

Applications of Simulation-based Analysis by Digital Twins for Next Generation Ports

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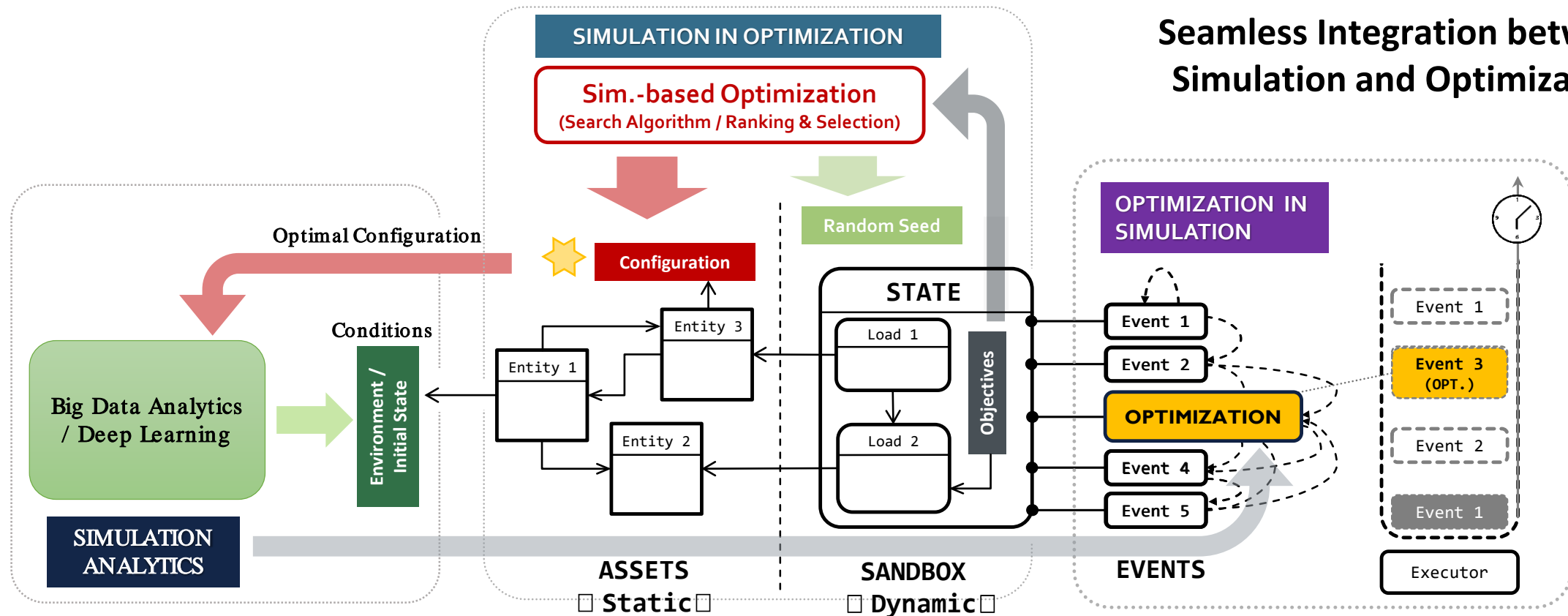
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Outline

- ▶ **Framework for Simulation-based Analysis**
 - ▶ **Simulation Evaluation**
 - ▶ **Simulation based Optimization**
 - ▶ **Hybrid Analysis**
- ▶ **Case Studies**
 - ▶ **Hierarchical Modelling for Mega Container Port**
 - ▶ **Capacity Planning for Container Terminals**
 - ▶ **Capacity Assessment for General Cargo Port**
 - ▶ **Yard Planning for Transshipment Terminals**
 - ▶ **Configuration Optimization for AGV Markers**
 - ▶ **Yard Block Reshuffling Analysis**

Framework for Simulation-based Analysis

Seamless Integration between
Simulation and Optimization

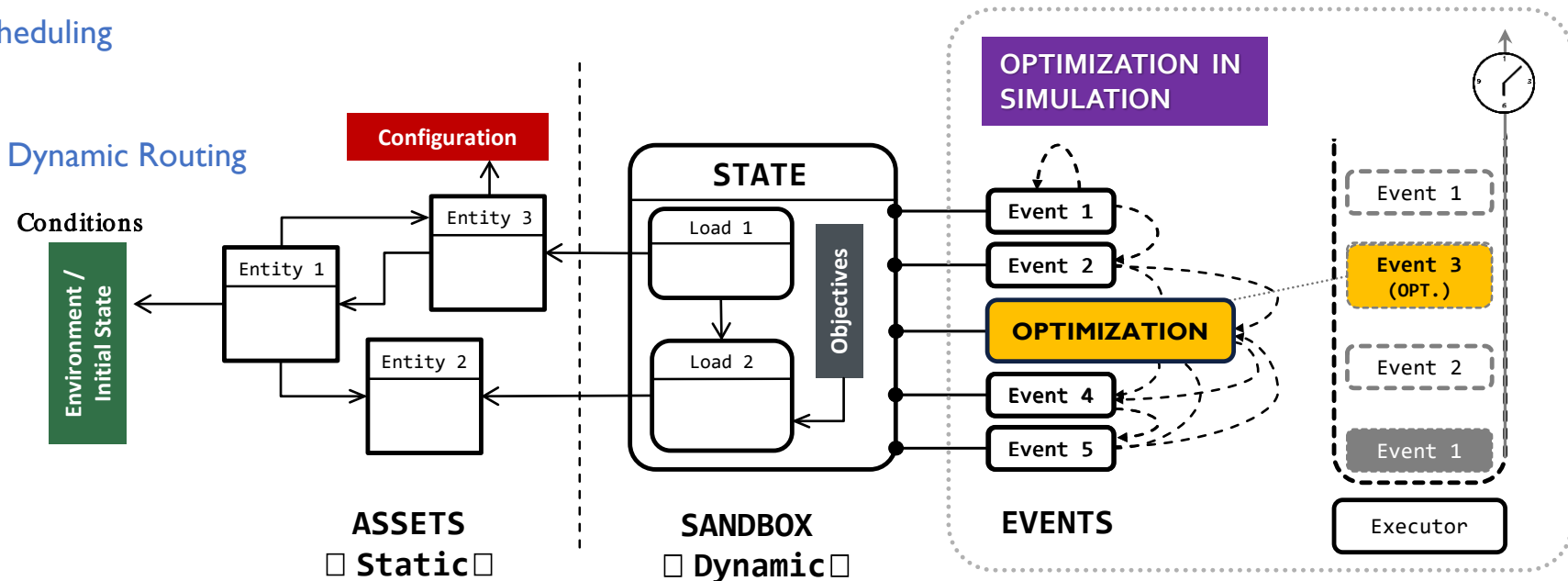


Framework for Simulation-based Analysis

Simulation Evaluation

- 1 Evaluation of a given system configuration
- 2 **Evaluation** of operational rules / optimization logics in dynamic and stochastic circumstances

