NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Ensuring High-Throughput Container Operations in Fully Automated Storage Yard of a Next-Generation Transshipment Port

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Container Storage Yard

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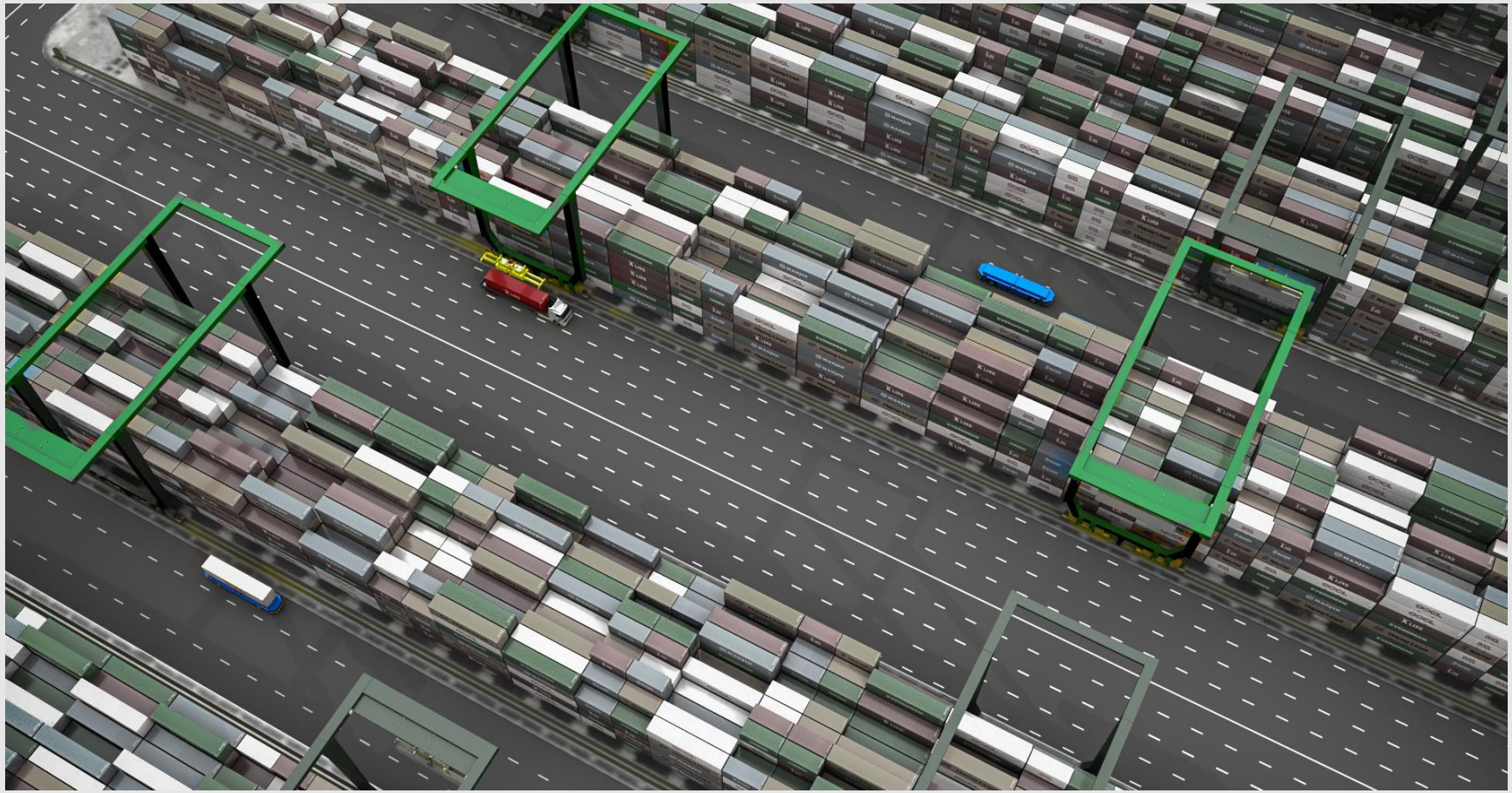
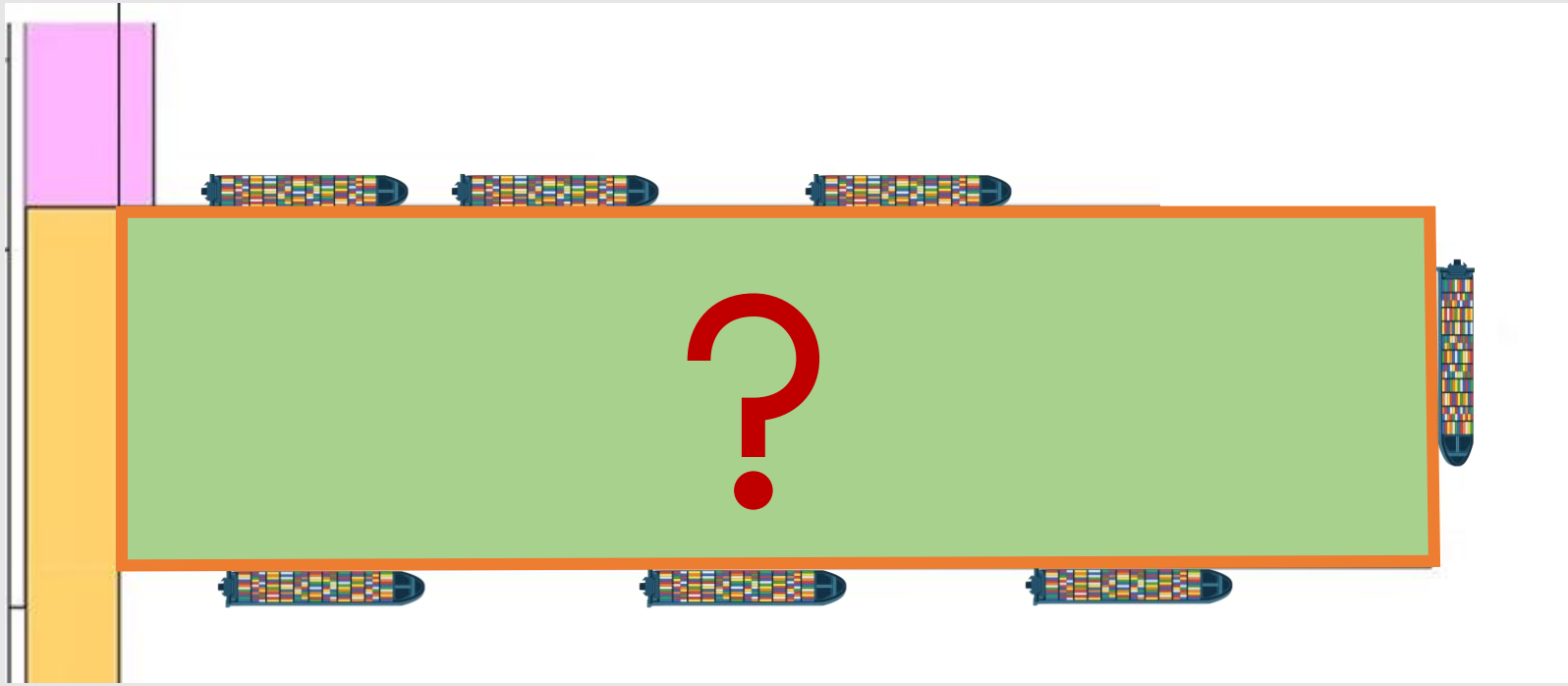


