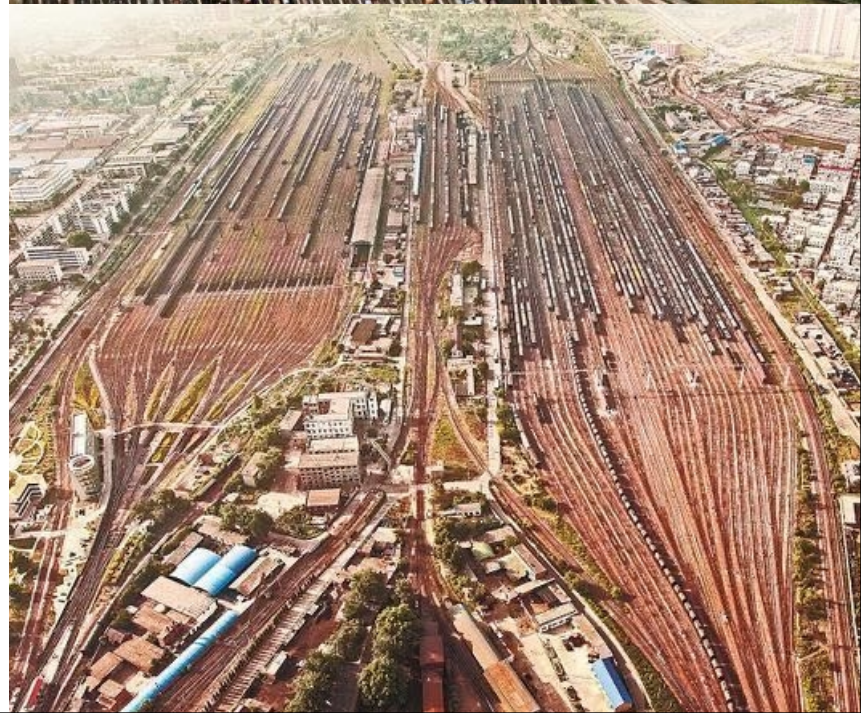
Hump yard performance simulation with AnyLogic



Jiaxi Zhao

INFORMS 2020

Yards and Terminals Virtual Session

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Objective

- Evaluate additional factors influencing hump classification yard capacity and performance
- Understand the interaction between yards and mainline, focusing on capacity
- Study the interaction of multiple yards in a network, continuing the network efficiency cycle research
- Develop a high-level parametric yard capacity and performance model

Previous Work

- Previous research has been focusing on yard **capacity study** and **performance analysis**
  - Lack **parametric yard model**

- No common yard simulation software has been used widely
  - Simulation **visualization**
  - **Flexibility** to modify the model (YardSYM, etc.)
  - Combine high **accuracy and flexibility**

- Need approaches towards **railroad network efficiency**
  - Lack the ability to **reflect the interaction between mainline and yards**

New Approach

- AnyLogic is a multimethod simulation modeling tool developed by The AnyLogic Company (former XJ Technologies)
  - Supports agent-based, discrete event, and system dynamics simulation methodologies
- AnyLogic has a **rail package** that allows a track layout to be built from CAD files
  - Flexibility for yard operations and layout
- The visualization provides **visual evidence** that the simulation model is making correct yard operating decisions
- A simplified **mainline model** can be built in AnyLogic to connect yards
  - Realize a network simulation

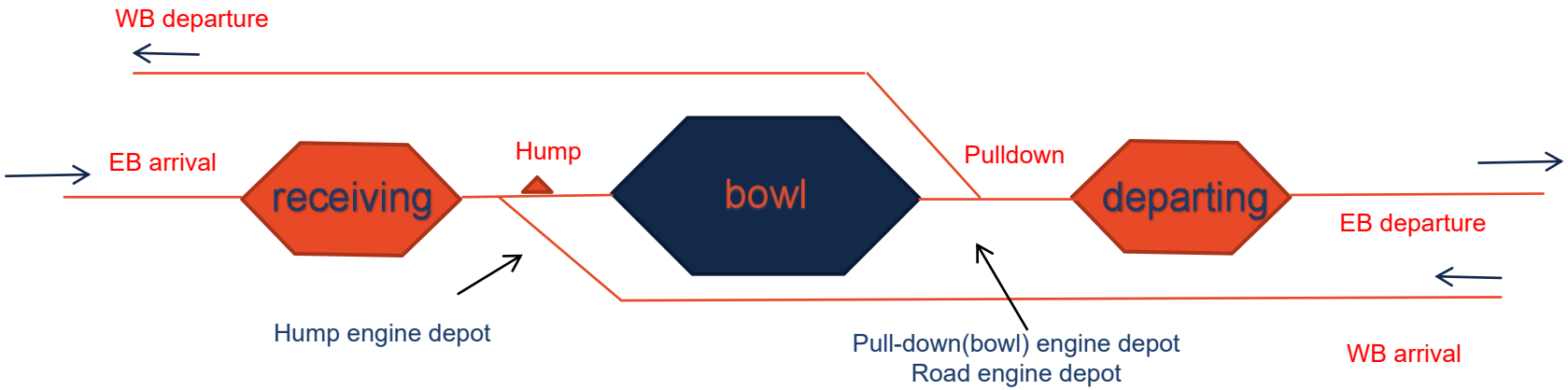
Potential variables

- AnyLogic offers a greater flexibility than previously used YardSYM

Features/ variables	YardSYM	AnyLogic
Yard layout (parallel/inline, geometry, number of tracks, track length, etc.)		
Inbound/outbound frequency and **unbalanced schedule**		
Number of hump engine and **number of pull-down engine**		
Bowl track length and **distribution**		
Block to bowl track assignment matching track length		
Outbound train composition (various number of blocks in outbound trains)		
Over-length block assignment strategy (building dirty blocks)		
Pull-down strategy (resolving dirty blocks)		
Pull-down schedule (adjustable assembly time prior to departure)		