- ▶ Berth Allocation / Scheduling
- ▶ Yard Allocation
- ▶ Vehicle Dispatching / Dynamic Routing

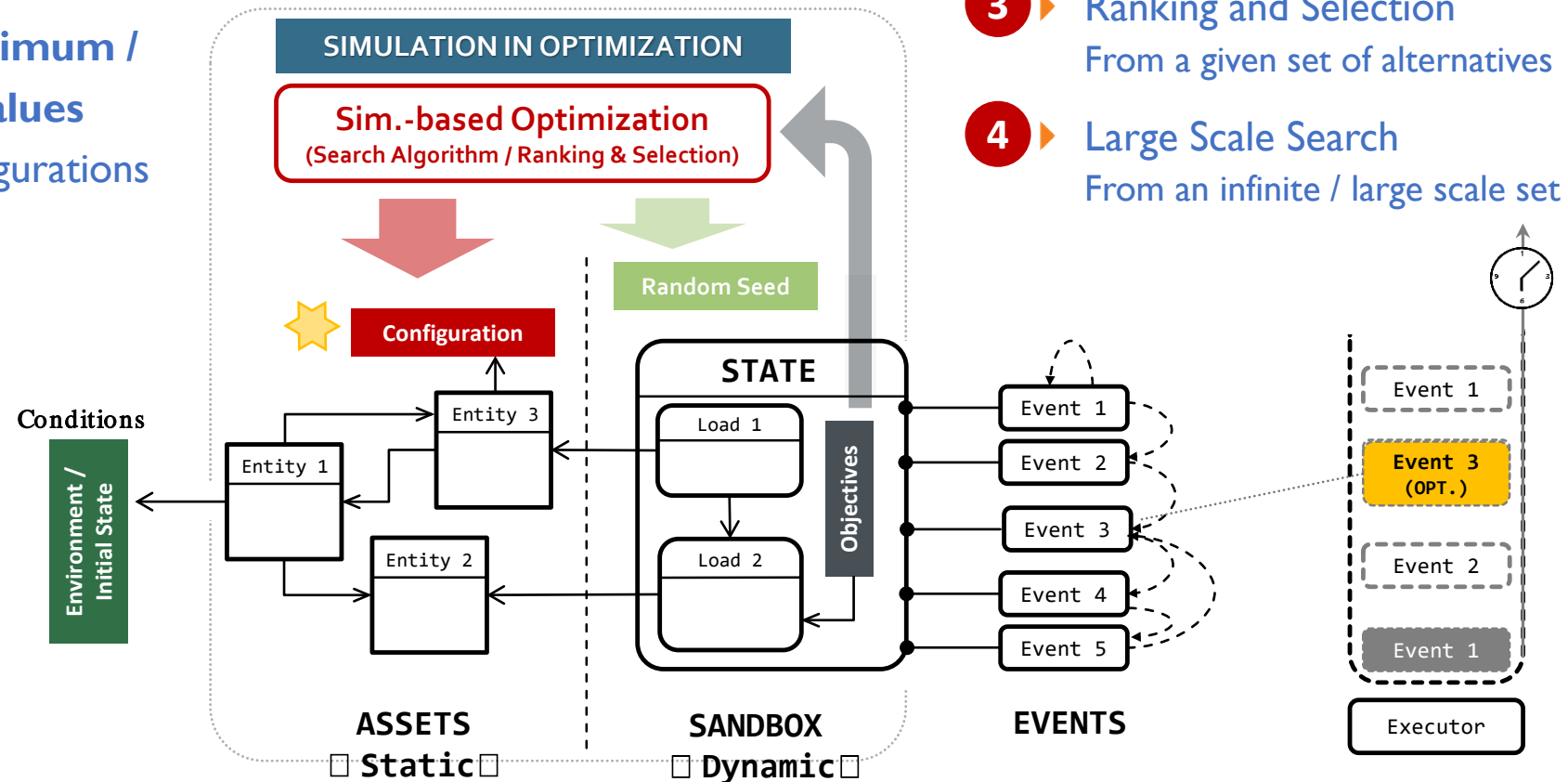


Framework for Simulation-based Analysis

Simulation based Optimization

- ▶ **Optimization** for maximum / minimum objective values by adjusting system configurations