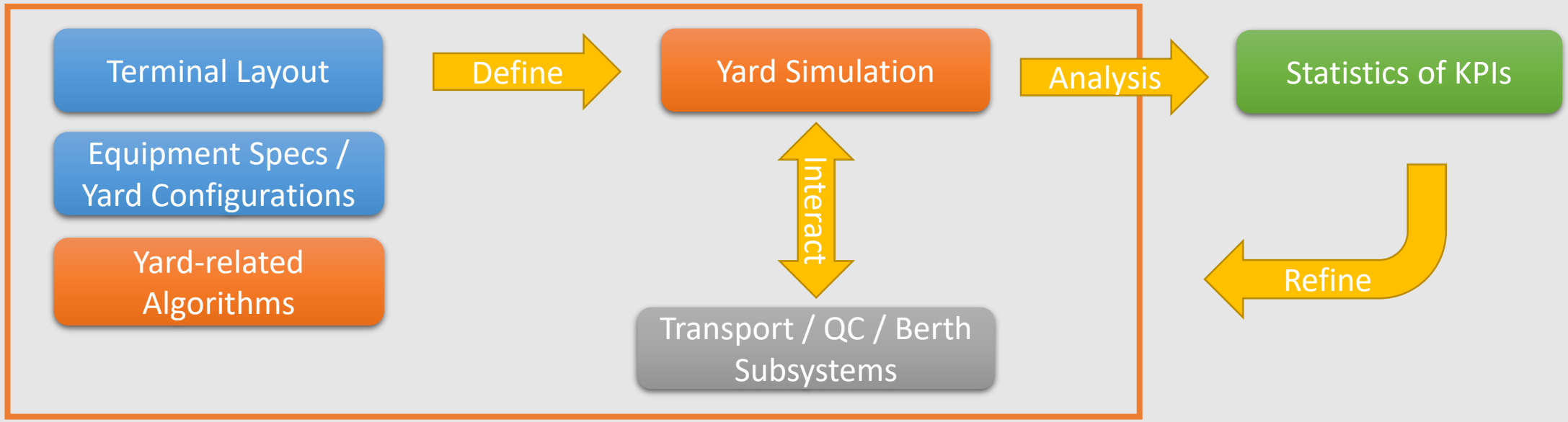
Tasks

- To propose, validate and evaluate different layout designs for next-generation container terminals
  - Fully automated
  - Full life-cycle tracking



Tasks

- To validate and evaluate different layout designs for next-generation container terminals
  - Fully automated
  - Full life-cycle tracking
- From algorithms to simulations



Requirements

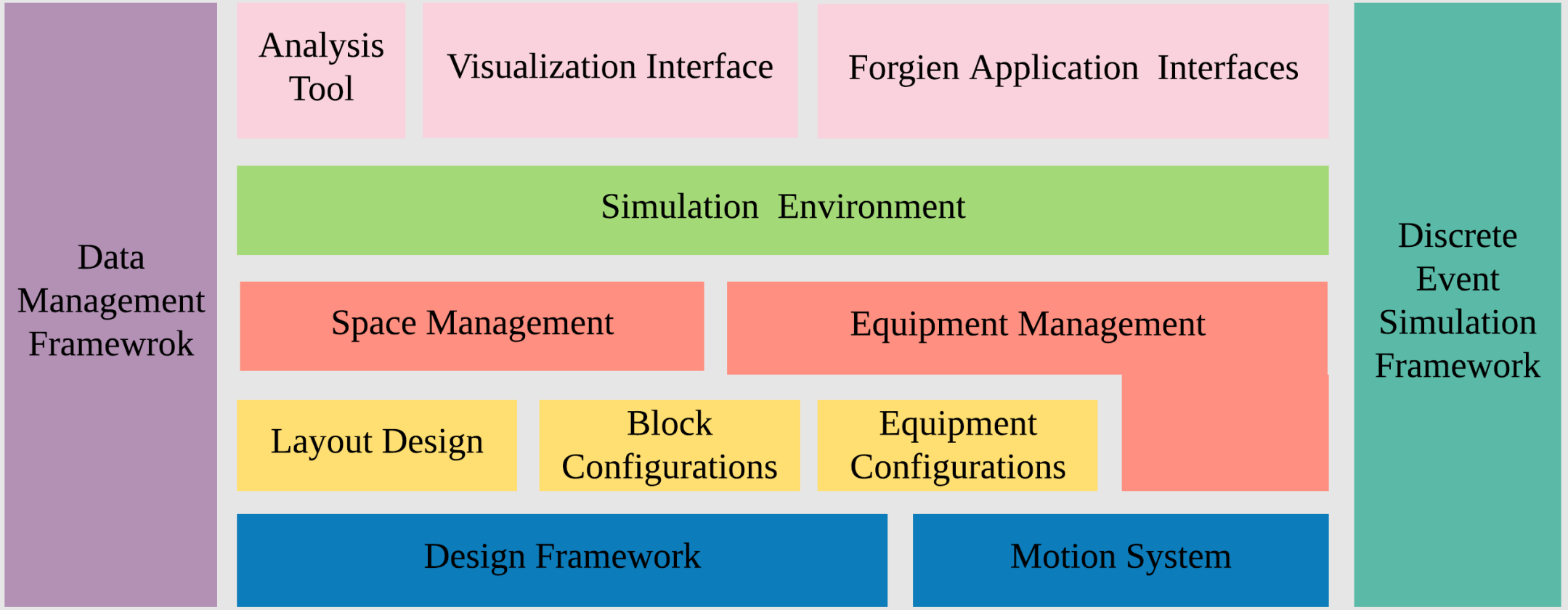
- Simulations
  - As a **decision-support tool**
  - The scale of our simulation is too large for existing tools (>100M events)
  - Existing tools are hard to customize (we need to propose and test new algorithms for the automated terminal)

Simulation

- Goals:
  - **Realistic and Accurate**: Box positions, Motions of YC components, Reshuffles, Neighboring YC interferences...
  - **Box-level trackable**: Keeps track of each single movement of each individual container and YC
  - **Reconfigurable**: Layouts, Equipment Specs, Stacking Strategies, Block Configs...
  - **Integrable**: Be able to interact with other sub-systems: Transportation / QCs…
  - **Rapid**: For quick evaluations of different schemes on large-scale datasets
  - **Analytics**: Tools for statistics and (interactive) visualization of simulation results