*Dirty track: bowl tracks with more than two blocks

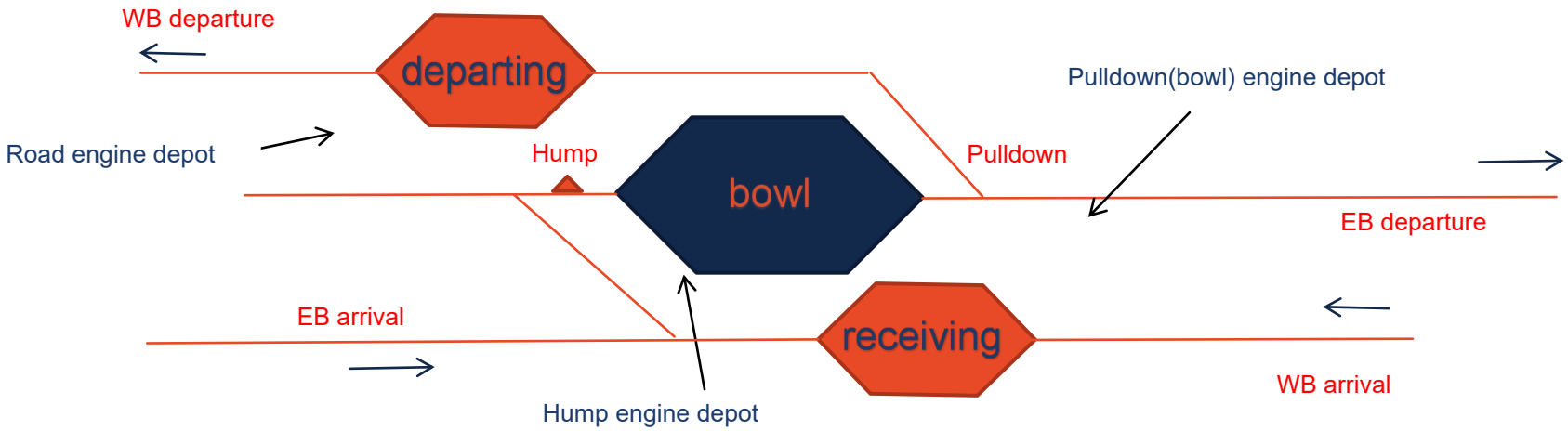
Basic Model- Inline Yard Layout



Generic Inline Yard Design

Receiving track	6 (>10,000 ft available distance)
Engine pass in receiving yard	1
Hump engine depot	1
Hump lead	1
Block formation track in bowl	32 (55-75 car length)
Rehump track in bowl	1
Pulldown engine depot	1
Road engine depot	1
Departure track	6 (>10,000 ft available distance)
Engine pass in departure yard	1

Basic Model-Parallel Yard Layout



Generic Parallel Yard Design

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Pulldown engine depot	1
Road engine depot	1
Departure track	6 (>10,000 ft available distance)
Engine pass in departure yard	1

Basic model Example

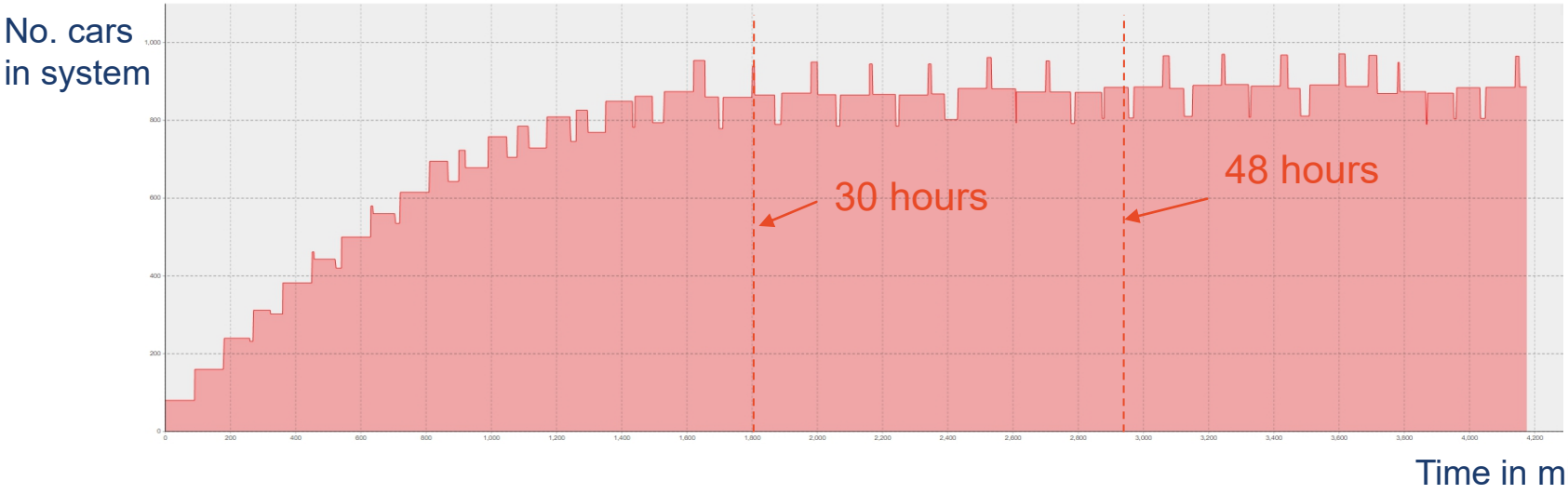
- Simulation display
  - https://www.youtube.com/watch?v=Ic-4yHDzqFI&feature=youtu.be

Performance measures	Example result (180 days)
Average dwell time (and distribution)	16.08 hours
Average idle time percentage in yard	70.3%
Average bowl idle time (and distribution)	10.97 hours
Hump utilization	46%
Pulldown utilization	32.7%
Extra hump work (number of re-hump cars per day)	6.48
Outbound train on-time* ratio	72.1%
Dwell/ idle time and distribution during each operation	available

*Trains finish assembly and departure inspection earlier or less than 10 mins late than schedule

