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Simulation for Improving the Efficiency of Port Terminals

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Overview

- Introduction
- Container Terminal (CT) overview
- Simulation Experiment
- Two Cases:
 - SimPort (**S**imulated container **P**ort) Model for Berth Allocation
 - Comparison of Horizontal Transport equipment
- Conclusion and Questions...



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Currently conducting research on techniques from Artificial Intelligence in Logistics.

Possess 18 years work experience in the following fields: Banking, Consulting, Education, Logistics, Marketing, Research, Sales, Shipping and Terminals while employed with companies such as: Evergreen, Sea Land, Bank of America, Deutsche Post, Sea Trade Reefer, Bristol Myers-Squibb Corporation, Maritime Transport and Logistics Advisors and Blekinge Institute of Technology.

From January 15, 2007, he will work with TTS Port Equipment AB in Gothenburg, Sweden on port projects.



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Background to the Problem in Container Terminals and Ports

- Ships are getting bigger and carrying more containers, up to 14,000+ TEU (Twenty foot Equivalent Unit).
- Containers are the main instrument for shipping general goods (15 million & increasing 8% p.a.)
- Vessels costing \$65,000 + per day.
- Importance of *Turn-around time* is paramount.
- Peak times leading to congestion and bottlenecks.
- Can't keep building more ports!
- Finally,... how is the terminal going to handle the management of such flows of containers?



Cost of delaying a 8 000 TEU container ship for one day

Capital cost of vessel (in US \$)	$85\,000\,000 \times 0.1 \times \frac{(1 + 0.1)^{20} - 1}{0.1} \times \frac{1}{350}$	28 526
Daily operating cost (in US \$)	$\frac{14\,494\,000}{350}$	41 411
Daily cost of containers (in US \$)	assuming 45 % 20 ft / 45 % 40ft / 10% reefer boxes $8\,000 \text{ TEU} \times 2.4 \text{ (sets per vessel)} \times [(0.45 \times \text{US}\$0.58) + (0.45 \times \text{US}\$0.90) + (0.1 \times \text{US}\$8.00)]$	28 147
Cargo inventory (in US \$)	$8\,000 \text{ TEU} \times 0.8 \text{ (load coefficient)} \times 10 \text{ ton} / \text{TEU} \times 0.08 \times \text{US}\$ 3\,000 / \text{ton} \times (1 / 365\text{d})$	42 082
Total		\$140 166

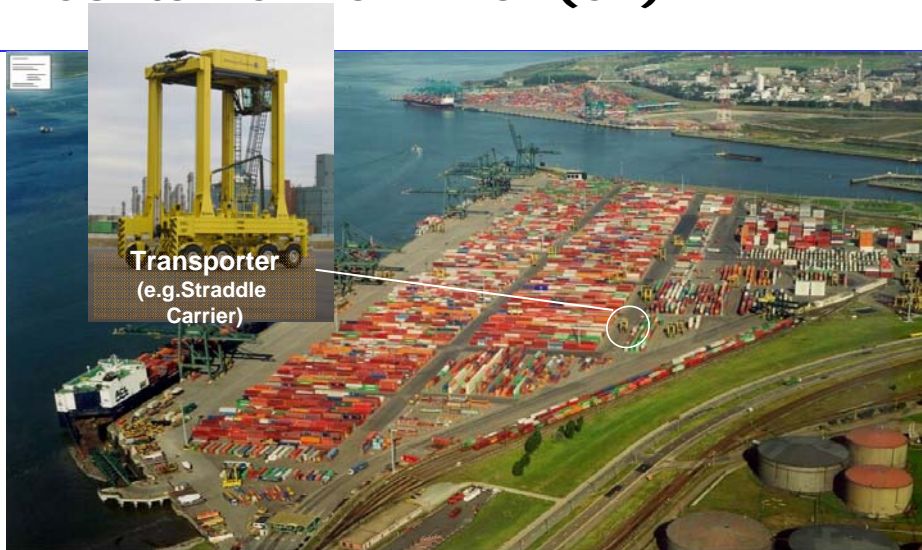
Source: Gustaf DeMonie



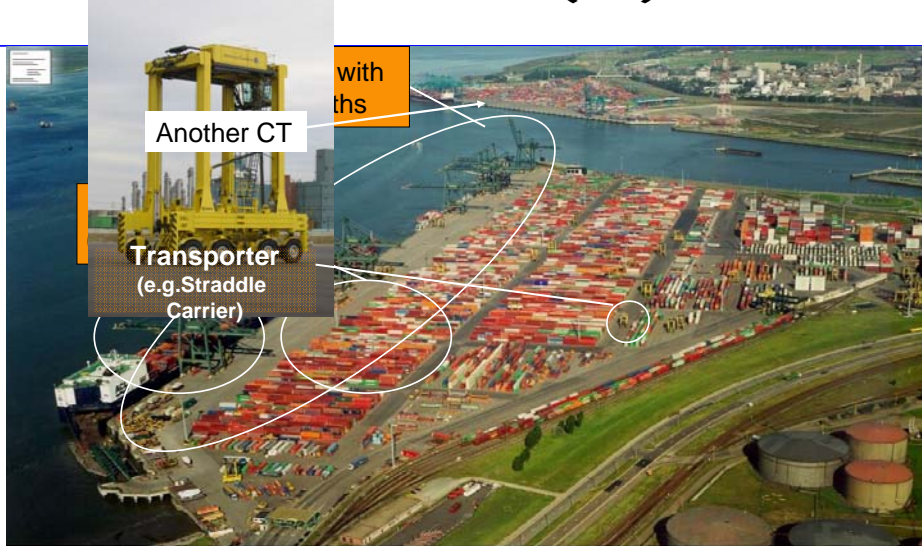
Container Terminal (CT)