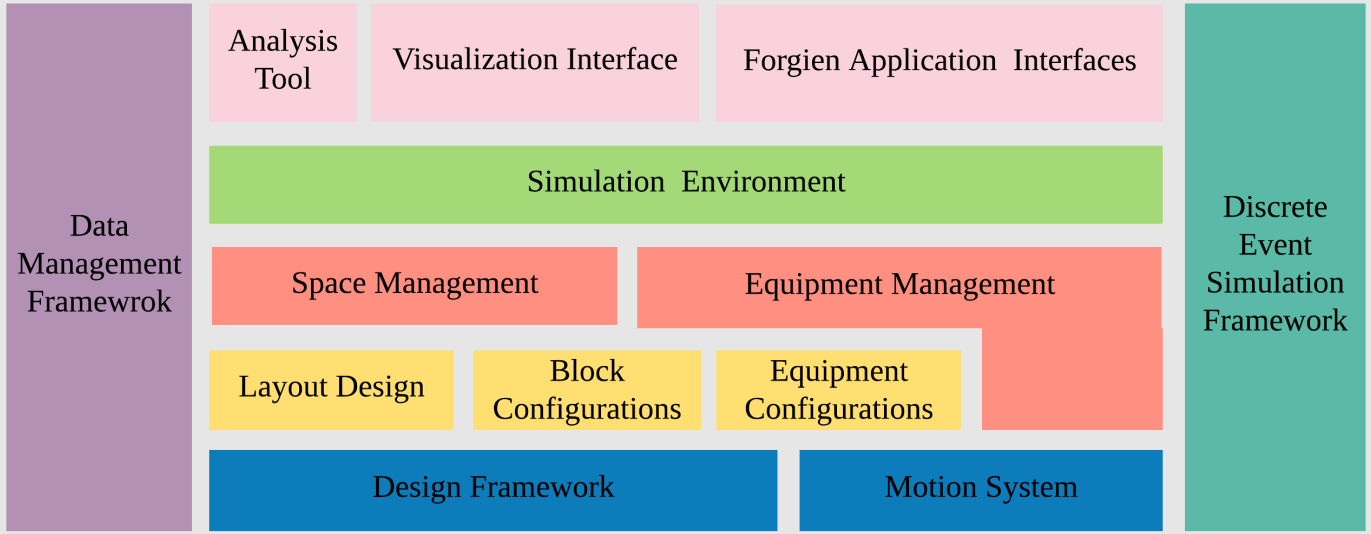
Simulation

- Architecture



Simulation

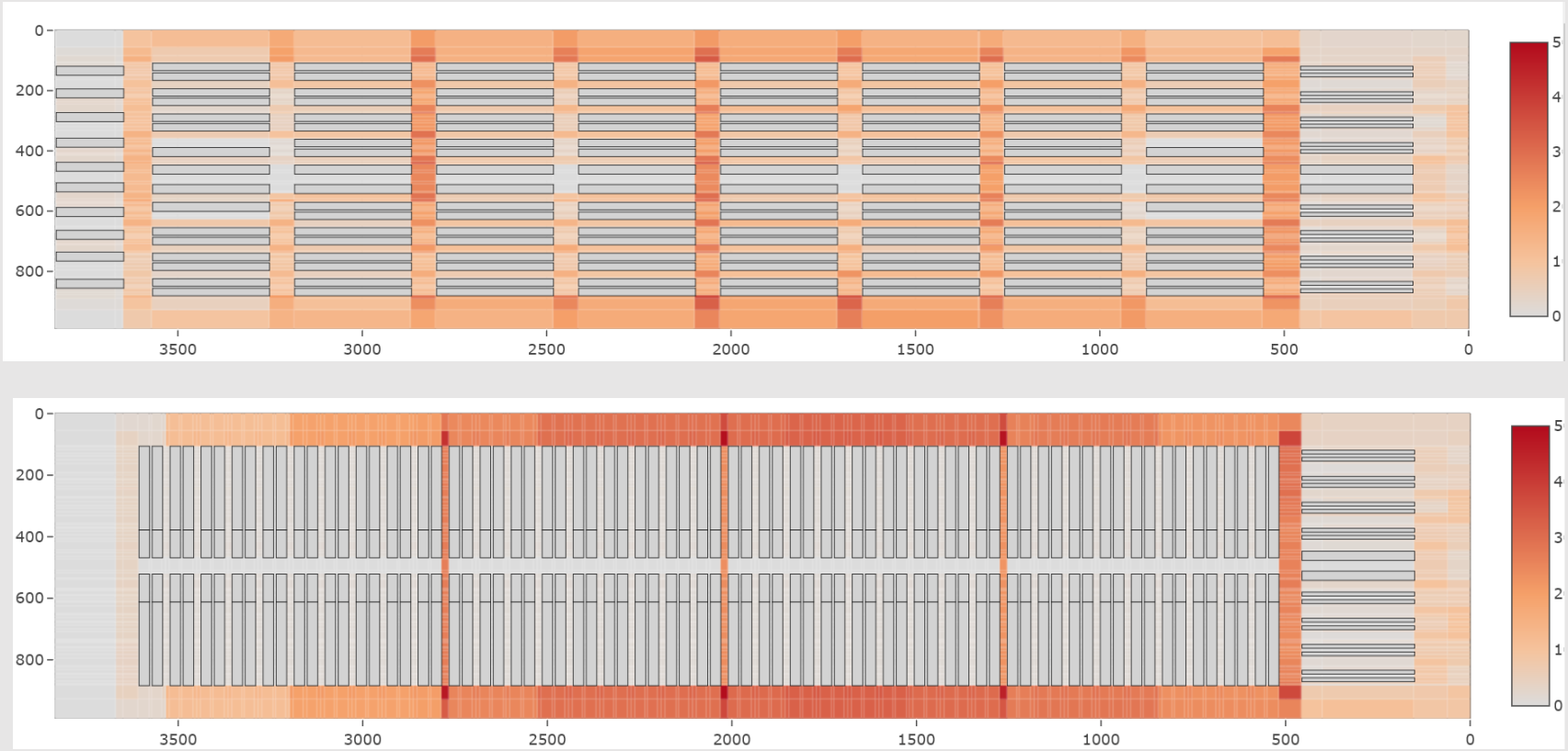
- Architecture



- Implementation
  - Python for interfaces, easy prototypes, design and configurations, analysis and virtualizations
  - C for speed: discrete event simulations, data structures and algorithms.