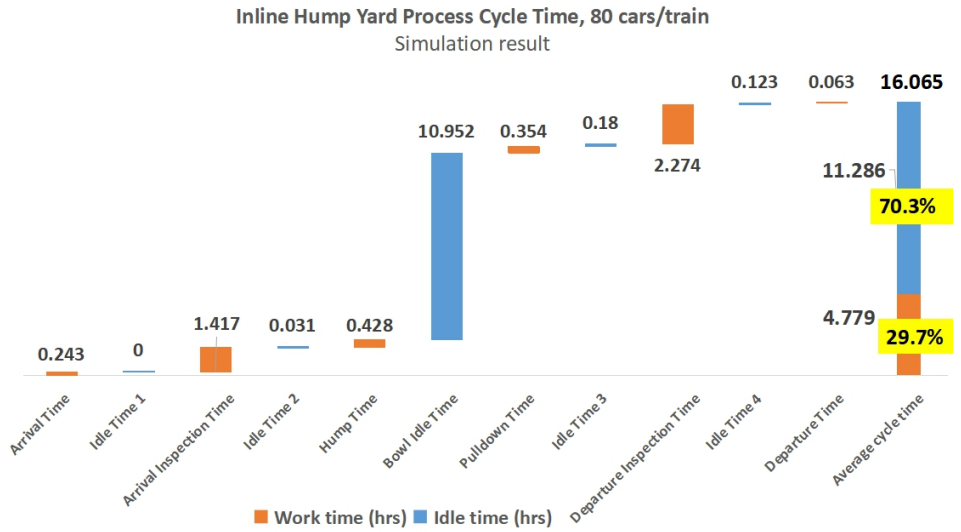
Performance Measures

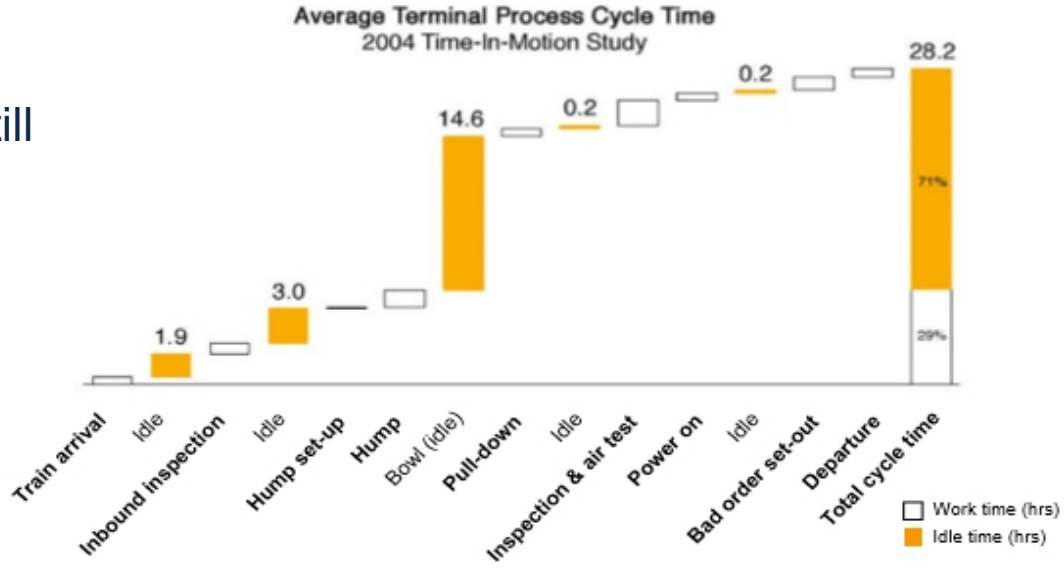
- When has model output stabilized?
  - The number of cars in system stabilizes
  - Starting with empty and idle
  - Reaches steady state after about 30 hours
  - For better results, start collecting data at 48 hours



Model Process Validation

- Select **proportion of the car dwell time that is idle** as testing measure
- Select **16 blocks**, **80 cars/train** as testing scenario
  - Simulation output: 70.3% of dwell time is idle
  - Published research: 71% of dwell time is idle (Logan* 2006)
- Additional forms of validation still need to be completed





*Dirnberger, J.R. 2006. Development and Application of Lean Railroading to Improve Classification Terminal Performance. Master's Thesis, University of Illinois at Urbana-Champaign, Department of Civil and Environmental Engineering, Urbana, IL, USA

Experiment design

- Constant factors
  - **16** inbound trains (same length) arrive evenly
  - **16** outbound trains (same length, each carrying 1 or 2 blocks) are scheduled to depart evenly

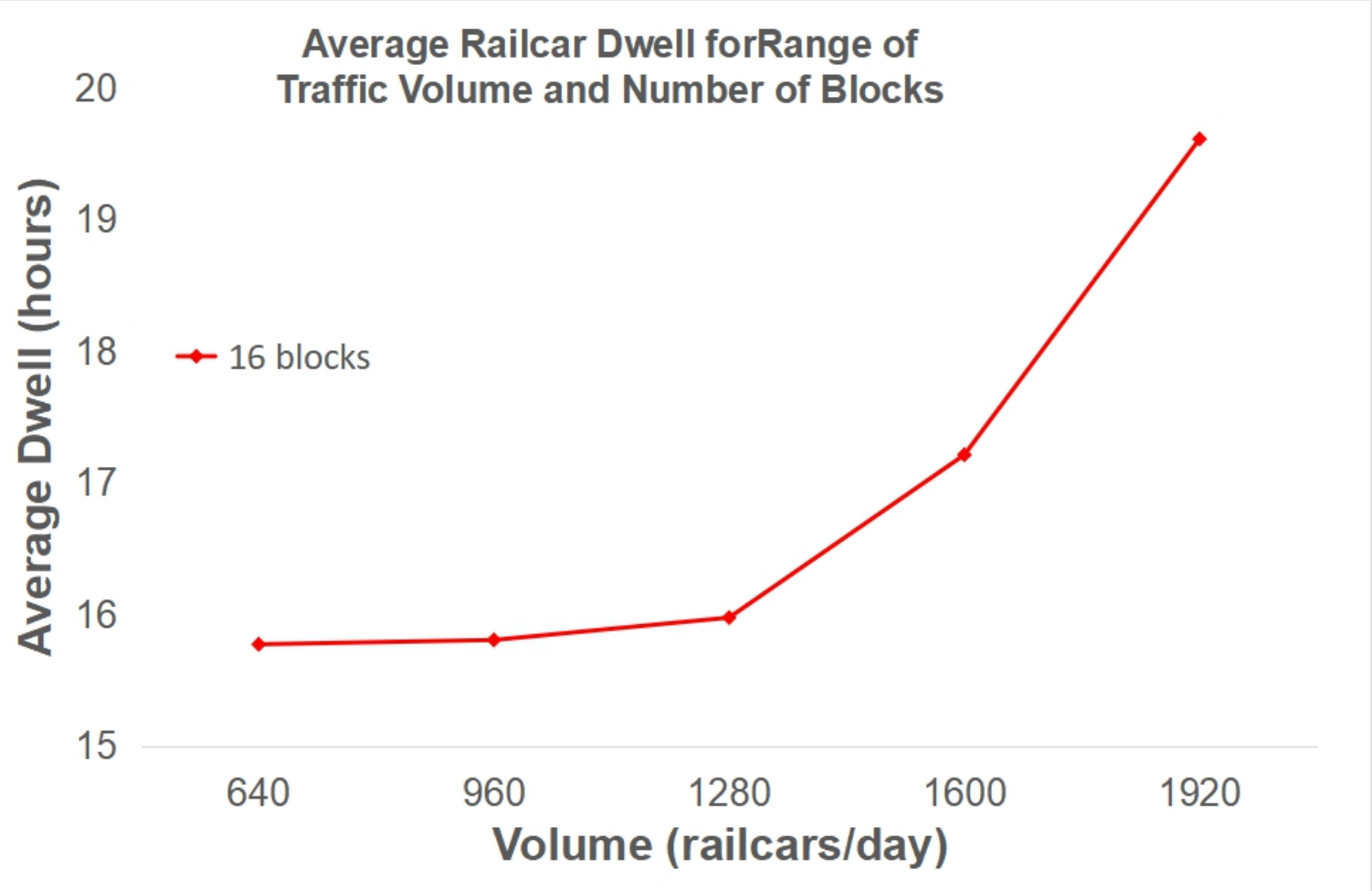
- Varible factors
  - **Volume**: 40-120 cars/train, i.e. 800-1920 cars/day
  - **Number of blocks built in bowl**: 16, 20, 24, 28, 32, hence number of tracks for over-length blocks: 16, 12, 8, 4, 0