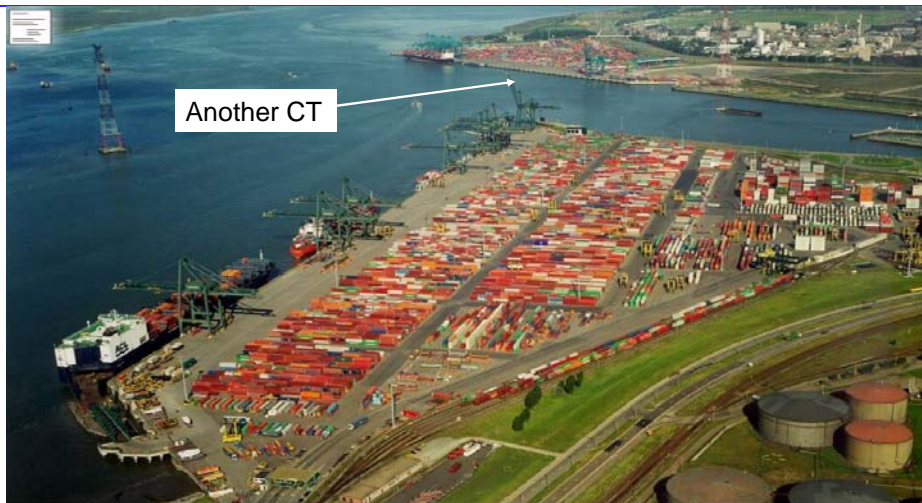
Container Terminal (CT)



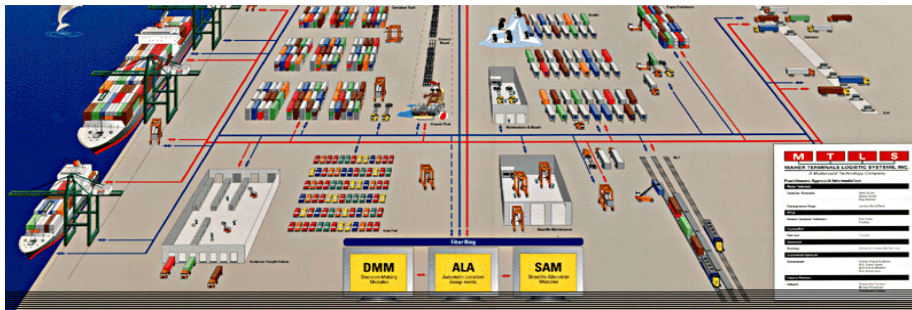
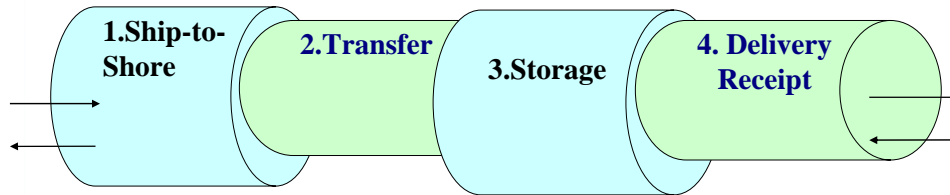
Container Terminal (CT)



Container Terminal (CT)

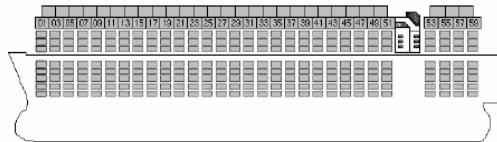


Container Terminal System and main processes in the subsystems



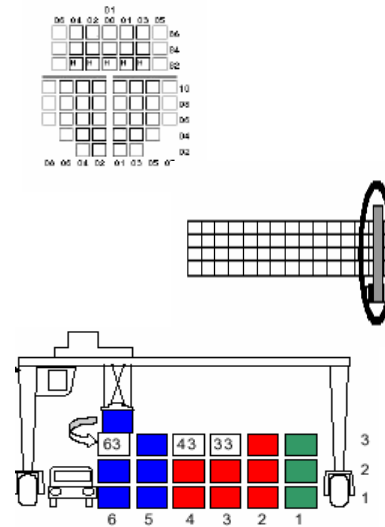
Ship-to-Shore System Problems

- Load profile
- Work scheduling for gantry cranes



Transfer System Problems

- Load sequence
- Routing problem
- Pickup sequencing



Storage System Problems

- Stacking density
- Yard configuration
- Automatic container allocation



Delivery and Receipt System Problems

- Control access to the terminal of the trucks
- EDI for container accuracy
- Artificial vision



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Two alternatives

Either physical expansion

- Build more terminals, hire more labour and Buy more equipment!

I like this approach!

Increased Terminal Performance

- lets use new ideas? i.e. efficient use of available resources by employing Simulation as the “*back-bone*” for Decision Support Systems.



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Simulation as a method

- Simulation consists of building a representation of the real world that is called a **model** and testing it under various “what if” analysis.
- Good reason for simulation is that it is a good way for people to form cognition; *action or process of acquiring knowledge*.