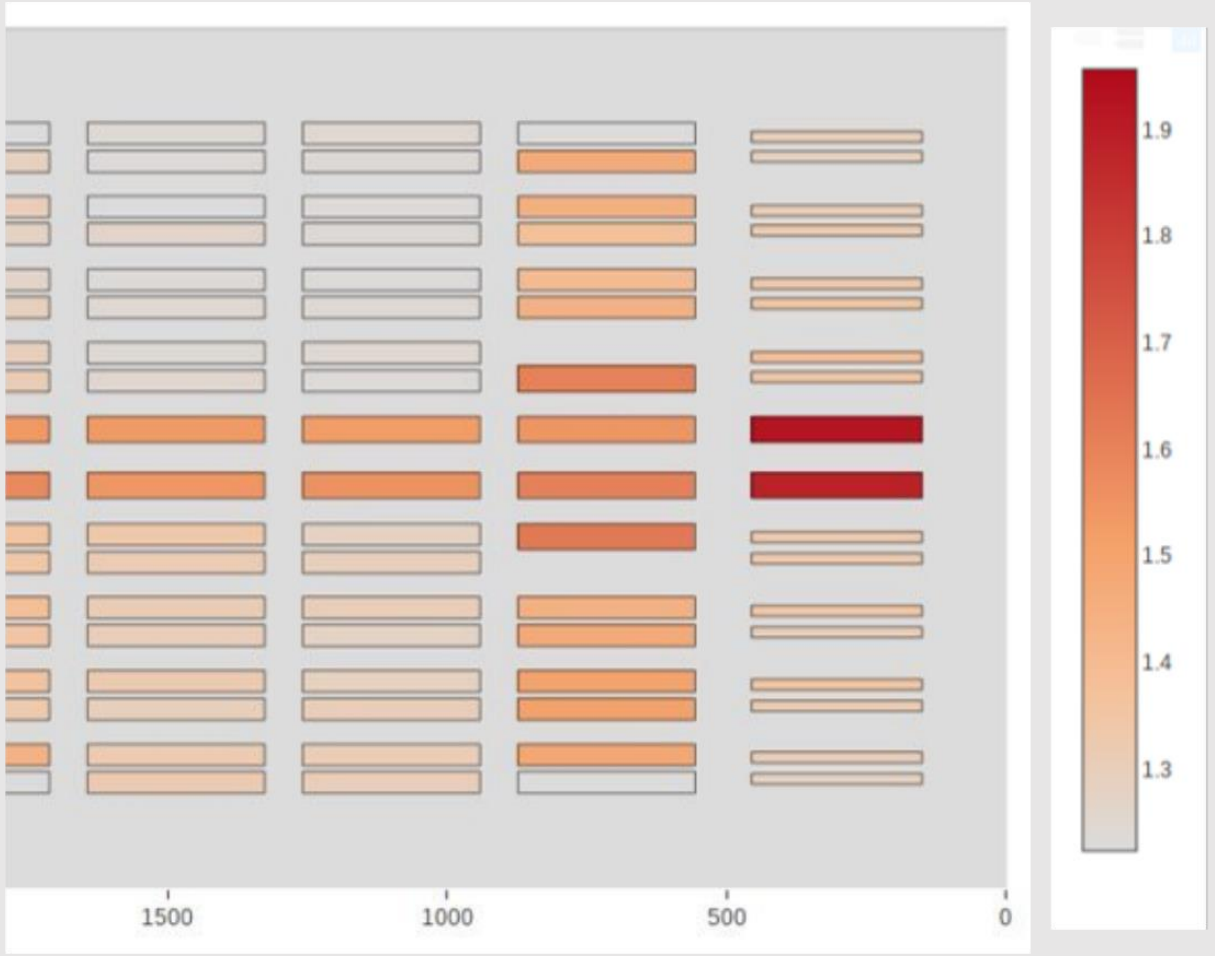
Simulation: Use Cases

- **Compare layouts**



Simulation: Use Cases

- Compare layouts
- **Locate hotspots**



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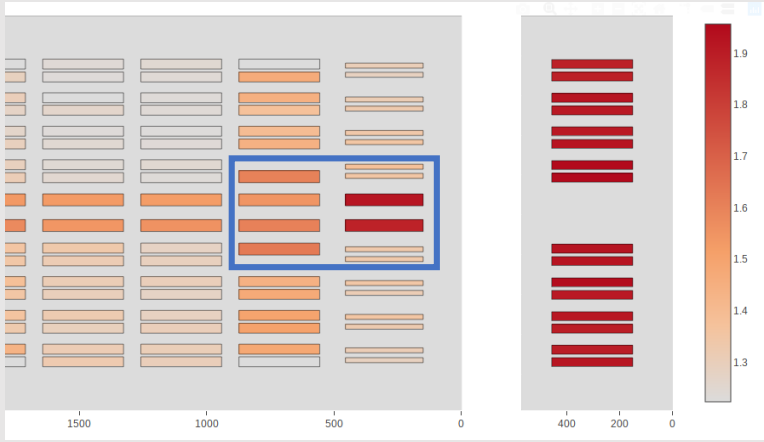
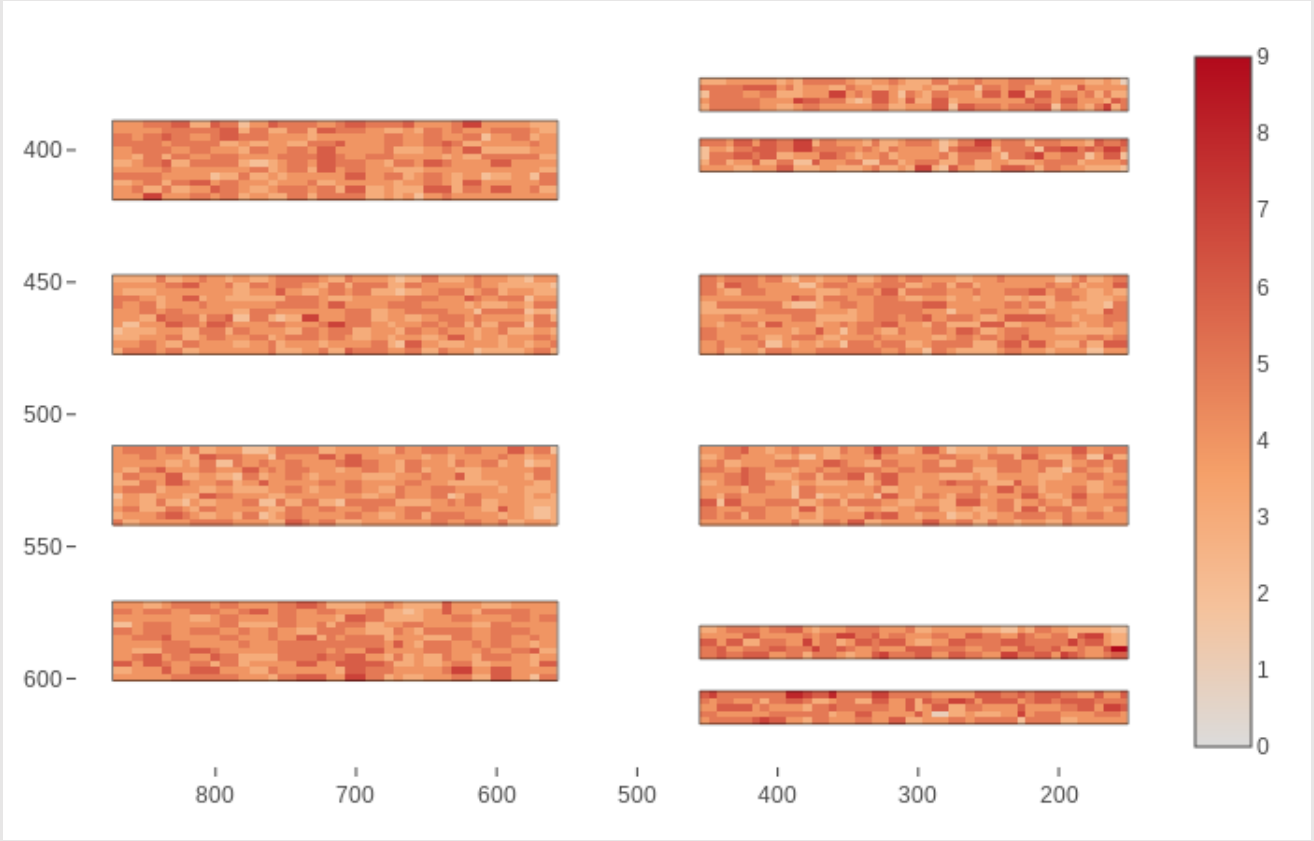
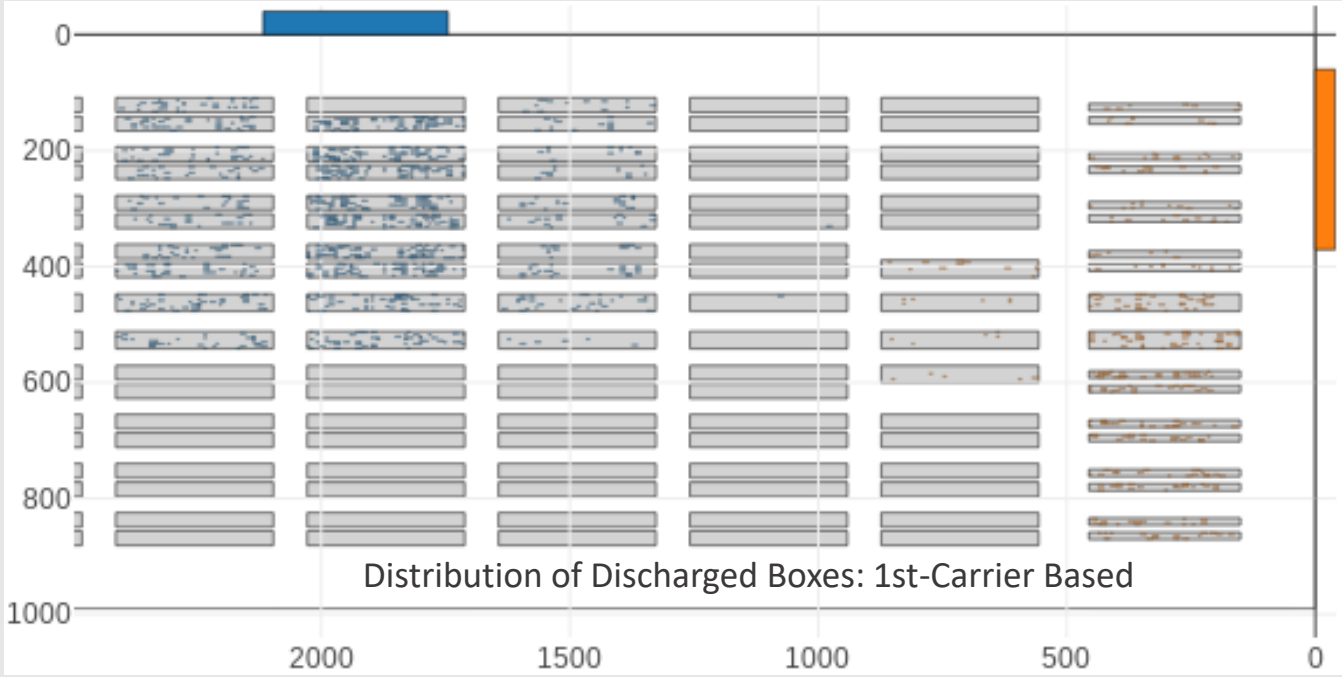