- Example block pattern: 1280 cars/day

Total volume	Inbound train length (in cars)	No. blocks	No. trains with 1 block	Block length (in cars)	No. trains with 2 blocks	Block length (in cars)	Outbound train length (in cars)
1280	80	16	16	80	0	40	80
		20	12		4		
		24	8		8		
		28	4		12		
		32	0		16		

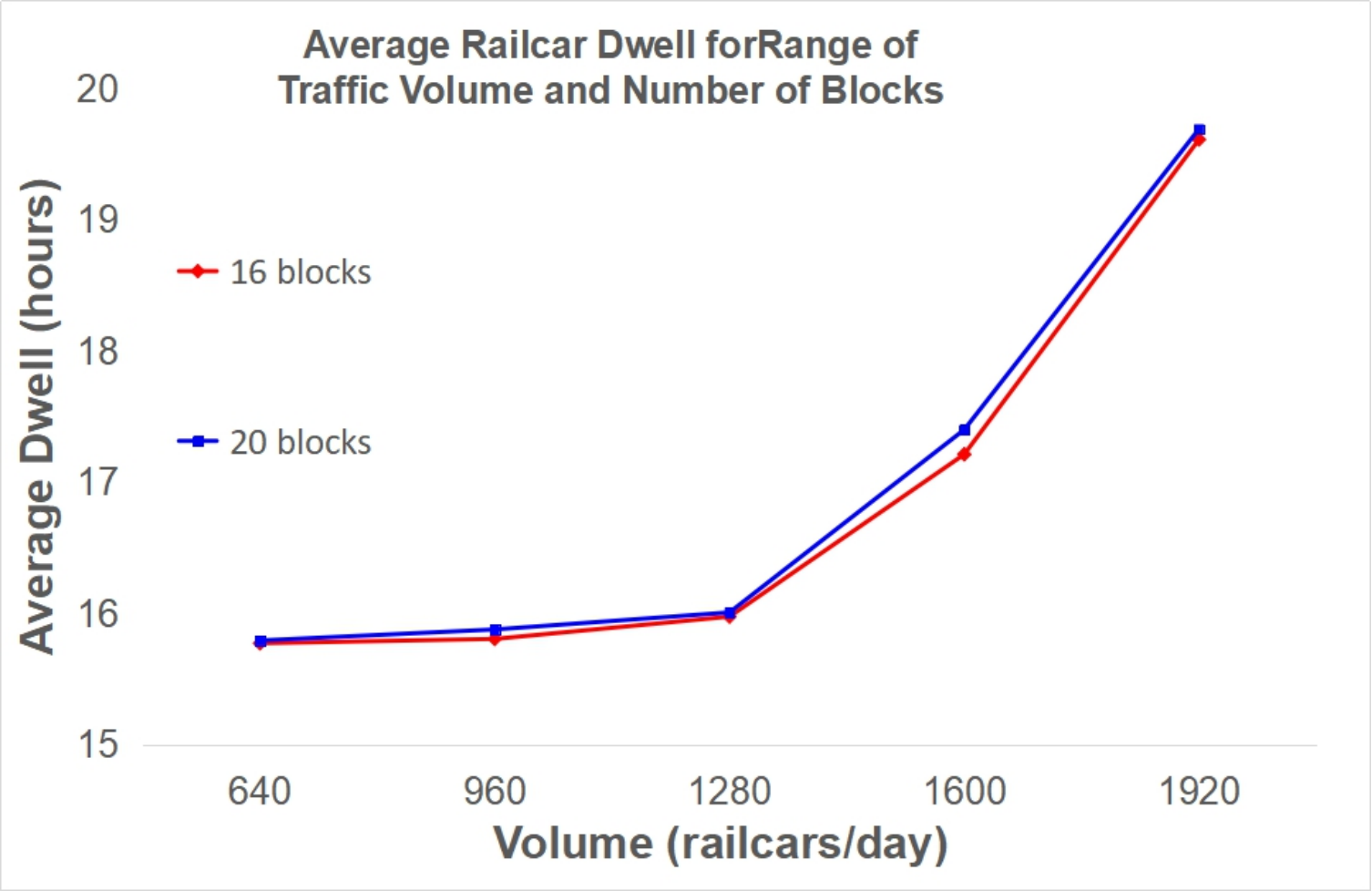