Modeling and Simulating the Elements or Objects in the System

- Two simulation approaches: Discrete and Continuous
 - For example, when simulating a queuing system, variables like “average queue length” of container ships at a port is continuous, since the queue length vary over time, while “average delay” for a container ship is discrete, since the average is calculated from the delay for each item in the queue
- Simulation Modelling: Viewed as more of art than a science
 - Difficulty in determining which aspects a real-world system, like a CT, actually needs to be incorporated into the simulation model, and what aspects can safely be ignored. Perhaps the hardest general problem in simulation.
- Verification, Validation and Calibration
 - Verification can be stated as building the *model right*,
 - Validation is often stated as building the *right model*.
 - Calibration is similar to tweaking/tuning of existing parameters



When to use Simulation and not

Some reasons for using simulation are:	Some reasons for NOT considering simulation are:
<ul style="list-style-type: none">▪ Cost▪ Time▪ Repeatability▪ Safety▪ Real system does not exist▪ Complexity▪ Training▪ Solving such problems:<ul style="list-style-type: none">–Random variables–Large number of parameters–Non-linear functions–Behaviour of a dynamic system	<ul style="list-style-type: none">▪ The problem can be solved using commonsense.▪ The problem can be solved analytically.▪ Easier to change or perform direct experiments on the real system.▪ Cost of simulation exceeds possible savings.▪ Proper resources are not available for the project.▪ Not enough time for the model results to be useful.▪ There are no data, not even estimates.▪ System behaviour is too complex.



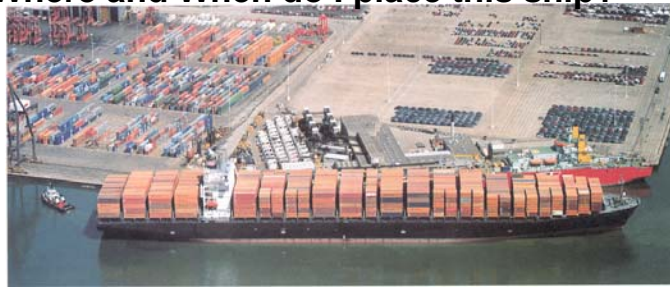
Case One for using Simulation:

Analyzing Berth Allocation Policies in a Container Terminal



Berth Allocation

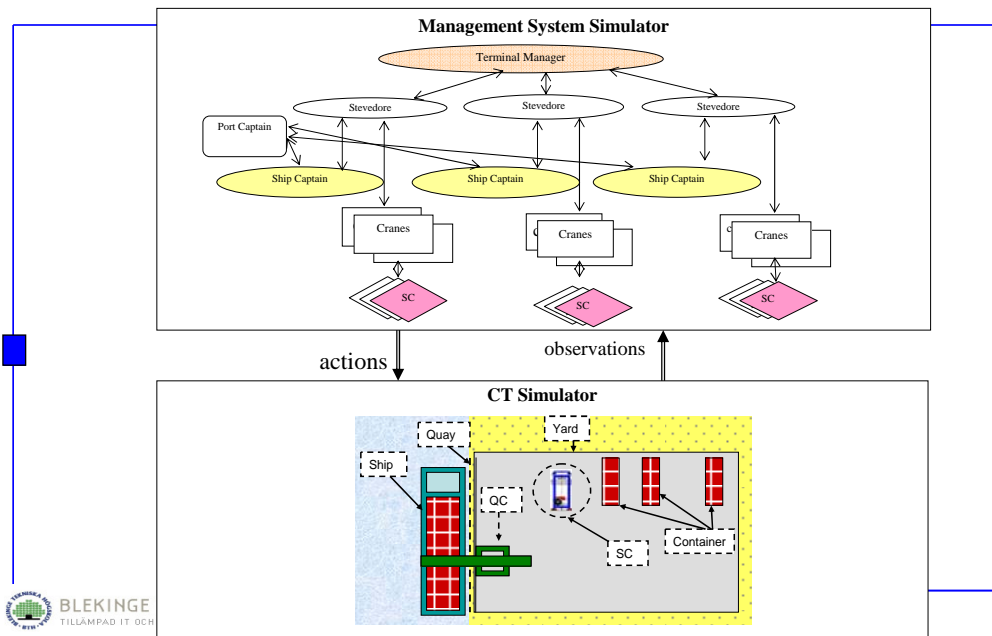
Where and When do I place this ship?



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SimPort General Architecture