- ▶ Port Design
- ▶ Equipment Selection
- ▶ Capacity Planning



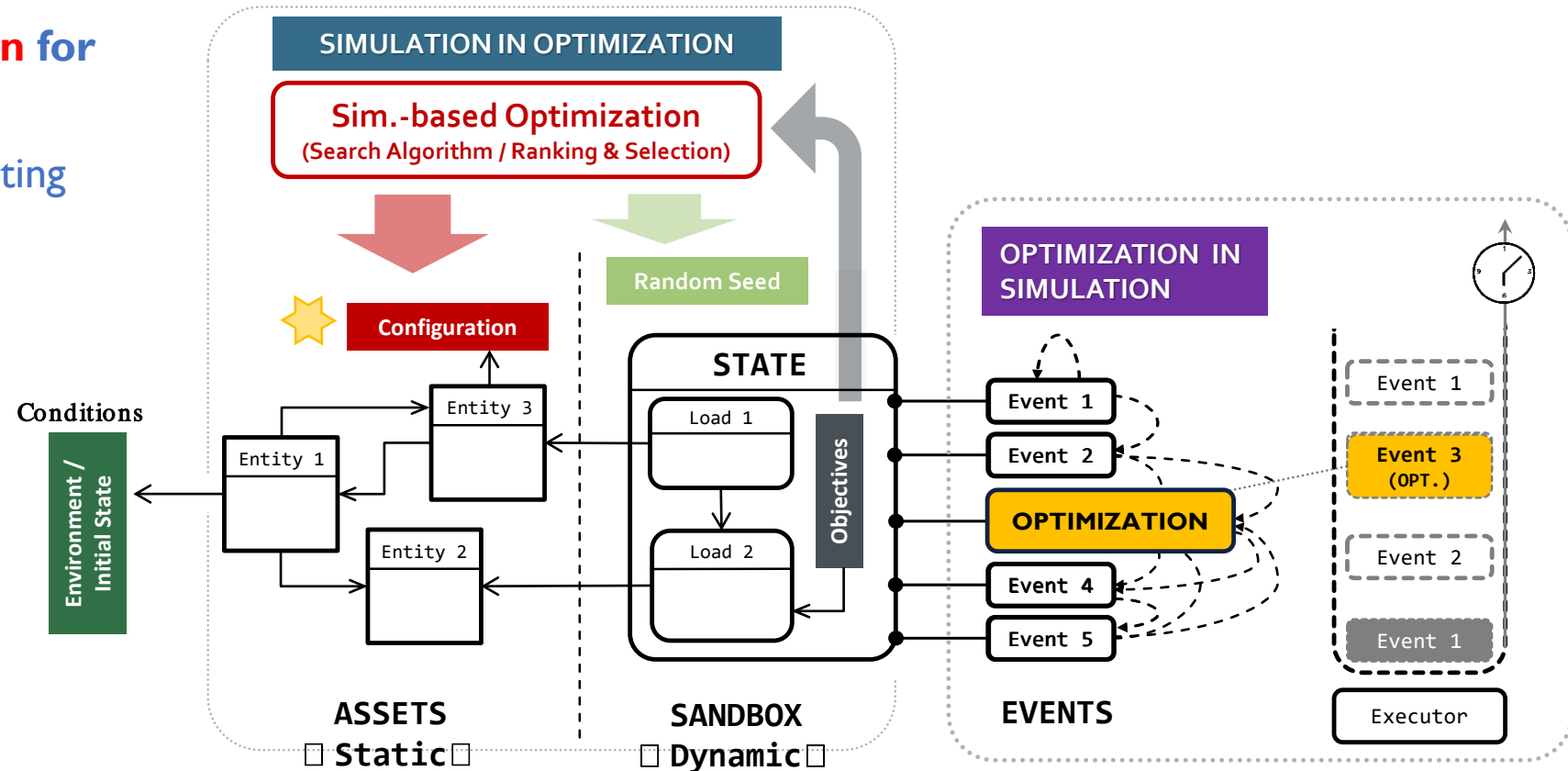
- 3 ▶ Ranking and Selection
From a given set of alternatives
- 4 ▶ Large Scale Search
From an infinite / large scale set

Framework for Simulation-based Analysis

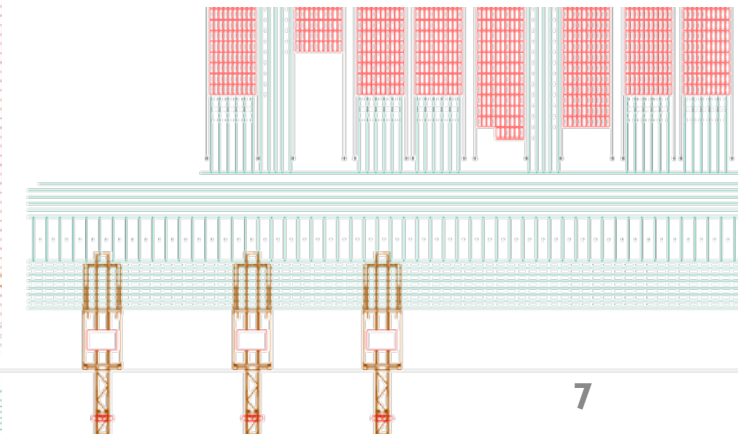
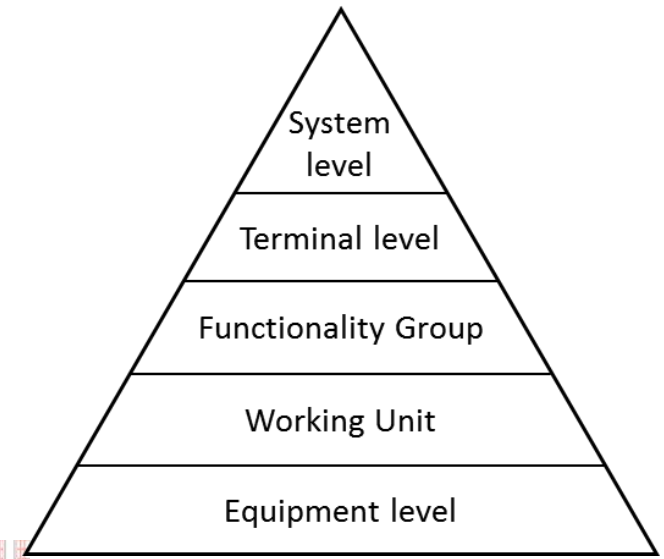
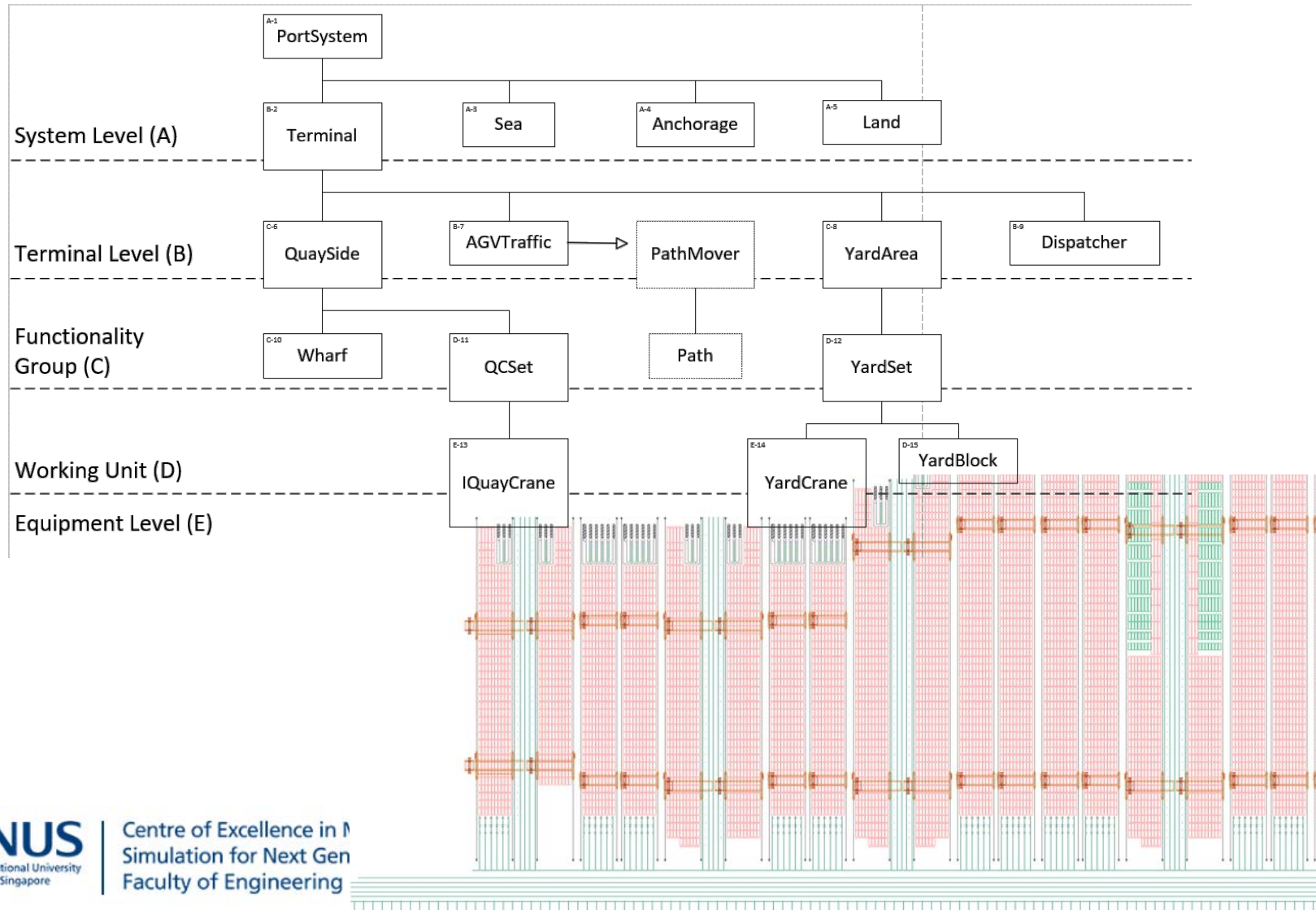
Hybrid Analysis