Preliminary Result- Dwell Time

- 16 blocks



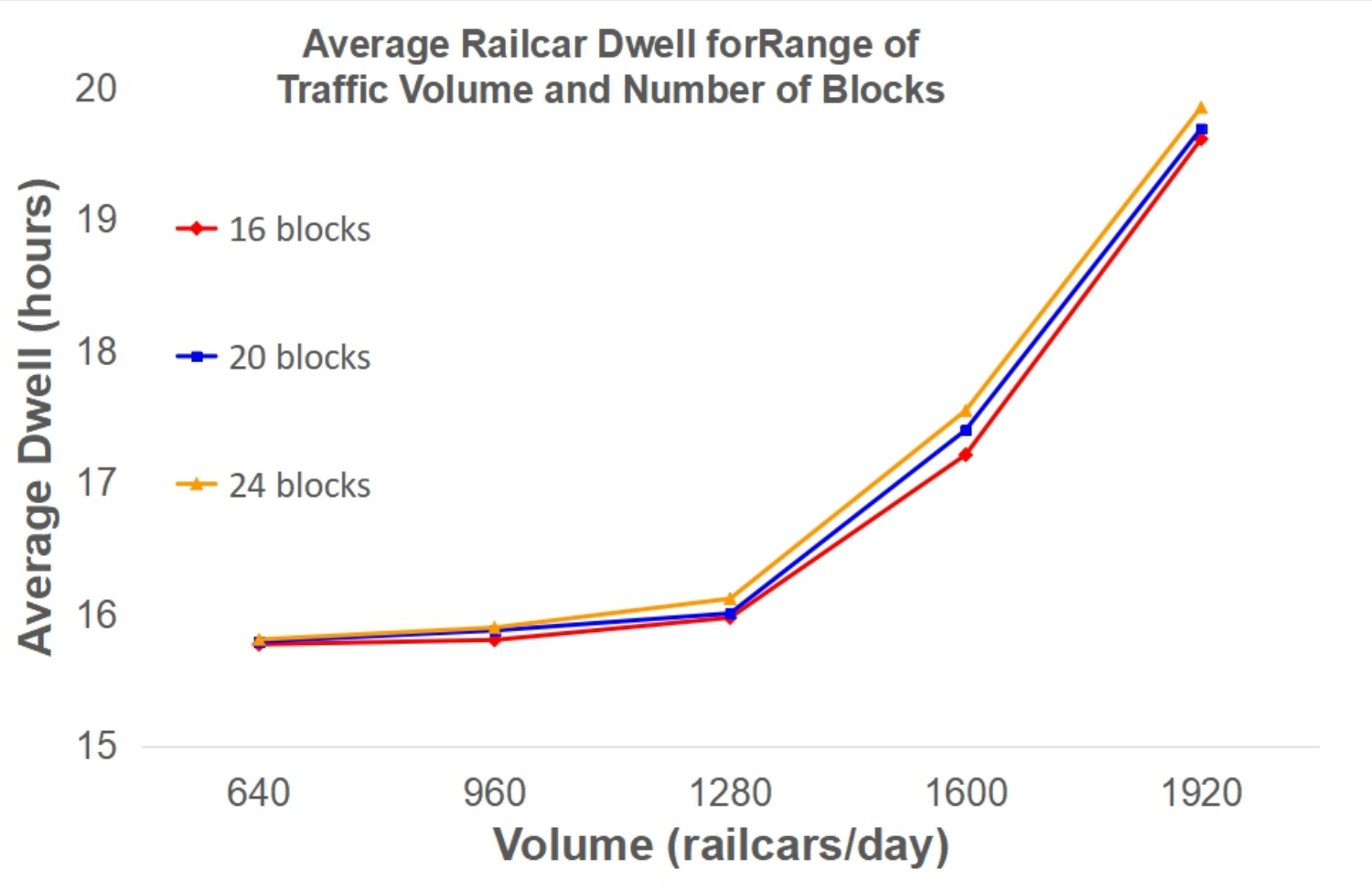
Preliminary Result- Dwell Time

- 20 blocks



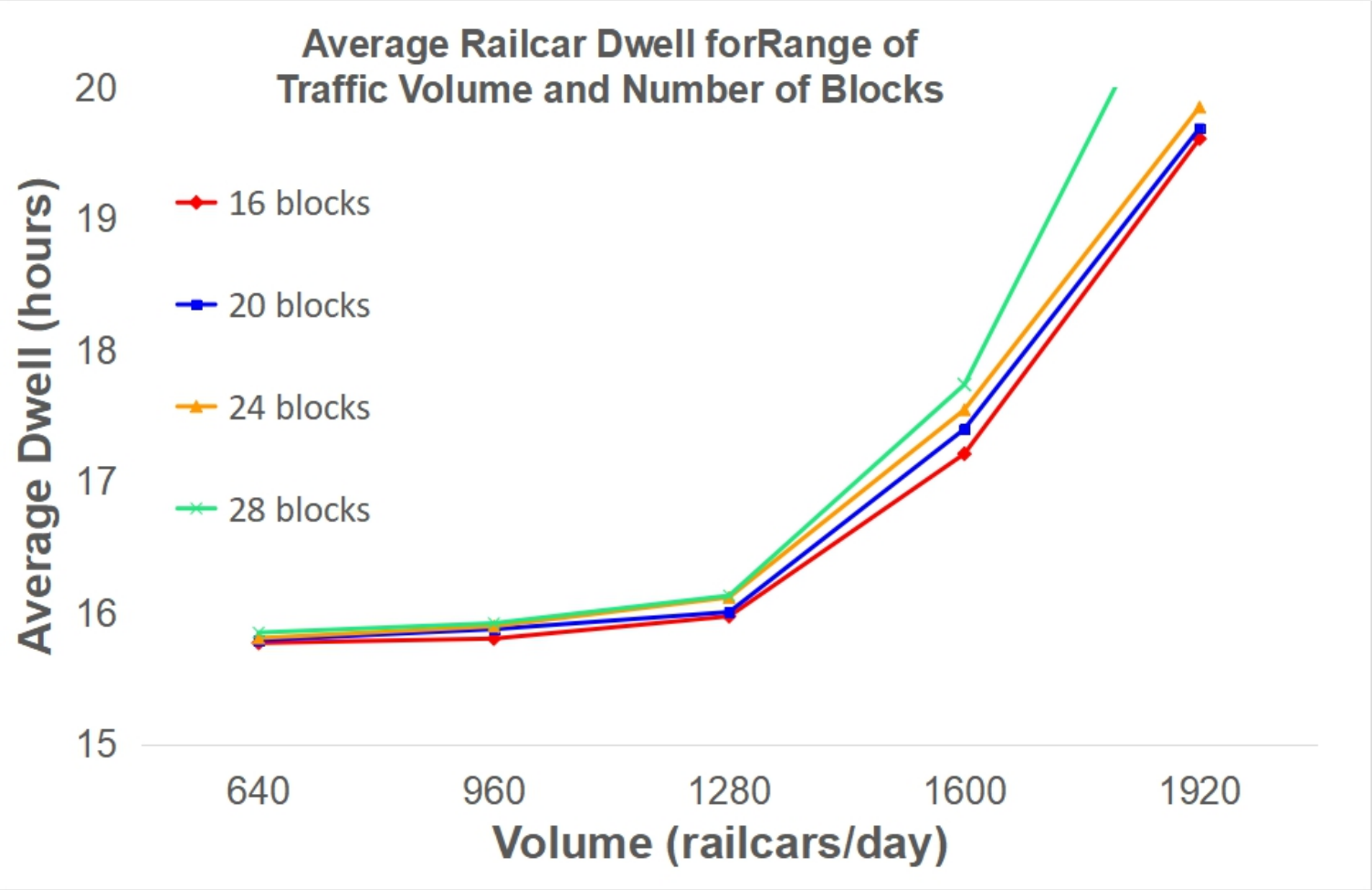
Preliminary Result- Dwell Time

- 24 blocks



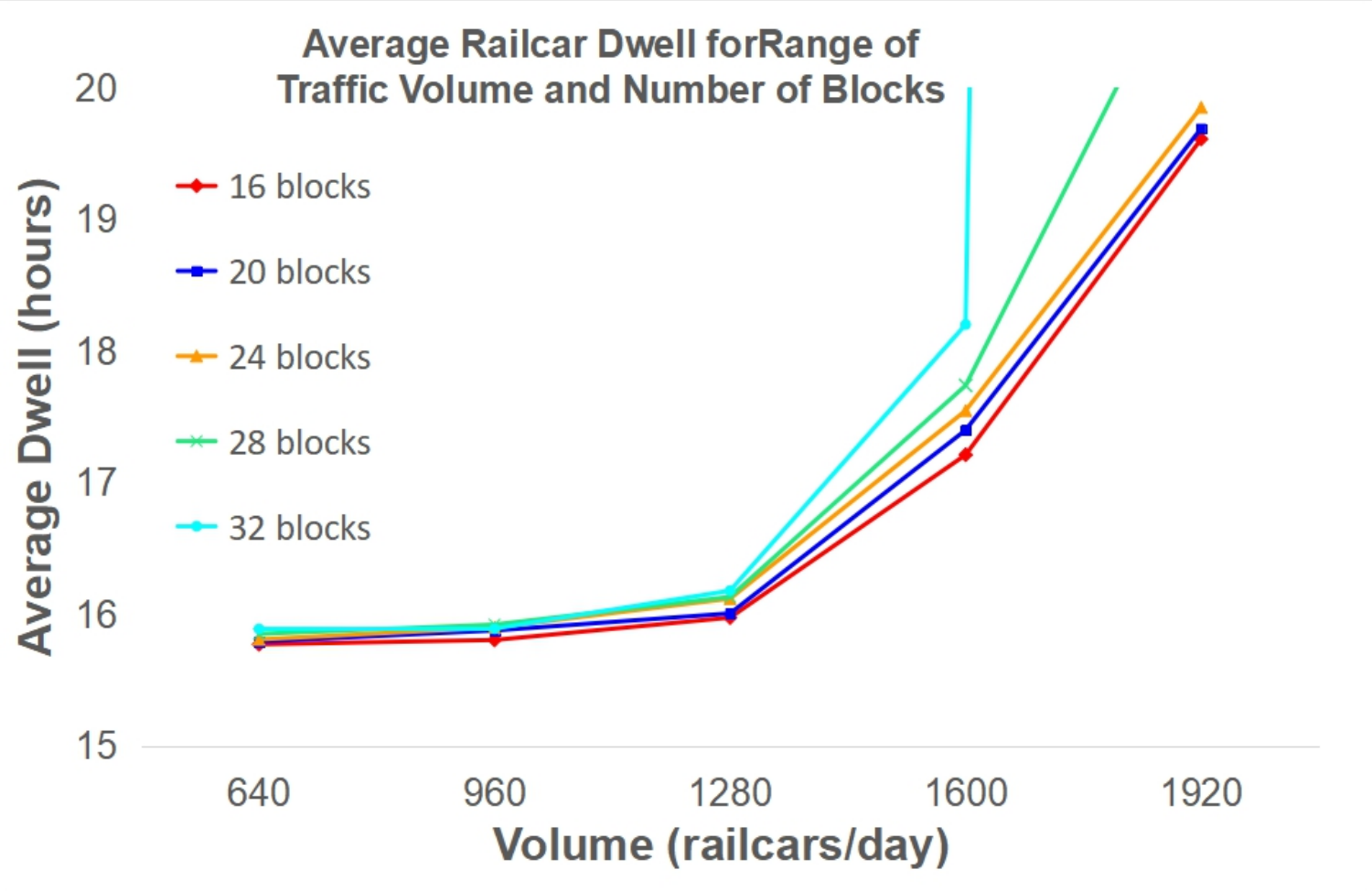
Preliminary Result- Dwell Time