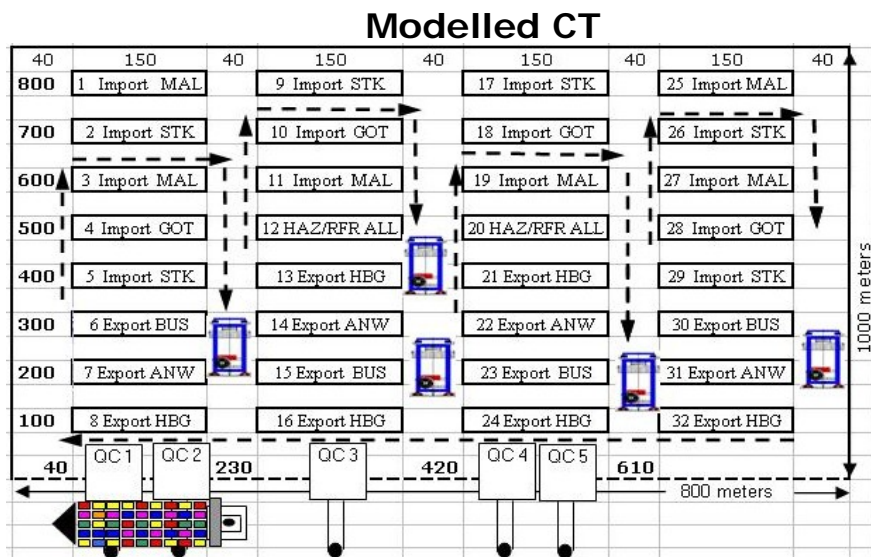


Input to Simport Simulation

- *Berthing Policy*: Overall Shortest Time (OTS) or Berth Closest to Stack (BCTS).
- *Sequencing Policy*: First In First Out (FIFO) or Highest Earning First (HEF) and Shortest Job First (SJB).
- *Sequence of arriving ships*: Ship Configurations and Container Assignment for each Bay arriving at CT in India
 - BCTS: FIFO, HEF, SJB
 - OTS: FIFO, HEF, SJB
- *Quay length*: Tested at 890 m to reflect the actual CT.
- *Terminal width*: Set at 1000m as it is at a 'real' CT.
- *Berth spacing*: The spacing is fixed at 200 m.



Simulation Experiment



Output from Simport simulator

- *Berth assignment plan*: Schedule for assigning ships to berth points along the quay.
- *Crane Assignment*: Cranes assigned, starting and final positions.
- *Service time*: The total time turn-around time, measured in hours, for all ships.
- *Straddle Carrier assignment*: SCs are assigned to a specific Crane?
- *Distance*: Measured in meters traveled by SCs in moving containers from the gantry cranes to the yard stacks and vice versa
- *Cost*: Terminal handling costs are charged by CT in handling a TEU.
- *Profit*: Ship profit is calculated



Simulation with SimPort

SimPort

Developed by Group Henesey

Located at:

<http://ipd.bth.se/lhe/Simport>



Simport Simulation Output

Results

Simulation: Chennai Test 09-24 OTS-FCFS
Terminal: Chennai

Terminal Result

Distance covered by transports:

Trans...	Crane ...	Ship	Distance
0	0	Anna	321830
0	0	Betty	86770
1	0	Anna	324130
1	0	Betty	85780

Total Distance: 3070050

Crane cost

Crane ID	Cost / H...
0	3434
1	3441
2	3439
3	3456
4	3449

Profit

Ship	Profit
Cindy	60250
Anna	69600
Betty	75400

Ship Result:

Ship	StartTime	EndTime	Turn Around...	Cost
Anna	D: 0, T: 08:00	D: 1, T: 01:28	17:28	66900
Betty	D: 0, T: 12:00	D: 1, T: 08:19	20:19	34600
Cindy	D: 0, T: 17:00	D: 0, T: 22:09	05:09	51500

Save to Database Export to Excel Close

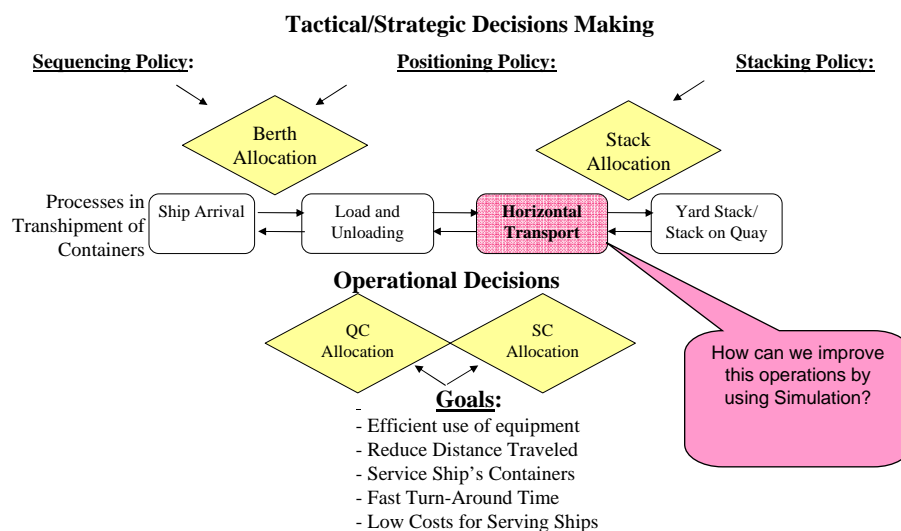
Simulation Policy:	Stacking by Ship Line					
	BCTS			OTS		
	FIFO	HEF	SJB	FIFO	HEF	SJB
Total distance (meters):	213460	219887	208806	239820	240115	238331
Average Ship Turn Around Time:	10:38	10:55	10:21	7:22	7:25	7:17
Average Waiting Time:	03:30	03:48	03:16	00:21	00:25	00:17
Total Costs (€):	187500	200500	187500	150700	151010	149600
Simulation Policy:	Stacking by Destination					
	BCTS			OTS		
	FIFO	HEF	SJB	FIFO	HEF	SJB
Total distance (meters):	205250	211430	200775	227333	229720	225875
Average Ship Turn Around Time:	10:20	10:37	10:04	7:13	7:10	7:07
Average Waiting Time:	3:23	3:41	3:10	0:13	0:10	0:07
Total Costs (€):	184500	194000	184500	148200	149300	147600

