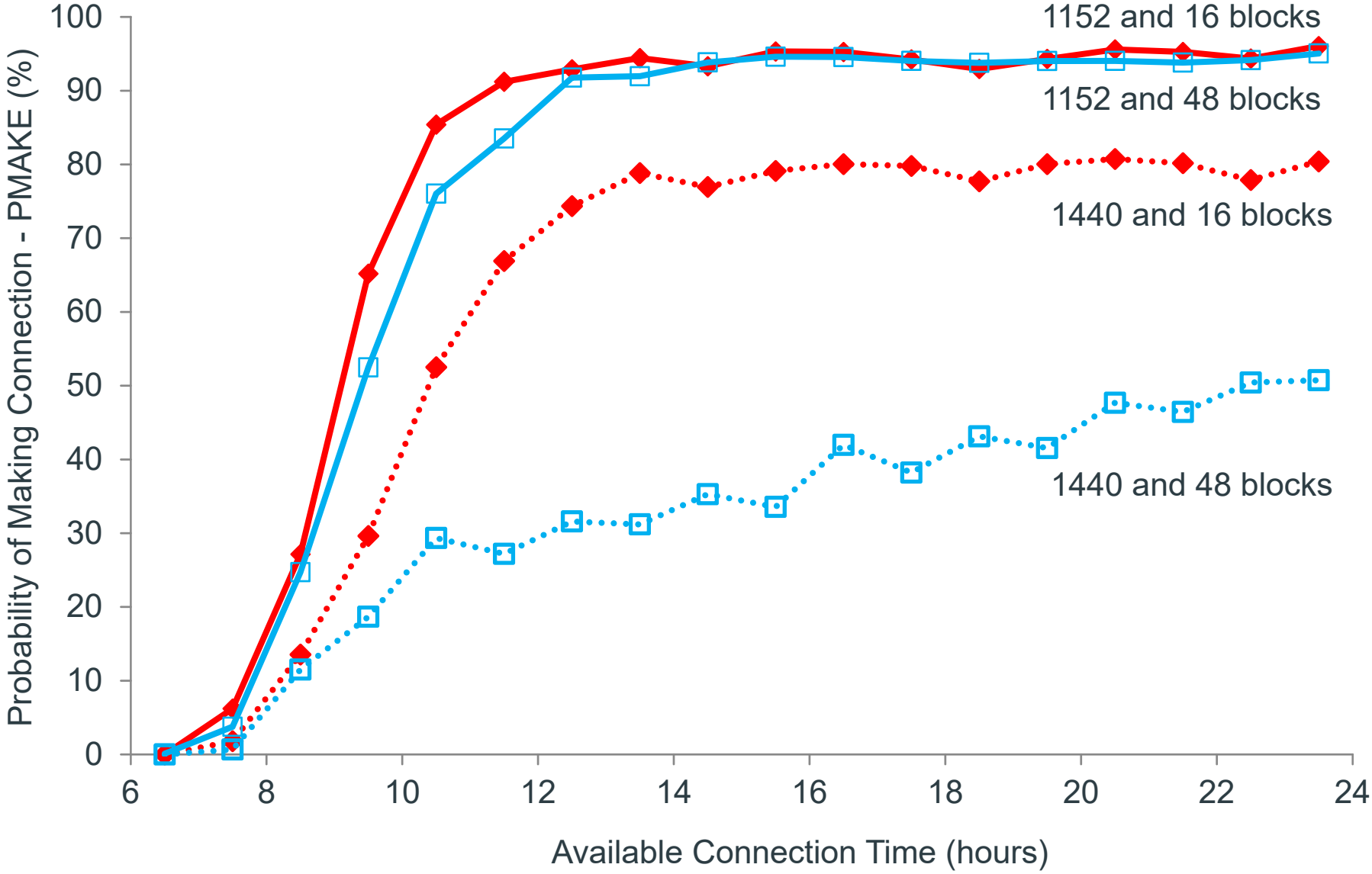
Blocks, Volume & Connections Achieved



Blocks, Volume & On-Time Connections



Blocks, Volume & PMAKE



Experiment 4: Variability

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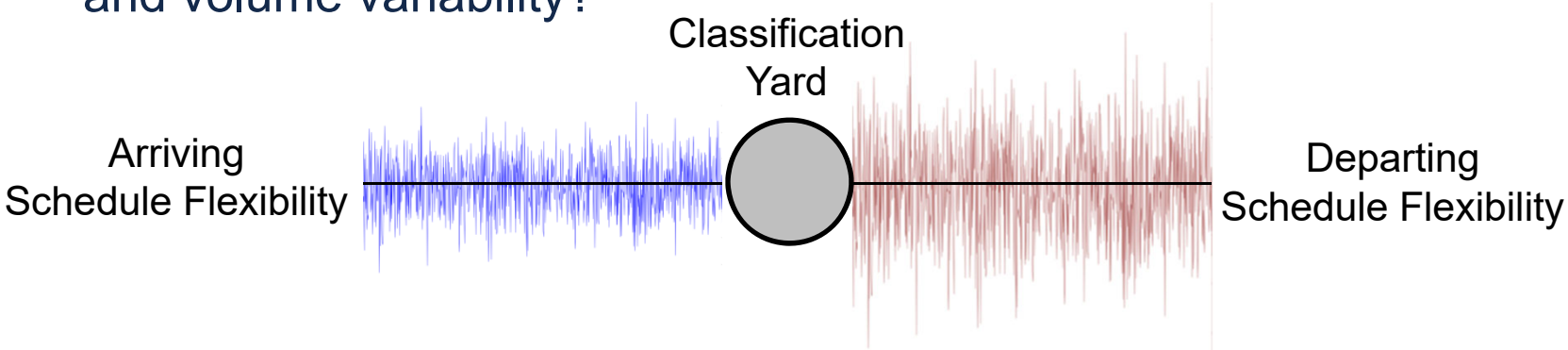
- Ongoing work investigates the influence of volume variation