Simulation: Use Cases

- Compare layouts
- Locate hotspots
- **Compare yard policies**



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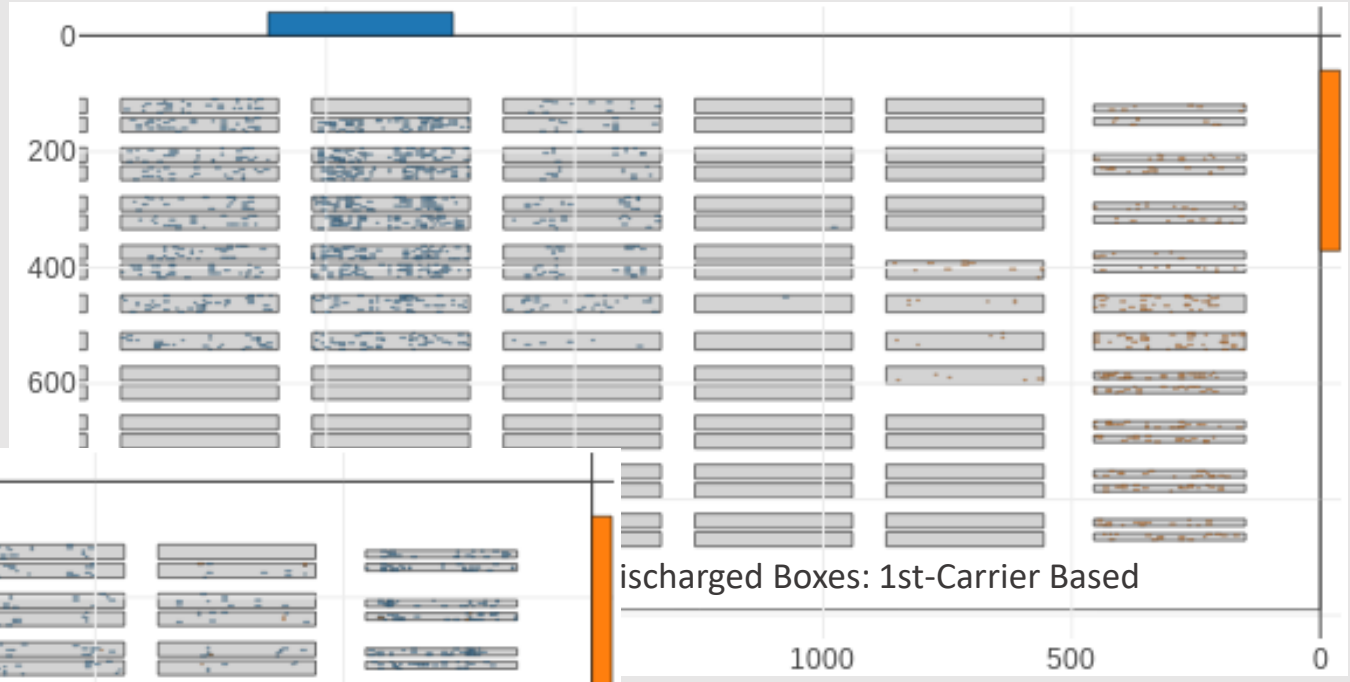
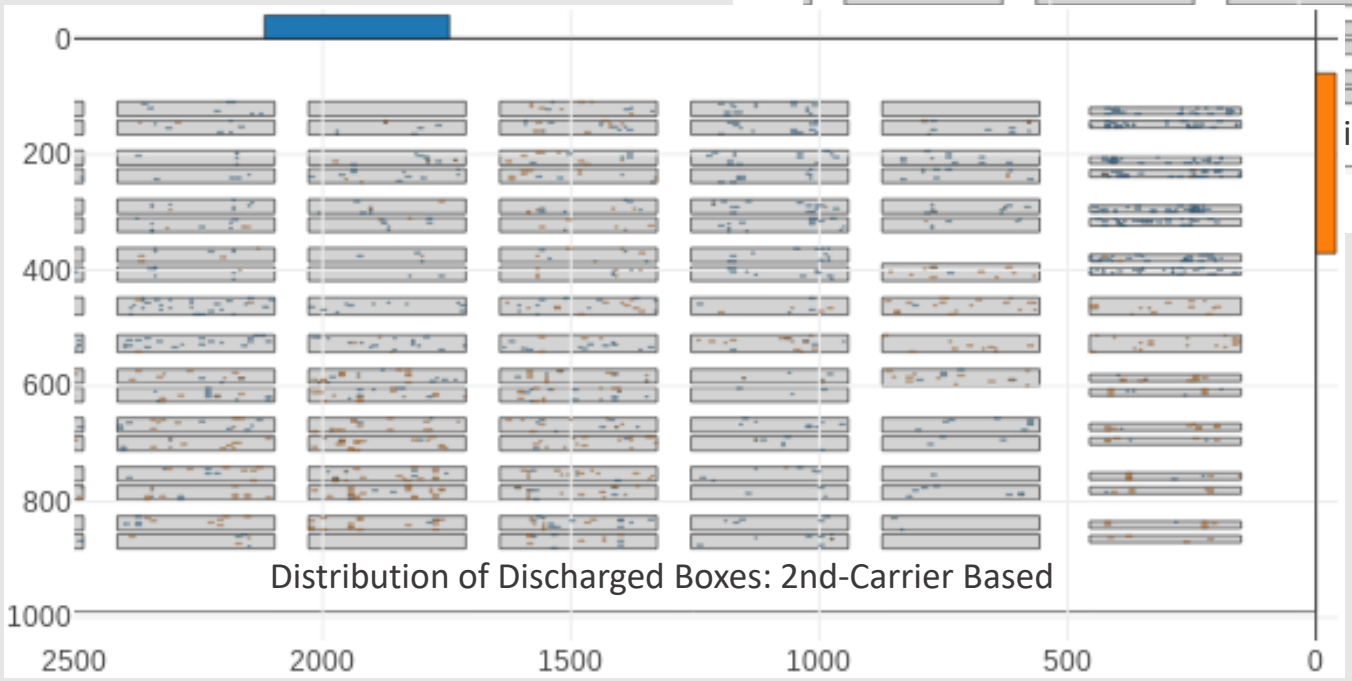