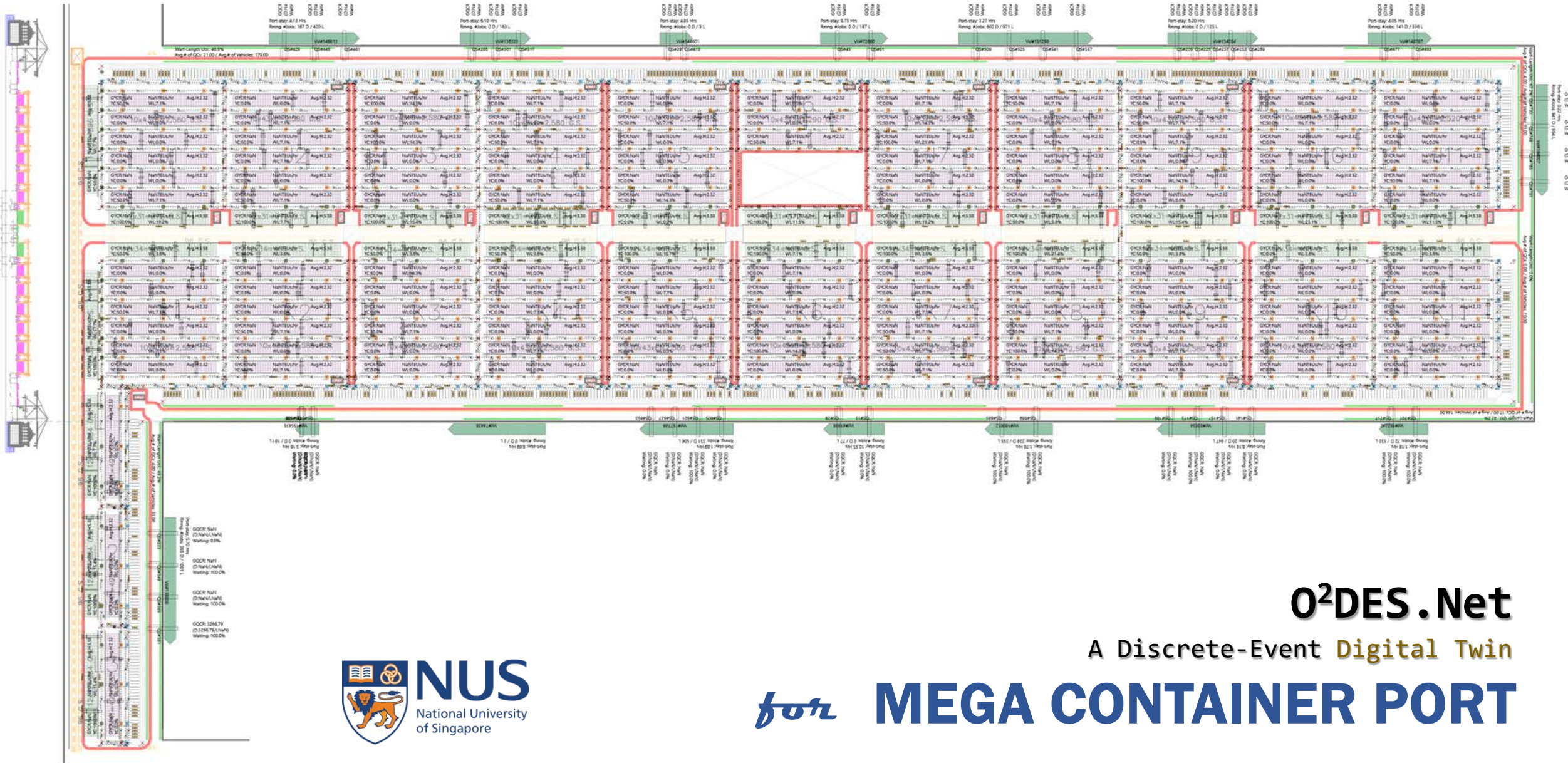
5 Hybrid Optimization for objective values by Evaluating and adjusting operational rules