and schedule flexibility on classification yard performance and capacity

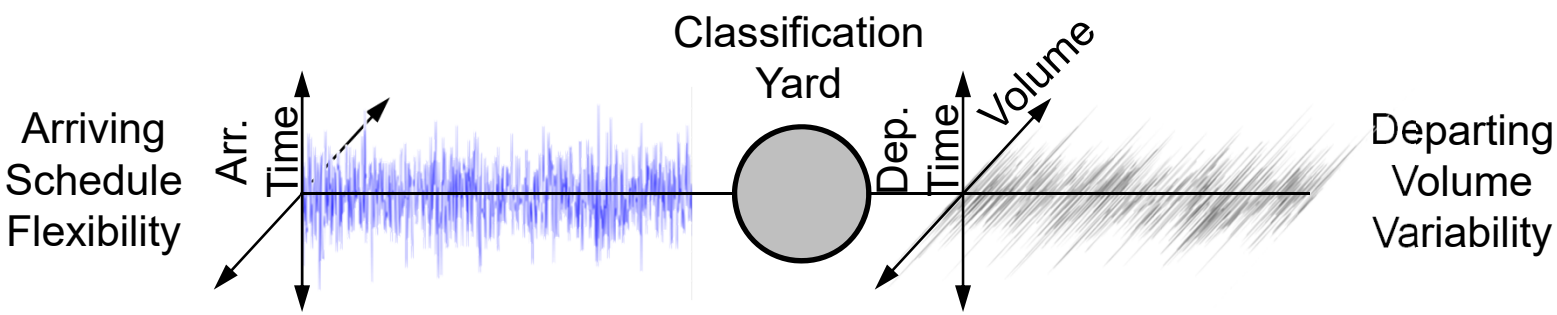
Propagation of Variability

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

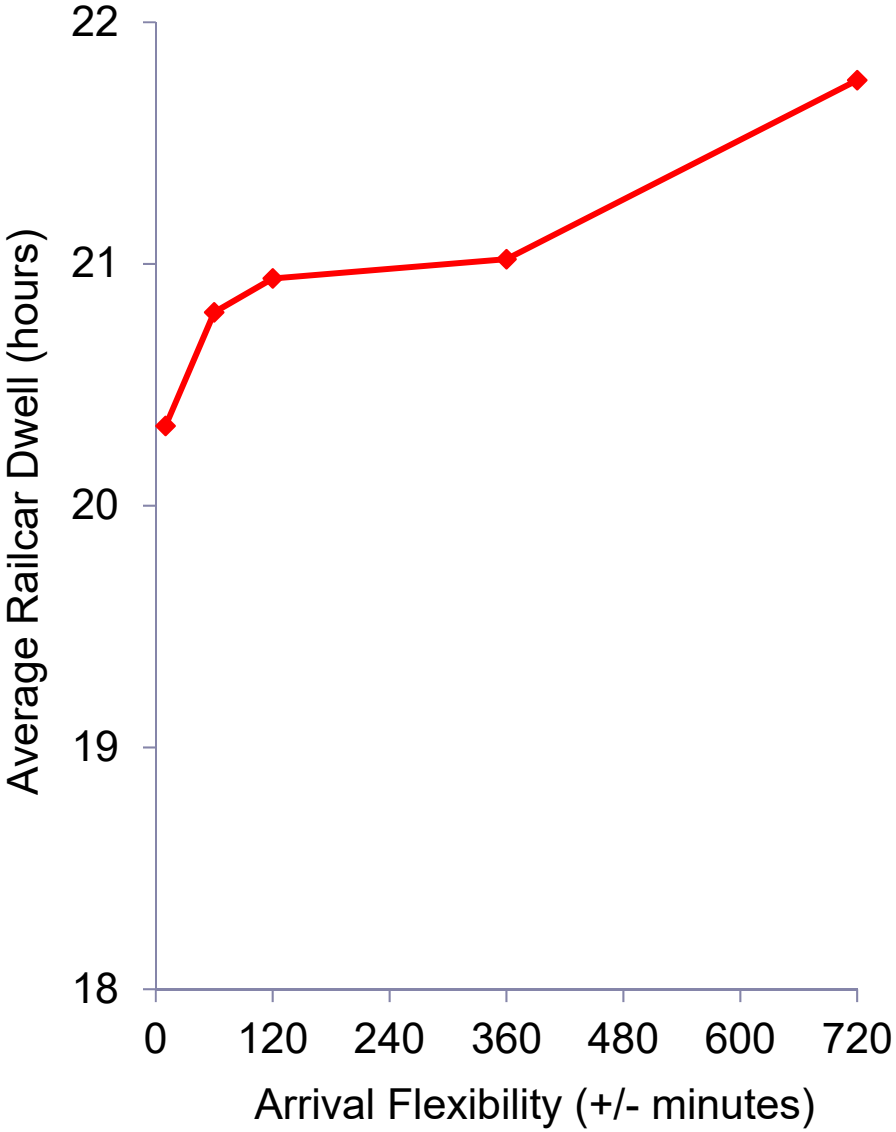
- 1) Does a classification yard amplify or dampen schedule flexibility and volume variability?