ischarged Boxes: 1st-Carrier Based



Distribution of Discharged Boxes: 2nd-Carrier Based

Algorithm: yard-space-allocation

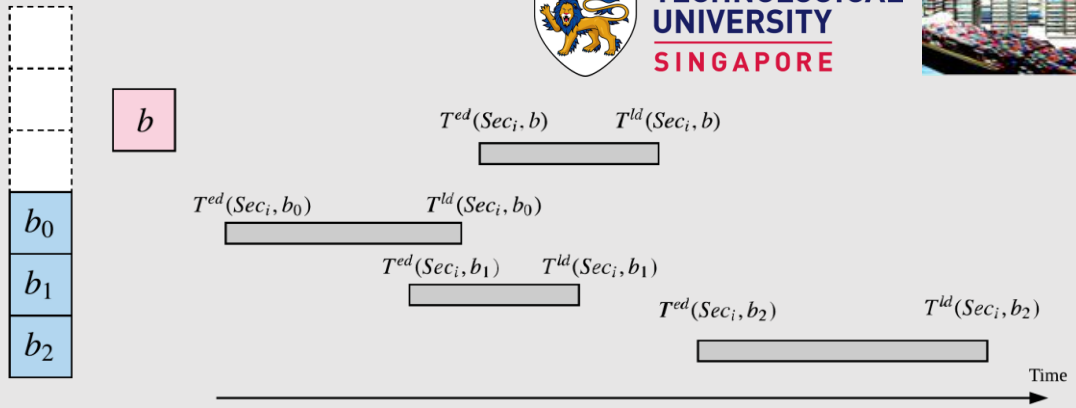
- Objectives:
  - YC Operation Delays
    - YC conflicts: multiple request on the same YC
    - Reshuffles: most counter-productive operations
    - Crane moving distances: especially gantry moves
  - Discharging/loading distances
    - Reduce traffic delays to improve quay-side throughputs
- Input:
  - Known: discharging time/position
  - Unknown: loading time/position
  - Partially known: 2nd carrier's estimations of arrival time, handling time

Yard-space allocation: a probabilistic way

- Estimating arrival and departure intervals
  - Discharging time + transport buffer time
  - 2nd carrier's arrival time + handling time + transport buffer time
    - Historical records, vessel spec...
    - Do not need to be very precious or accurate: period of 1-2 days

- **Probabilities of YC conflicts and reshuffles**

Probability of reshuffles



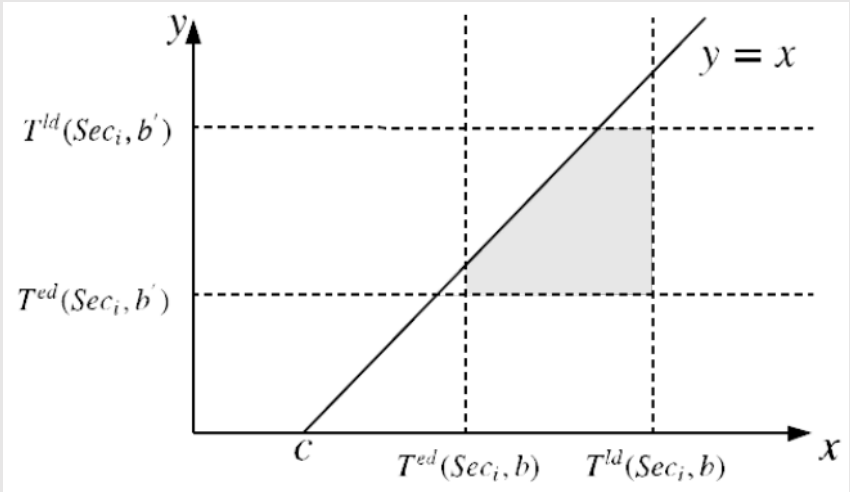
- A newly-arrival *b* will block *b'* :

$$P_{rsf}(b, b') = Prob(x \geq y)$$

$$T^{ed}(sec_i, b) \leq x < T^{ld}(sec_i, b),$$

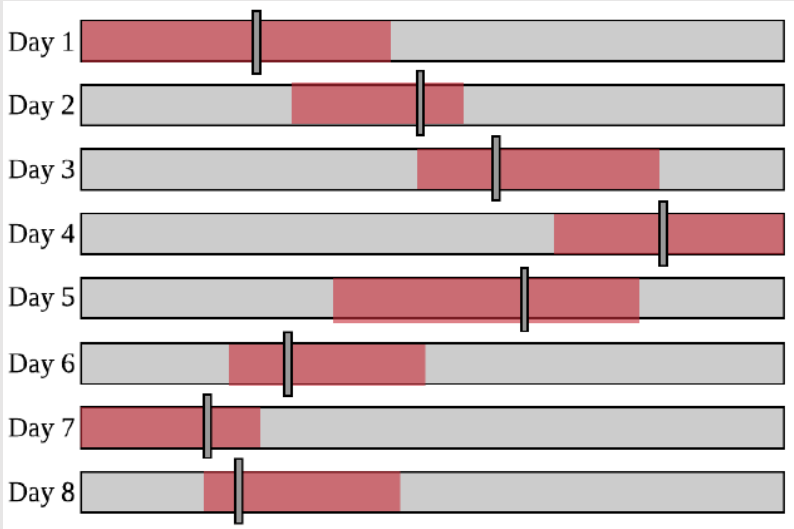
$$T^{ed}(sec_i, b') \leq y < T^{ld}(sec_i, b').$$