- ▶ Port Design
- ▶ Equipment Selection
- ▶ Capacity Planning



Hierarchical Modelling for Mega Container Port





O²DES.Net

A Discrete-Event Digital Twin



MEGA CONTAINER PORT

Capacity Planning for Container Terminals

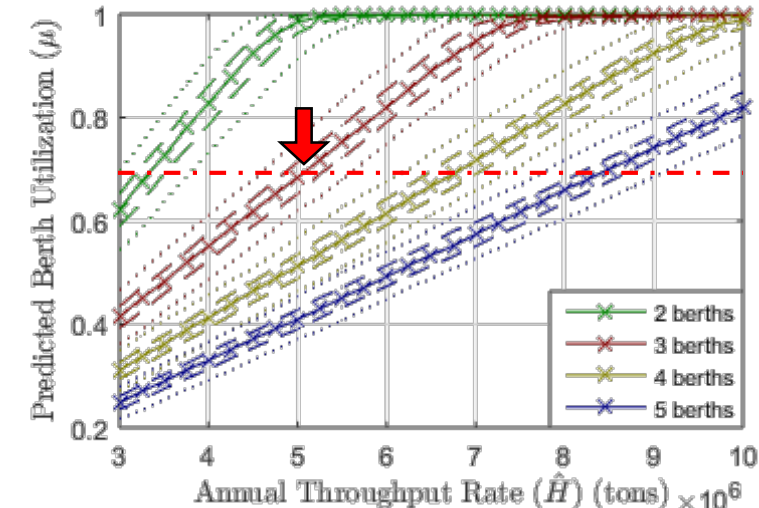
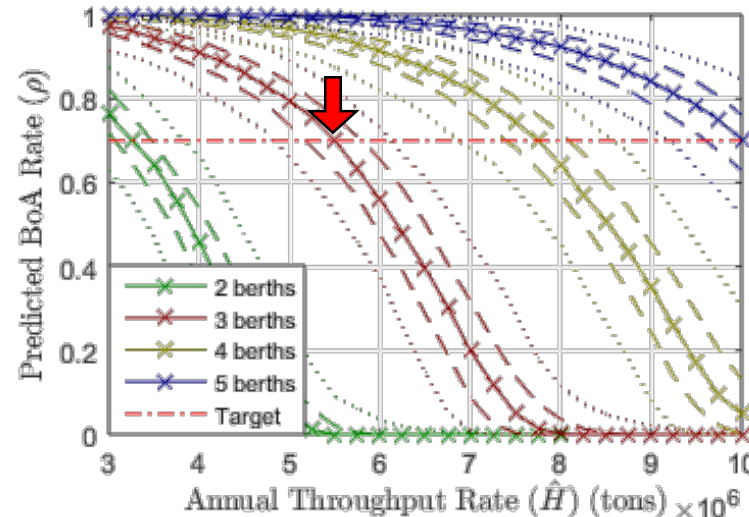
► Definition of Capacity Assessment for Port Terminals

Given a configuration of the port terminals, the capacity assessment is to find the **maximum** throughput it is able to handle, respect to the constraints that,

- 1) the BoA rate shall be above a threshold, and/or
- 2) the utilization of port facility shall be below a threshold,

in which, the BoA rate and utilization of port facilities shall be evaluated by a Discrete-Event Simulation.

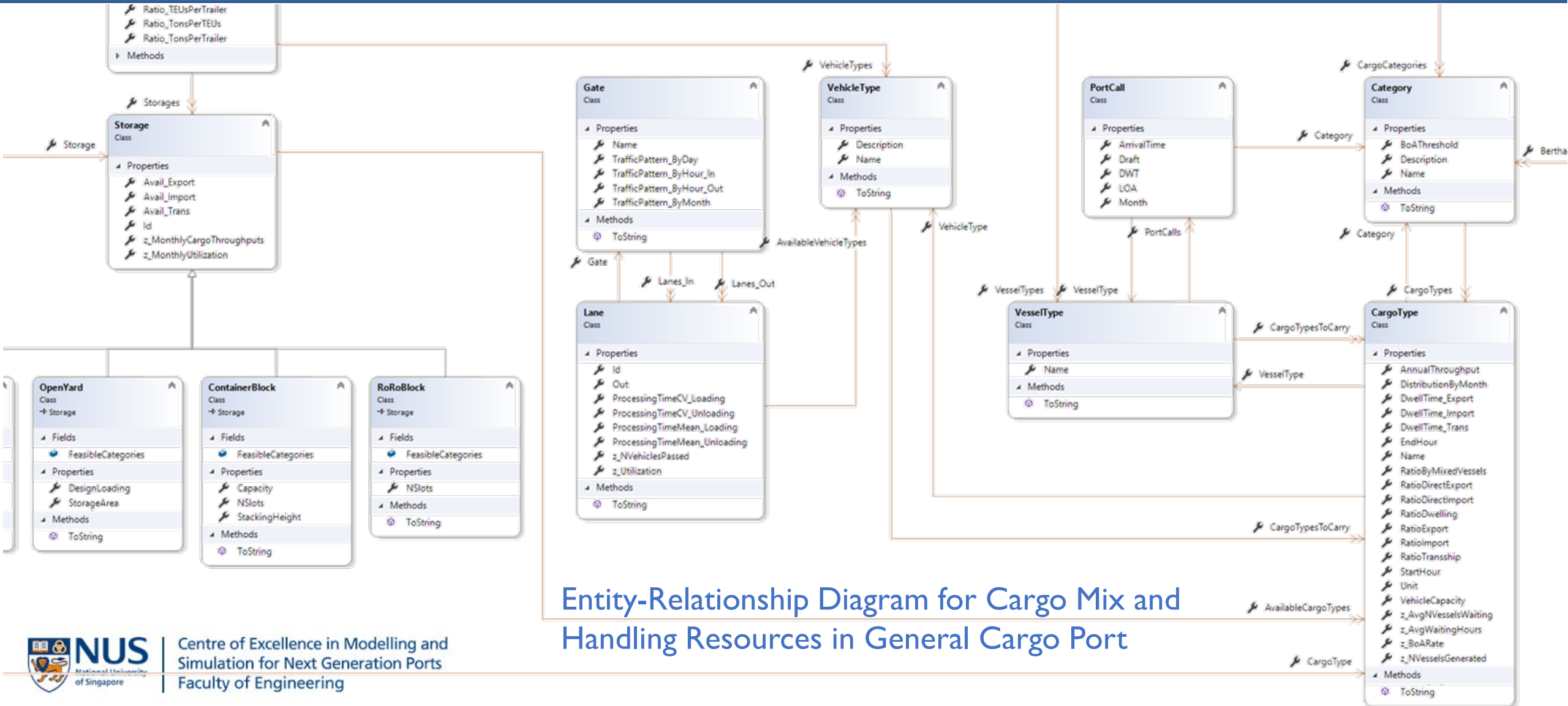
Example:
capacity assessment for cement terminals by considering BoA rate and berth utilization (Li et al. 2017)



Capacity Assessment for General Cargo Port

- General cargo ports are very **unique** in comparison to the container ports, in terms of
 - **variety** of cargo types, and the respective equipment that handles the cargo;
 - mix of different cargo types **sharing** the same pool of port facilities;
 - the **pattern** of vessel arrivals (bus mode vs. taxi mode), which plays an important role in BoA rate;
- The studies of capacity assessment on container ports **cannot be directly applied** to the general cargo ports.
- The existing study on the general cargo ports has focus only on an **isolated single cargo type**, which is insufficient.