- 28 blocks



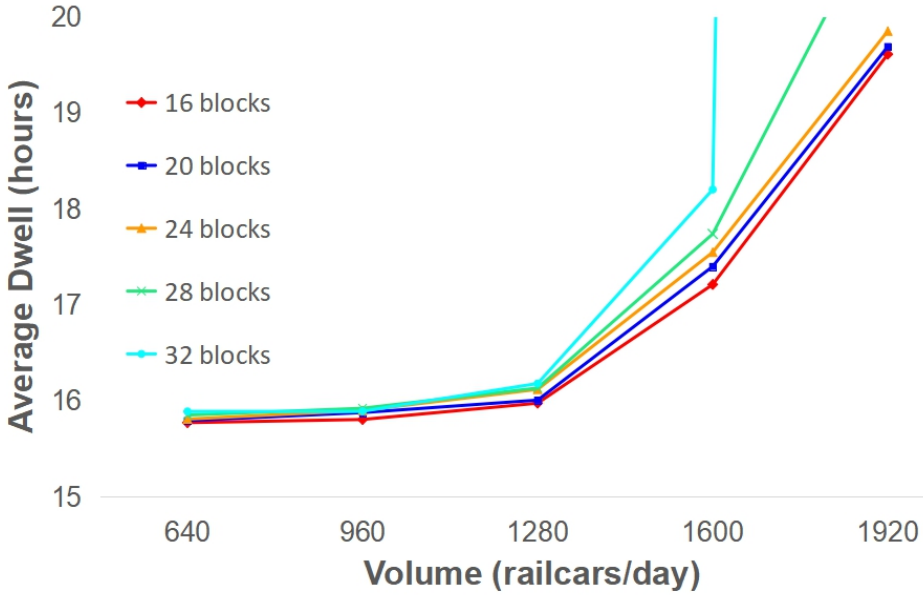
Preliminary Result- Dwell Time

- 32 blocks

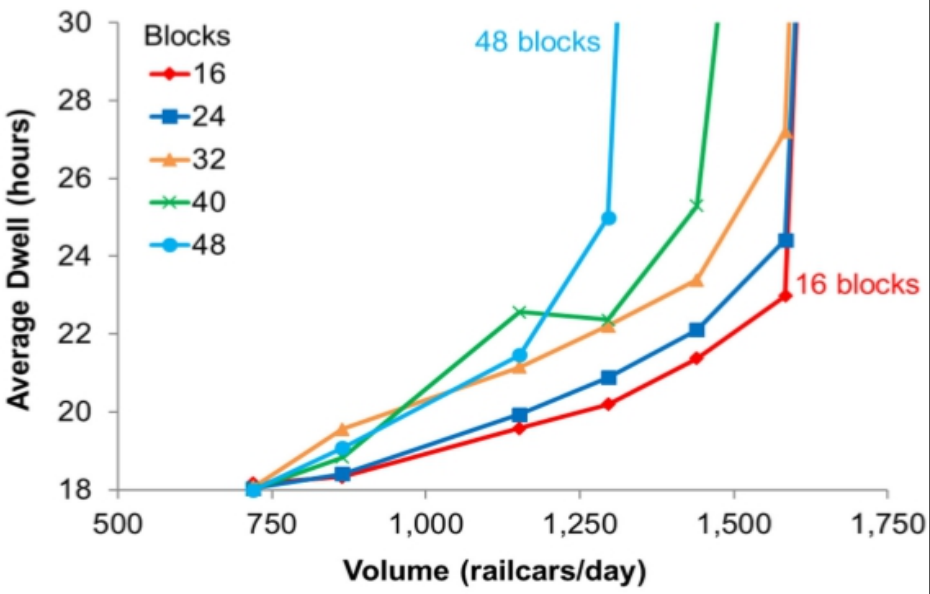


Comparison to Previous Research

- Average railcar dwell for range of traffic volume and number of blocks



Anylogic Result

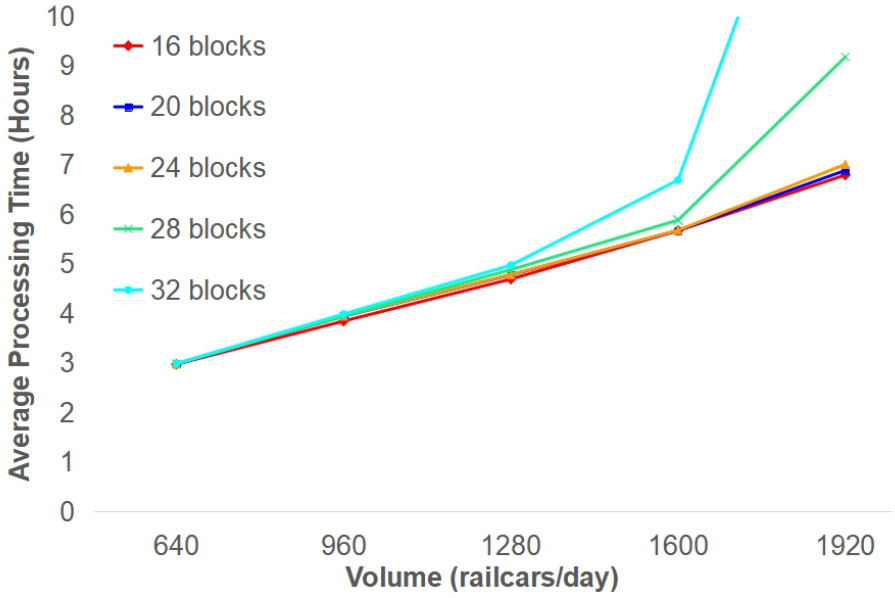


YardSYM Result*