Case Two for using Simulation:

The Comparison of Various types of Horizontal Transport Equipment



Modeling the Decisions in the Transshipment of Containers



Simulation; Comparison of Horizontal Transport Systems

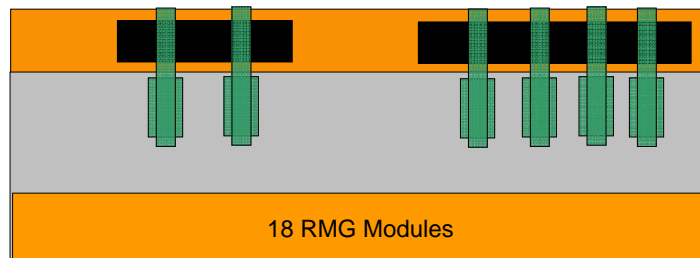
- Conventional AGV
- C-AGV (TTS) Cassette-AGV
- ShC Shuttle Carrier, manual driven
- AShC Automatic Shuttle Carrier



Simulation: Assumptions

A ship arrives at CT with 2000 boxes to be loaded and unloaded

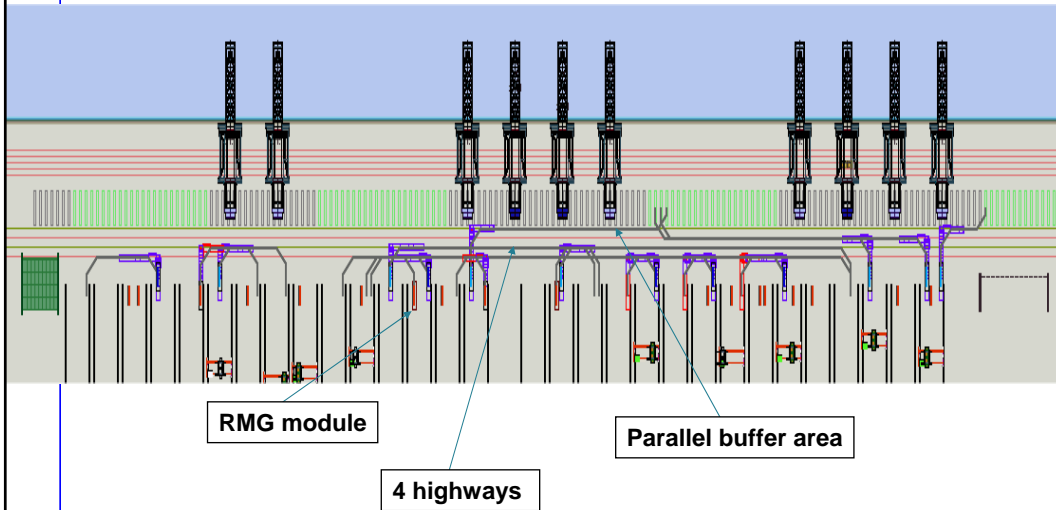
- 6 QC at average 45 crane cycles
- TL handling inside crane cycle
- 20% of boxes twin-lifted
- 50% import, 50% export



- 18 RMG modules; 60 TEU long, 8wide and 5 height
- 2X 18 = 36 RMGs
- Landside: 166 boxes/h