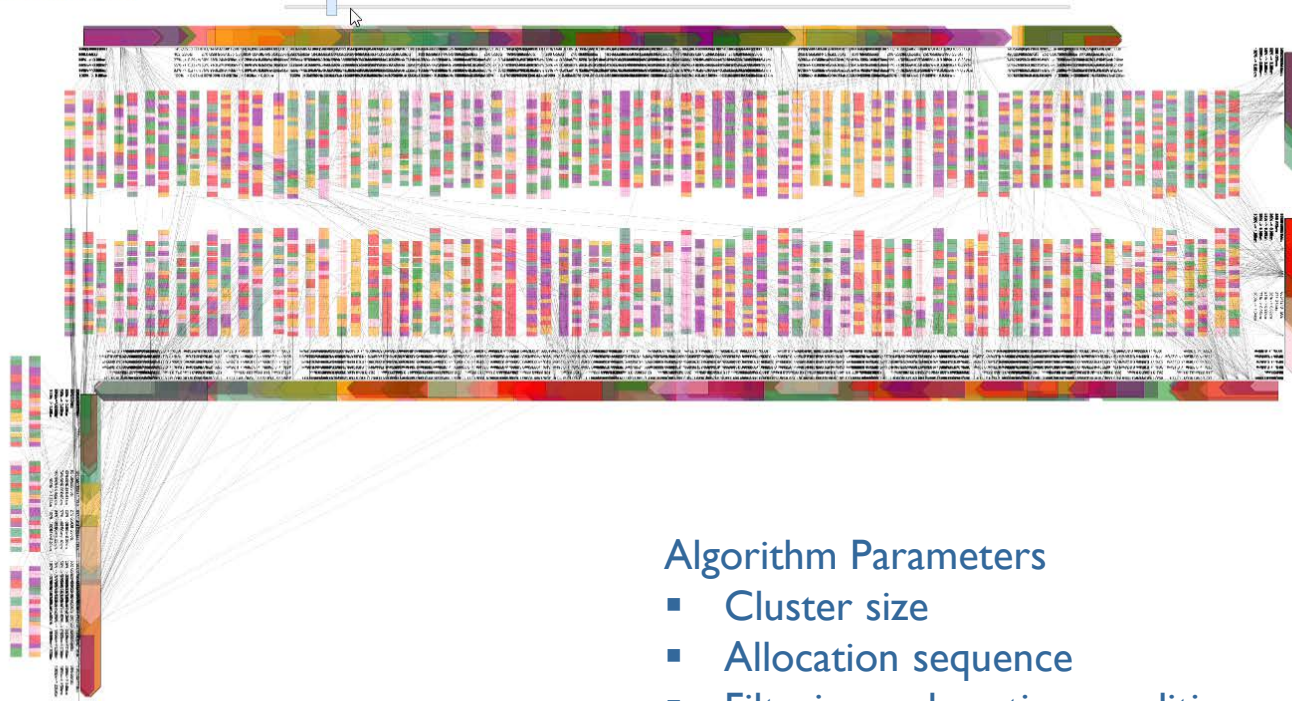
Capacity Assessment for General Cargo Port



Entity-Relationship Diagram for Cargo Mix and Handling Resources in General Cargo Port

Yard Planning for Transshipment Terminals

Time: 0 Days 10 Hours



Yard Planning - Port Simulator

Annual Throughput (mTEUs)

#Slots / Assignment

#Slots / Blk / Vsl

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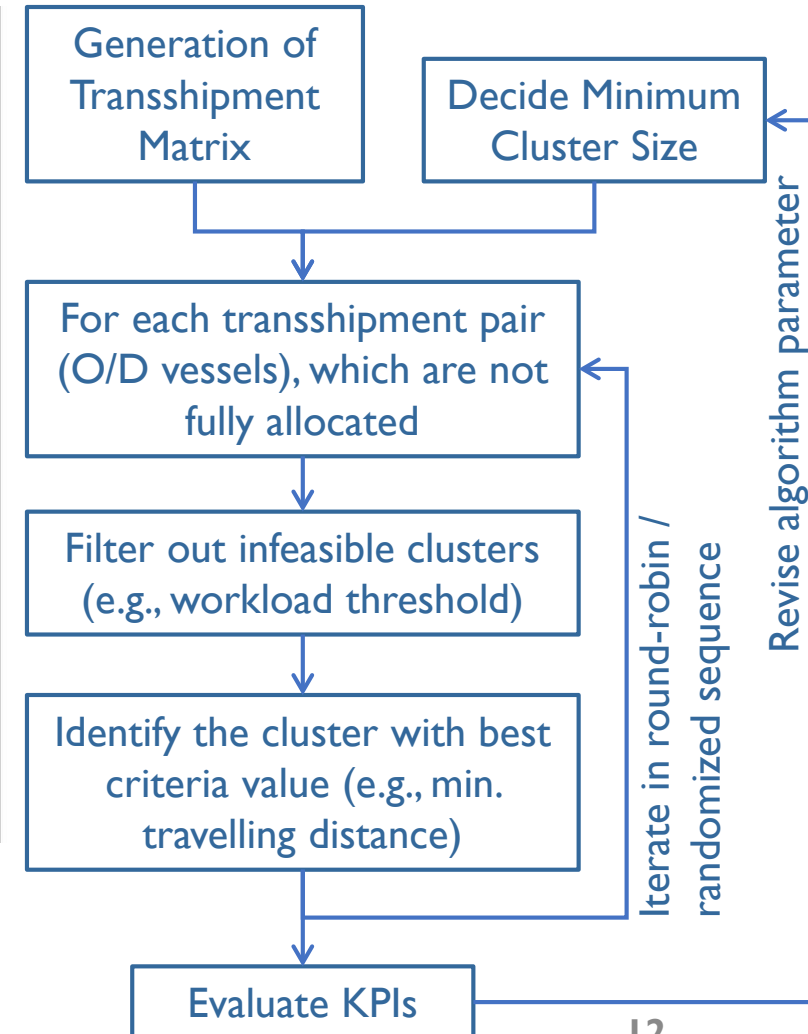
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Algorithm Parameters