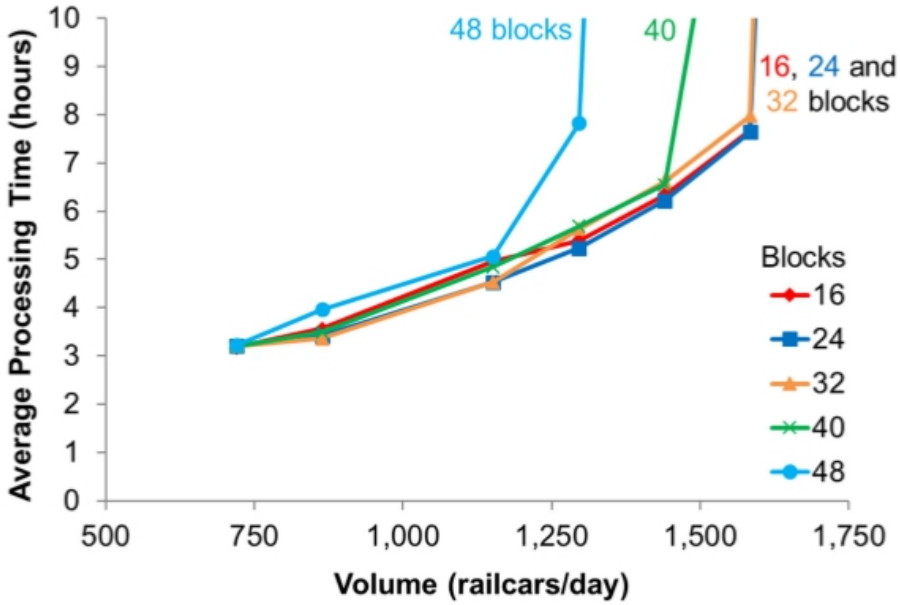
* Dick, C.T. 2019. Influence of traffic complexity and schedule flexibility on railway classification yard capacity and mainline performance. Ph.D Dissertation, University of Illinois at Urbana-Champaign, Department of Civil and Environmental Engineering, Urbana, IL, USA