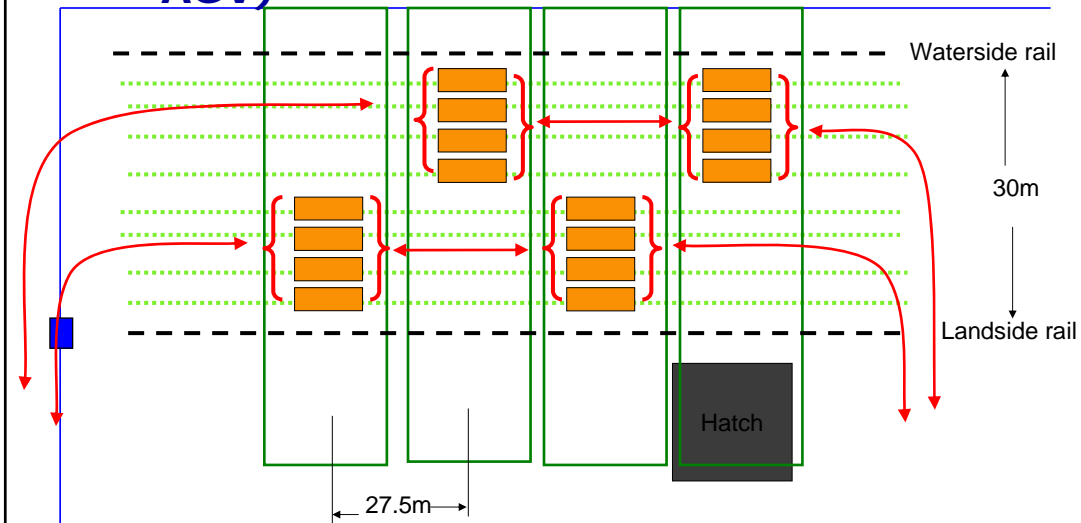
Simulation: Traffic pattern and rules



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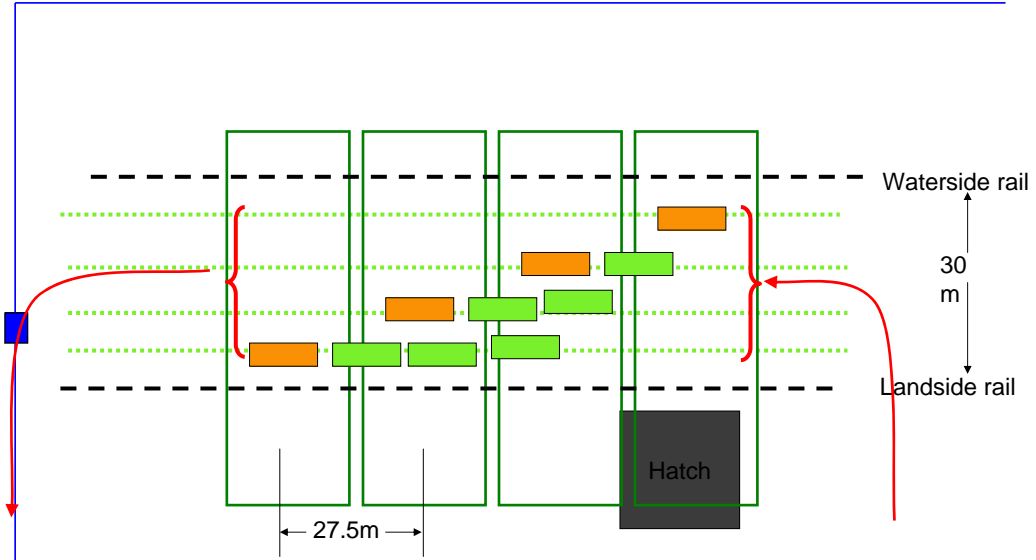
Assumptions Process in crane gauge (Cassette AGV)



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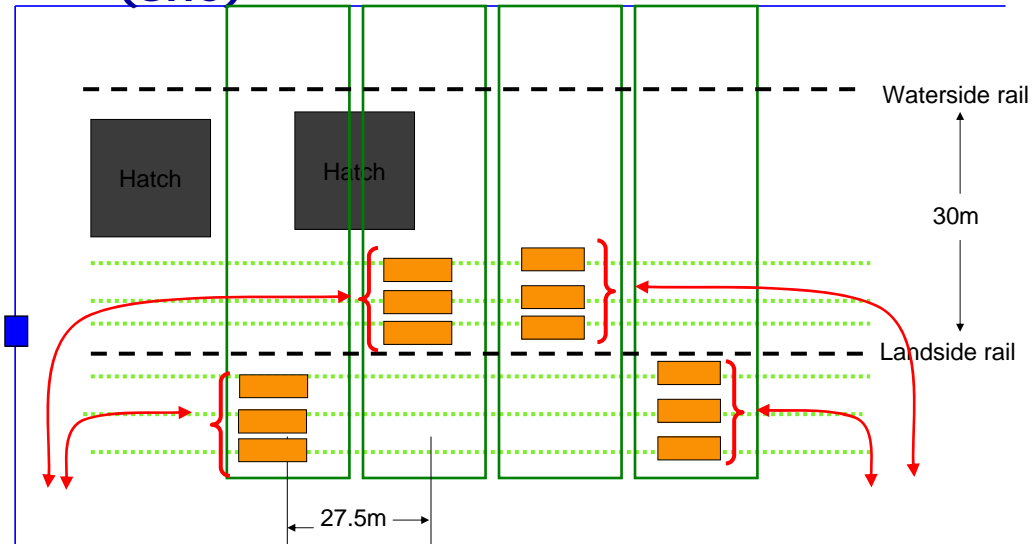
Assumptions Process in crane gauge (AGV)



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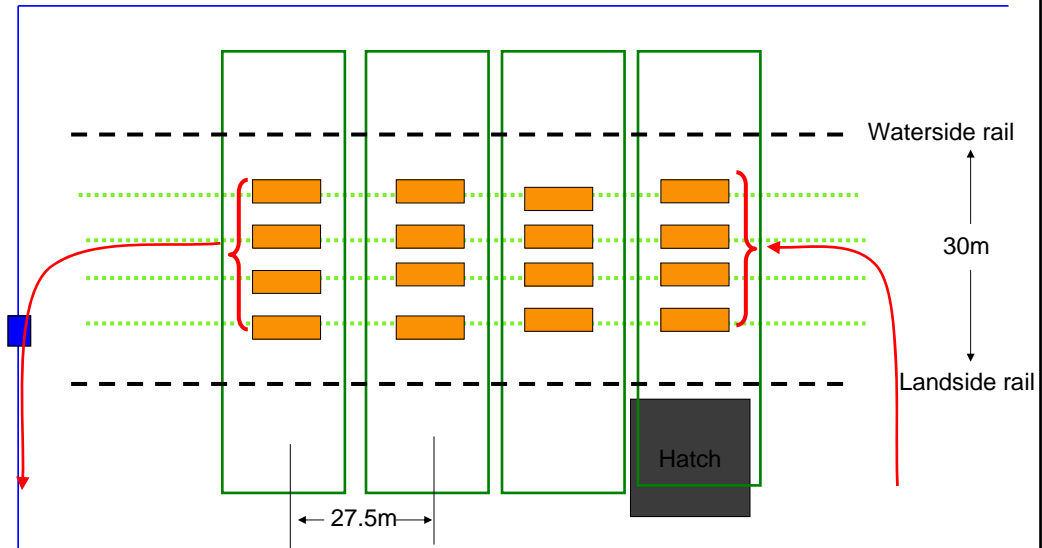
Assumptions Process in crane gauge and backreach (ShC)