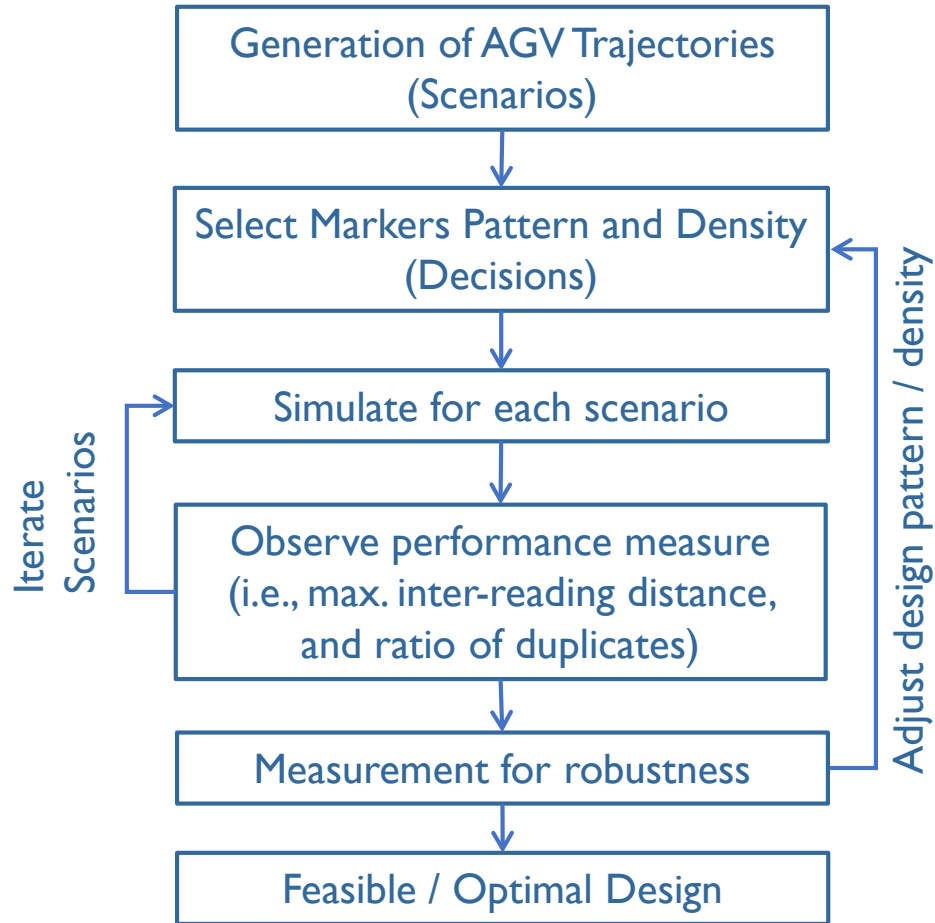
- Cluster size
- Allocation sequence
- Filtering and sorting conditions

Algorithm KPIs

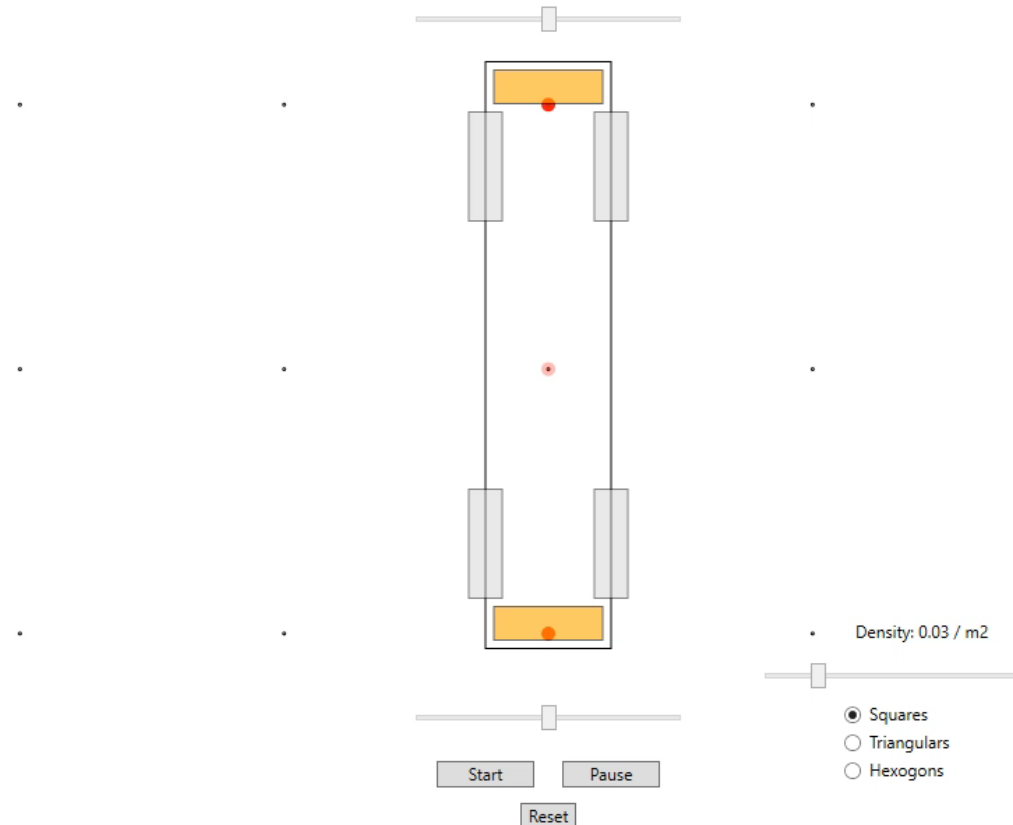
- Spread if yard-crane work loads
- Travelling distances
- Computational efficiency