Preliminary Result- Process Time

- Average processing time for range of traffic volume and number of blocks
  - Processing time: Yard dwell time minus idle time



Anylogic Result



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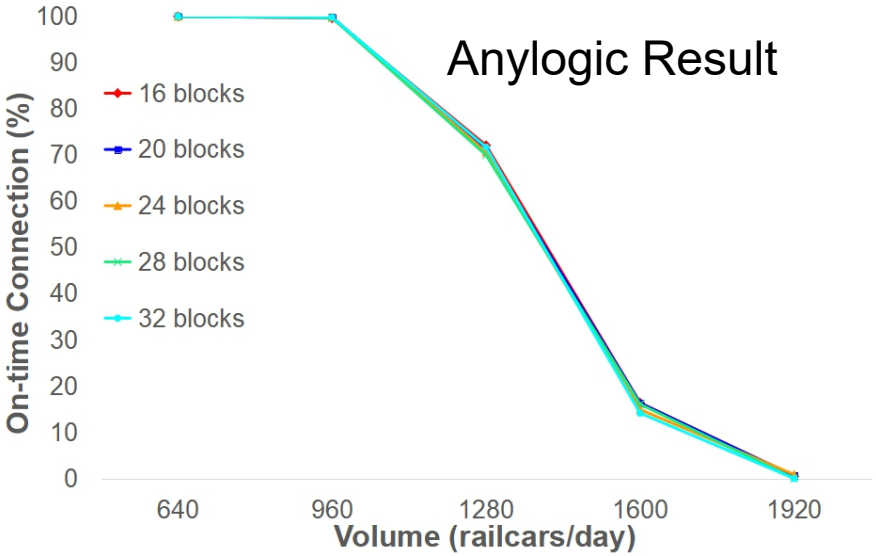
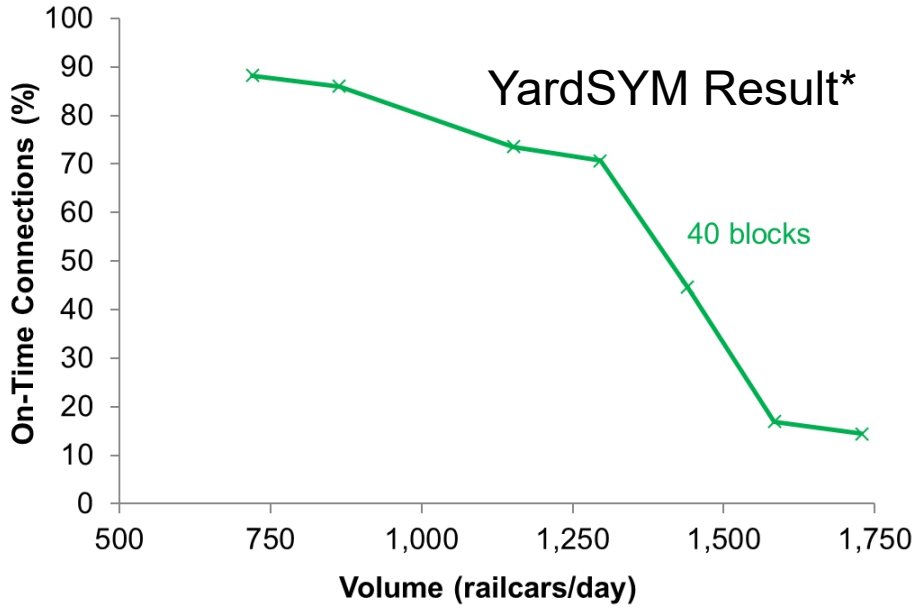
Preliminary Result- OTC

- On-Time Railcar Connection for Range of Traffic Volume and Number of Blocks
- "On-Time Connections" (OTC) defined as proportion of railcars :
  - Making planned connection to outbound train
  - And connecting train departs less than 10 minutes after planned time





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Future Improvements

- Collecting data for other metrics, e.g. RCRT, track occupancy ratio, etc.
- Improve bowl track assignment strategy to match block length with track length
- Improve over-length track assignment strategy to minimize complexity in dirty tracks
- Improve pull-down strategy to solve dirty tracks properly

Future Experiments

- Simulate different operating strategies:
  - Bowl track assignment
  - Over-length track assignment
  - Pull-down rules
- Geometry changes such as:
  - Add a pull-down lead to eliminate pull-down bottleneck
  - Vary pull-down lead length
- Comparing above results among different layouts
  - Inline, parallel, and mixed
- Build and connect simplified mainline models to investigate interactions between mainline and yards as a network, to therefore study the network efficiency cycle

Thank you for your attention!

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NURail Center

ASSOCIATION OF AMERICAN RAILROADS

Appendix

Operation Parameters and Assumptions

Initial mainline speed	30 mph
Cruise speed in yard	15 mph
Hump speed	3 mph
Train acceleration	1 ft/s^2
Train deceleration	0.5 ft/s^2
Hump engine count	2
Pulldown engine count	3
Arrival inspection	5 mins+1 min/car
Hump turnout switching interval	15 secs
Pulldown coupling check	2 mins+12.5 sec/car
Departure inspection	30 mins+1.3 min/car
Hump schedule	FIFO
Pulldown schedule	3 hours before departure
Car length	50 ft
Resolve dirty track*	Hump when the track is full
Resolve re-hump track*	Hump when the track is full
Departure Schedule	Early trains held until scheduled departure time

*Dirty track: bowl tracks with more than two blocks
*Re-hump track: bowl tracks that store humped cars when pull-down is processing on the same track