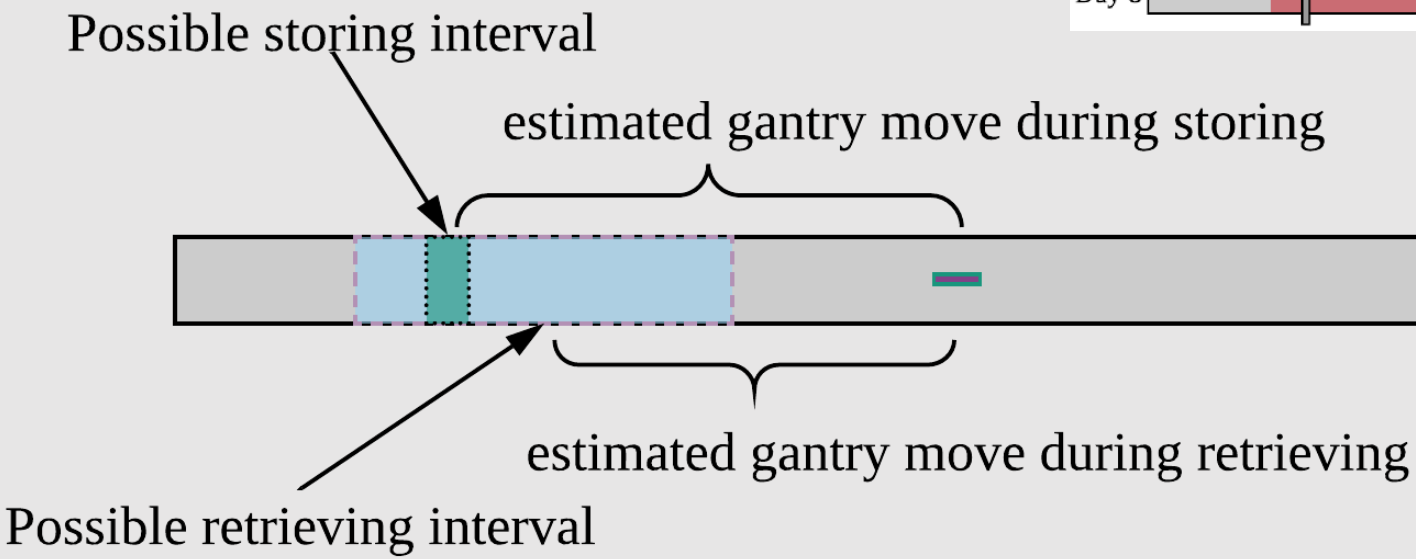
- Calculating the probability: a geometric way



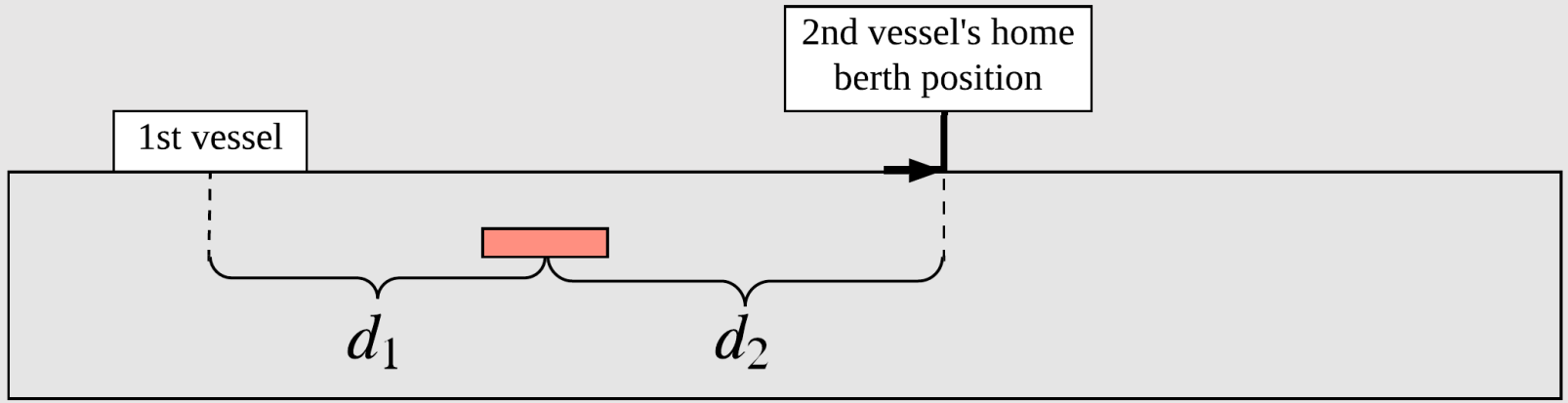
Gantry Moving Distances

- A periodic and cyclic pattern:





Discharging / Loading Distances



- Discharging position & Home berths
- Distances projected to the shoreline/quay
- Add penalties for traffic interferences between man-driven movers and AGVs
- Paired twenty-foot boxes

Algorithm

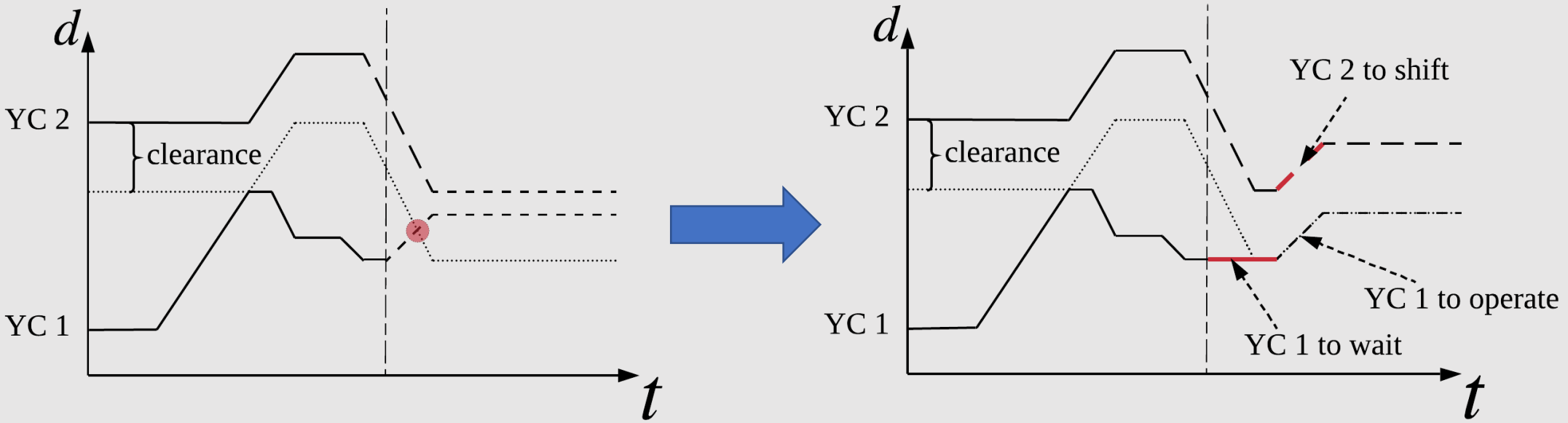
- In-block stack-selection:
  - Objectives: reshuffles & gantry moves
- Block-section:
  - Expectations of YC delays & discharging/loading distance

Other Algorithms & Policies

- Dynamic updates of information
  - Whenever new pieces information is available
  - For more accurate predictions and estimations
- Reshuffles:
  - Like the in-block-section approach, but with more accurate information
  - Choosing target stack according to
    - Probability of future reshuffles
    - Trolley moving distances
    - And other factors...