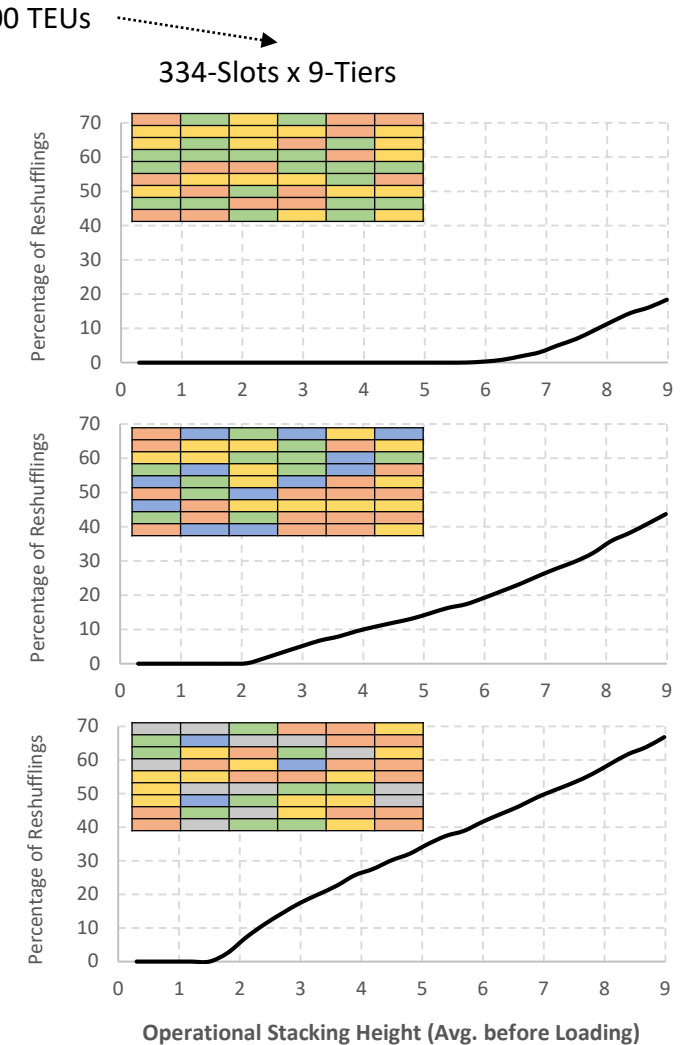
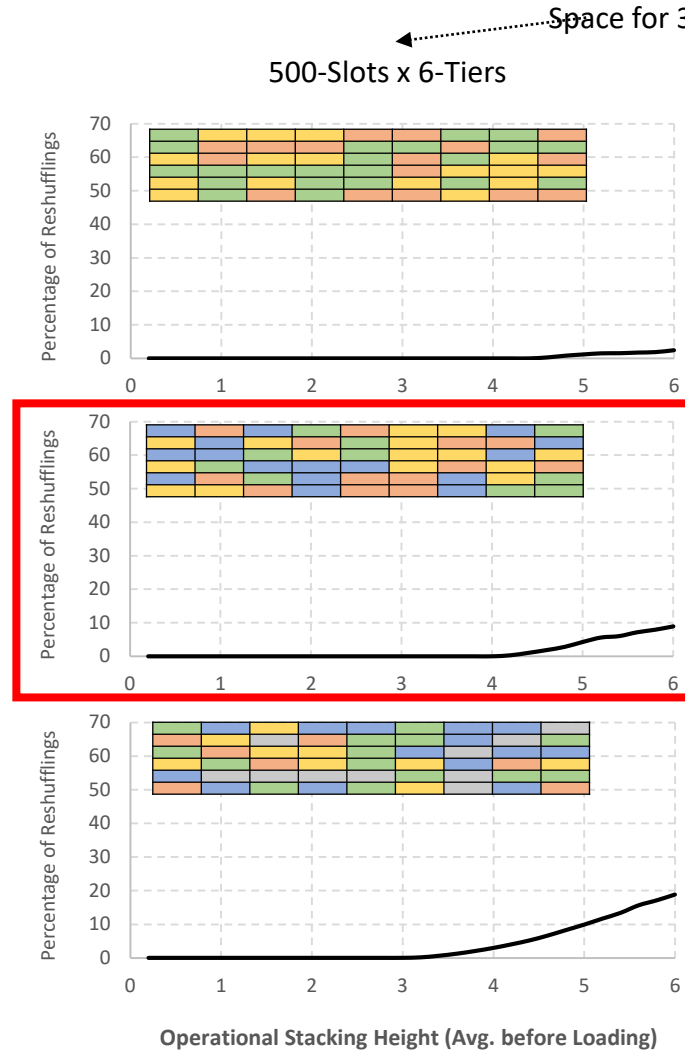
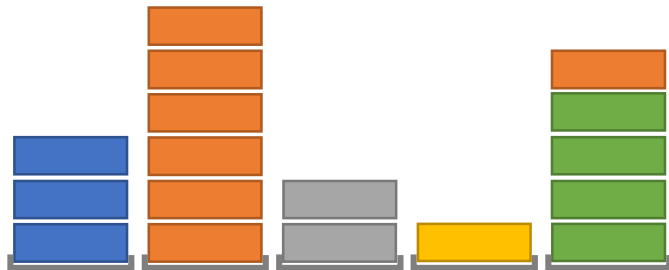
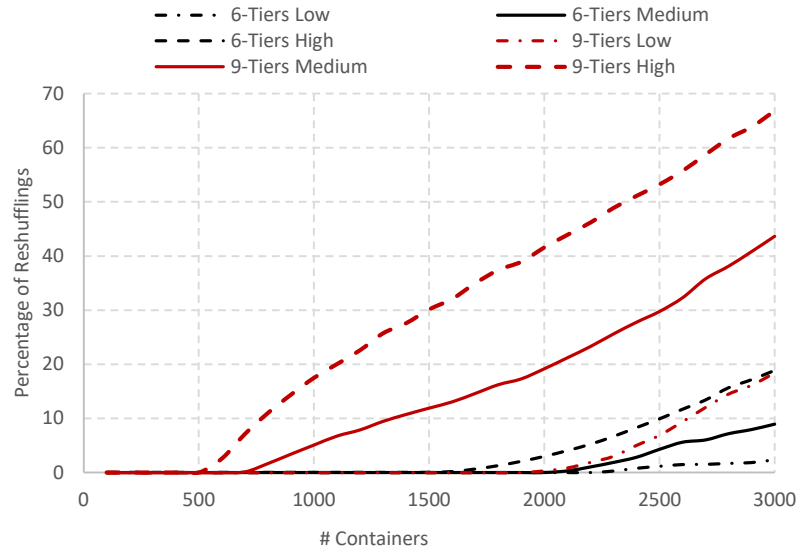
Optimization for AGV Markers Configuration



00:02:56
 X:0.00, Y:177.00, Degree:0.00
 Wheel Angles: 0.0, 0.0
 Inter-Reads Distance: Avg.2.76m, Max.5.50m
 Duplicates: 0.00%



Yard Block Reshuffling Analysis



Low-Variety
(300 Ccategories)

Medium-Variety
(400 Ccategories)

High-Variety
(500 Ccategories)

A Simulation-based Capacity Assessment Toolbox For Jurong Port

Thank you!

Q&A