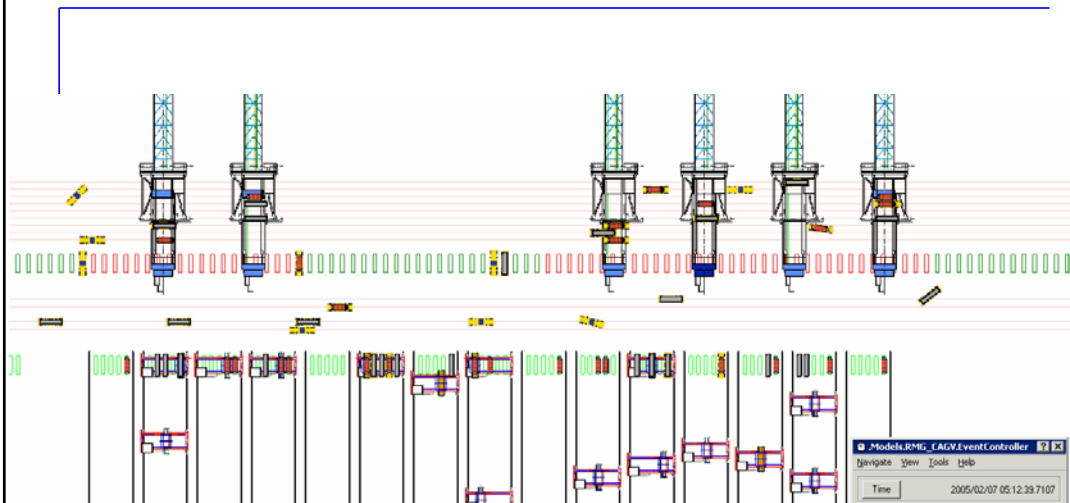
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Assumptions Process in crane gauge (AShC)



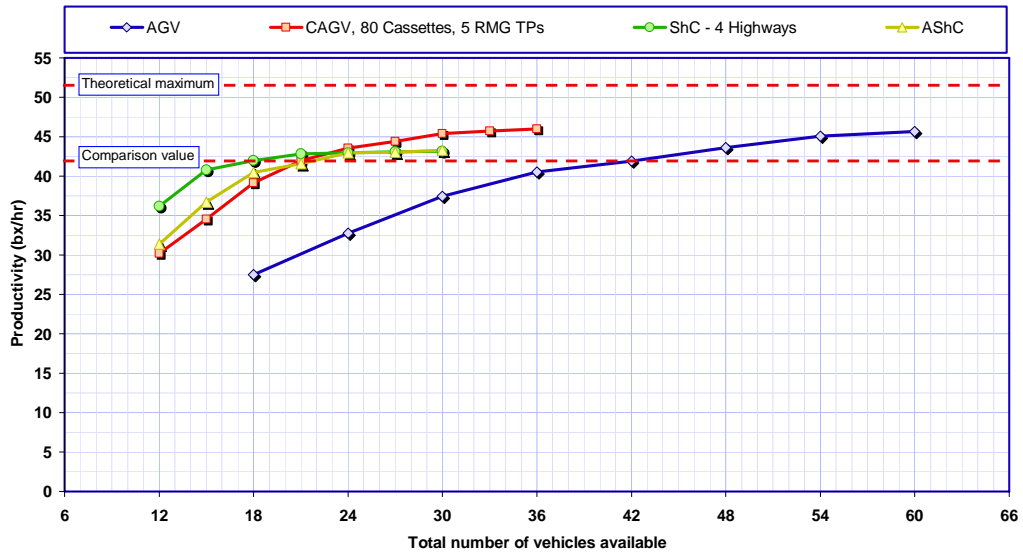
Efficient Cassette Systems Containerport Simulations



Results

QC productivity - Comparison AGV - CAGV - SC - AShC

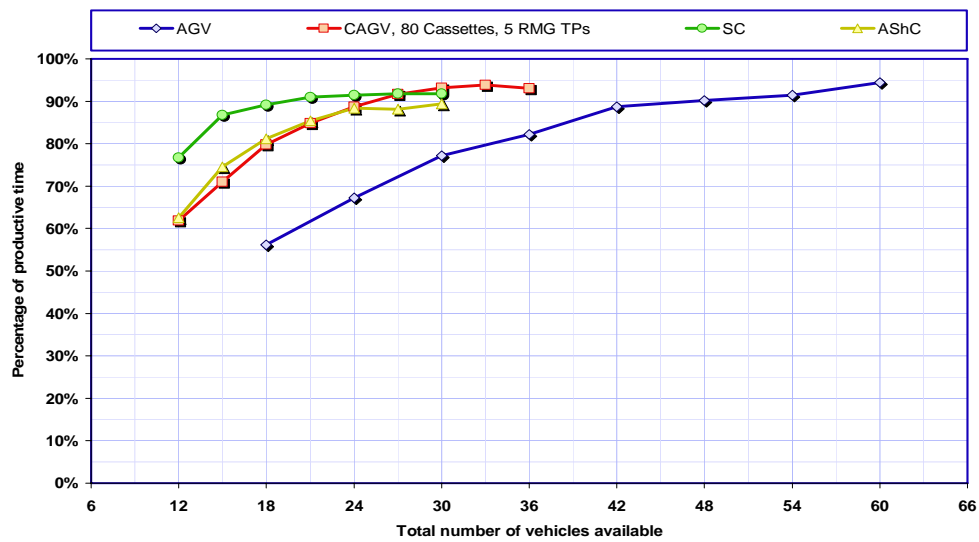
[6 QCs @ 45 ccph, 20% twinlift bays, 18 RMG modules, 166 landside bx/h]