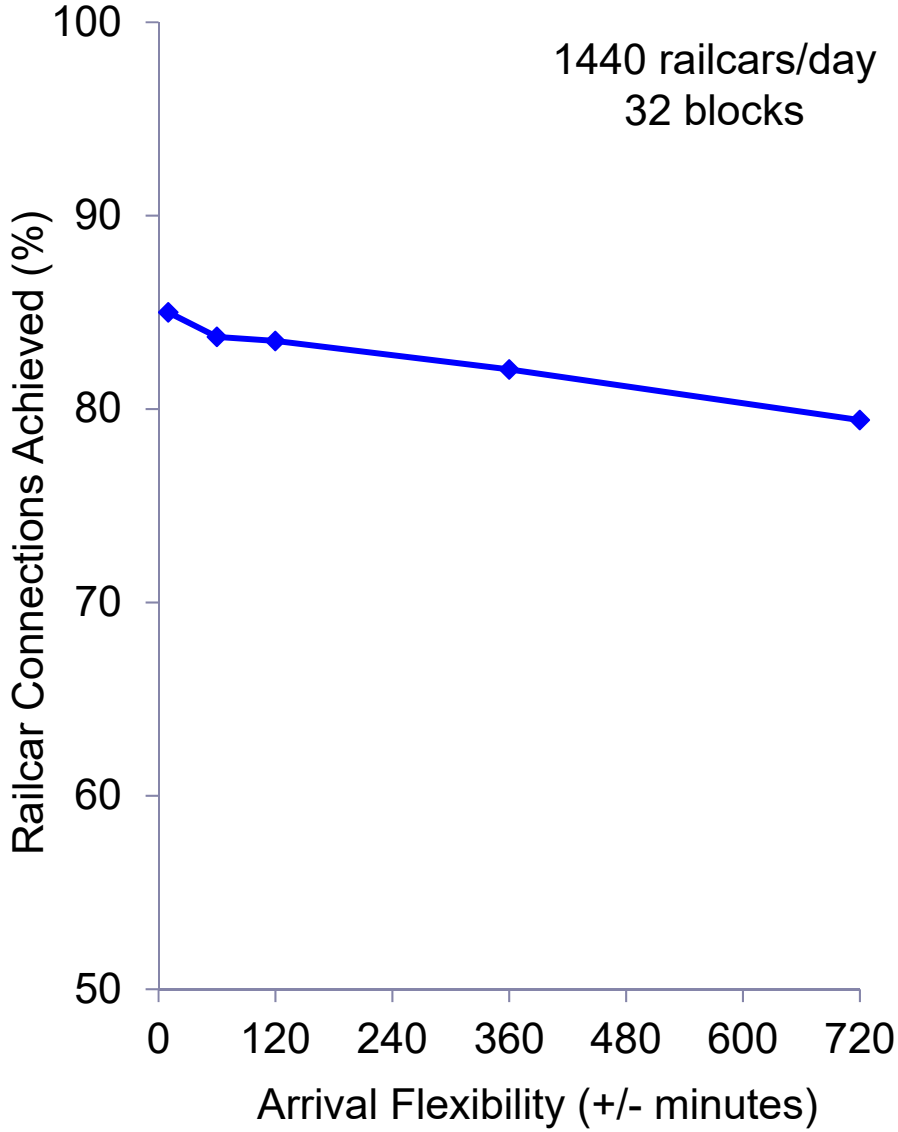


- 2) Does a classification yard transform schedule flexibility into volume variability and vice-versa?



Flexible Arrivals and Yard Performance





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!

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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