Other Algorithms & Policies

- Pre-reshuffles
  - When YC is idle, reshuffle boxes blocking the most urgent box
    - Urgency: estimated departure time, gantry moving distance, number of blocking boxes
- YC Interferences
  - Detect on-the-fly, by tracking the trajectories of gantry moves



Results

- Ship arrivals generated according to Singapore 2030 by MPA
- Transshipment boxes, import/export boxes, inter-finger boxes, inter-gateway boxes...
- > 1.3M/berth/annum
- > 25M boxes, 3000 vessels, 19 berths
- >90% BOA
- 184 Blocks, 390 YCs
- 3-month simulation

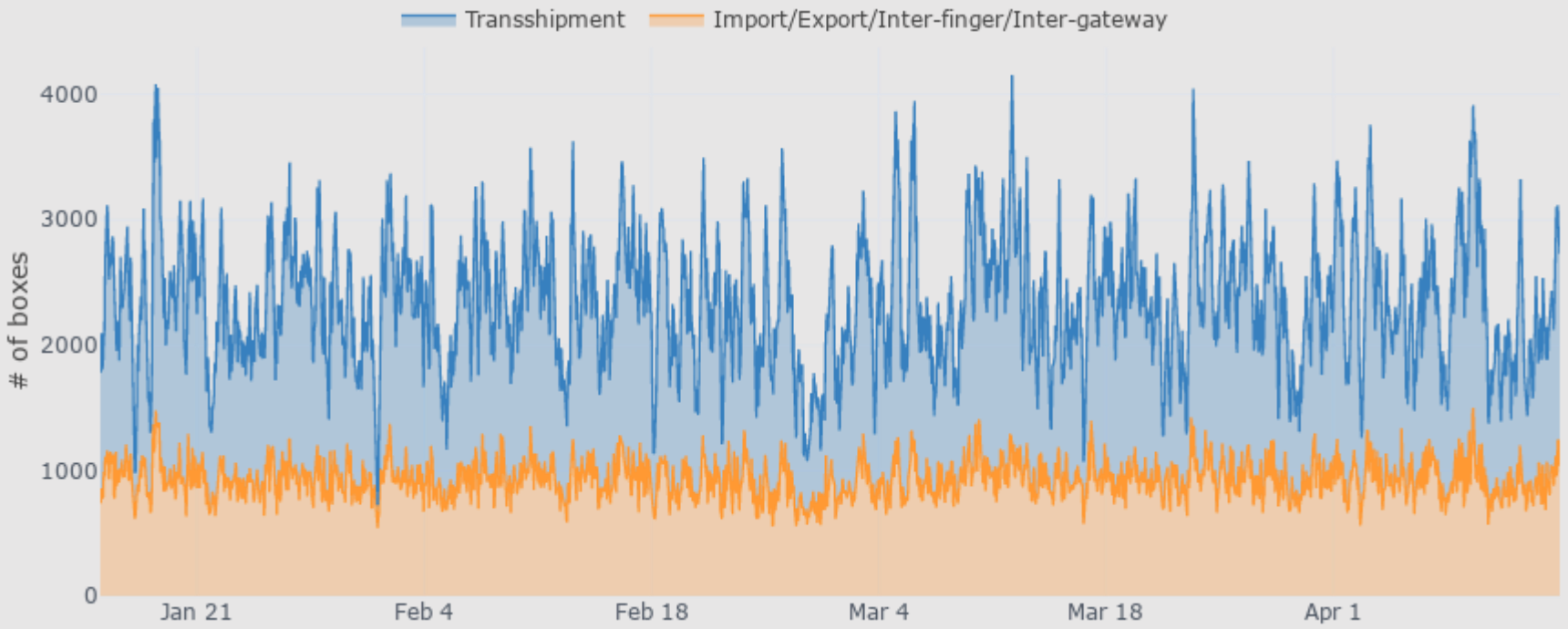
Results

- Running time: ~1.5 hour

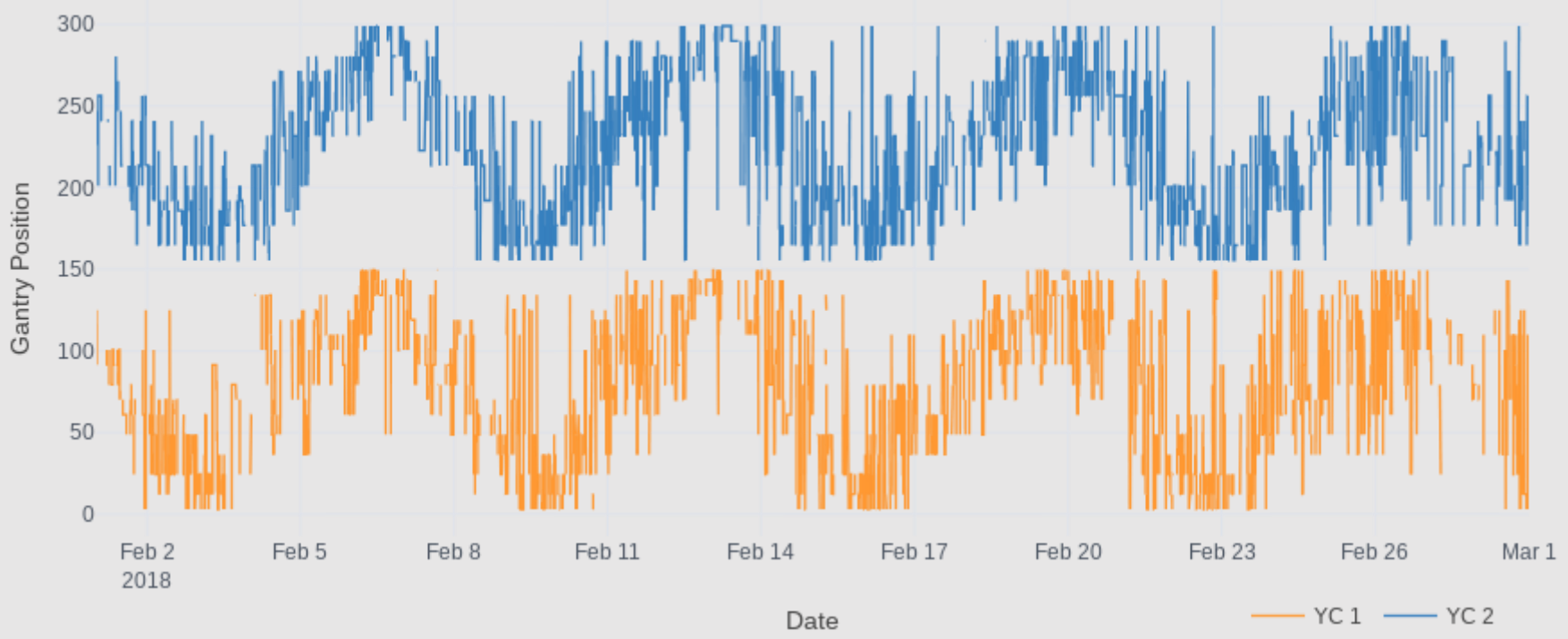
Yard Utilization	41.10%
YC Utilization	17.32%
YC Productivity	28.2/35.9/42.6
Gantry Moving Dis.	39.0

Reshuffling Rates (overall)	25.84%
Reshuffling Rates (after pre-reshuffling)	0.77%
Waiting time for retrieving	Avg: 00:00:45 99%: 00:03:13 Max: 00:13:55
Retrieving operation time	Avg: 00:01:23 99%: 00:02:04 Max: 00:08:55

Results


Transshipment
Import/Export/Inter-finger/Inter-gateway
# of boxes
4000
3000
2000
1000
0
Jan 21
Feb 4
Feb 18
Mar 4
Mar 18
Apr 1

Results


300
250
200
150
100
50
0
Gantry Position
Feb 2
2018
Feb 5
Feb 8
Feb 11
Feb 14
Feb 17
Feb 20
Feb 23
Feb 26
Mar 1
Date
YC 1
YC 2

Visualization (in progress)

Acknowledgments

- Singapore Maritime Institute
- Maritime and Port Authority of Singapore
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- ZPMC

Thank you!

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