Results

QC productivity - Comparison AGV - CAGV - SC

[6 QCs @ 45 ccph, 20% twinlift bays, 18 RMG modules, 166 landside bx/h]



Simulation Comparison conclusion for 6 vs 10 QCs

- System behavior are almost identical in both 10 and 6 QC configurations.
- All except the AGV system require a few more vehicles to sustain the performance levels.
- The AGV system is slightly better equipped to deal with the larger distances.



Simulation System comparison conclusion

- Cassette AGV and AShC are very close performance wise.
- ShCs have to drive less than AShCs because half of them operate in backreach.
- RMG utility is higher for the regular AGV system compared to the Cassette AGV system.
- The balancing of load and discharge boxes on the RMG WS TP is complex for decoupled systems..
- The AShC system is not capable to reach the 90% mark within the tested equipment variation.
- The AGV system is the only system not affected by the increase in #QC.



Simulation Overall conclusion

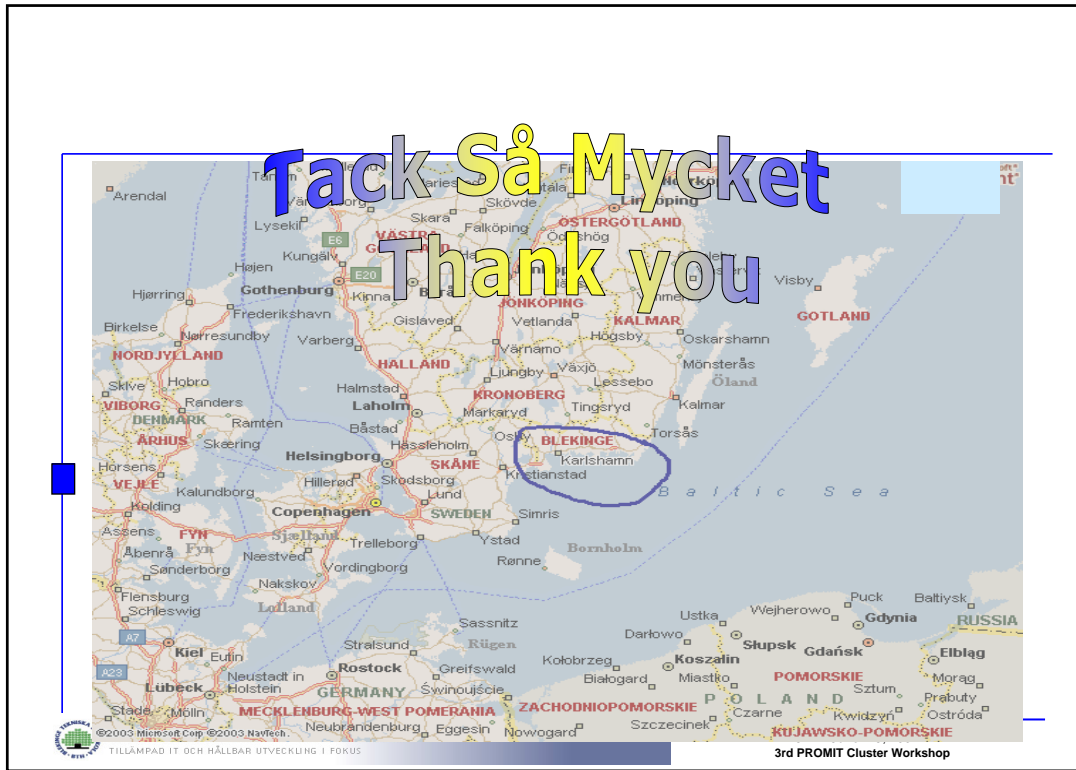
System	10 QCs		6 QCs	
	Required vehicles per QC to reach 85% of the possible QC productivity @ 45 ccpc	Required vehicles per QC to reach 90% of the possible QC productivity @ 45 ccpc	Required vehicles per QC to reach 85% of the possible QC productivity @ 45 ccpc	Required vehicles per QC to reach 90% of the possible QC productivity @ 45 ccpc
Cassette AGVs	3.5	5.0	3.5	4.5
Regular AGVs	6.5	8.0	6.5	8.0
Shuttle carriers	2.5 (3)	3.5 (4)	2.8 (3)	3.5 (4)
Automated Shuttle carriers	4	n.a. Could not manage 90%	3.5	4



Simulation Future work

- Identify additional problems to the current model
- Consider the level of detail necessary
- What factors, objects should be considered in the improved conceptual model
- Add modules for investment and operational costs
- Close **cooperation** with CT and transshipment experts





Conclusion and Questions?..



Cassete System will be implemented in APM Terminal's new facility in Portsmouth, Virginia and opening ceremony is Sept. 7, 2007.

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