Improve Inter Terminal Transportation: *Using Agent Technology*

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Introduction

- Trend of containerization is increasing since introduction of container in 1960
- e.g. Port of Rotterdam: 360,000 TEU[1] in 1970, 10.8 million in 2007, 15.9 million in 2020 *(Albert Douma, 2008)*
- Expansion of container ports
- Multi terminals in a single port
- Inter-terminal transportation (ITT)

[1] *TEU = Twenty Equivalent Unit*

Motivation


50
50


WE WANT SAFE STREETS
NO MORE TRUCKS


Benelux port delays costing car
Congestion at Antwerp and Rot
17 Augustus, 2007 - CONGESTION char
CBRB voorziet forse tariefsverhoging binnenvaart
Containers staan ECT tot aan de nek
Nieuws 20 februari 2007, auteur: Ferdi den Bakker
Nieuwe vertragingen bij ECT Delta Terminal
Contargo voert congestietoeslag in
16 juli 2007 – Nieuwsblad Transport.nl
Binnenvaart is wachten bij ECT beu

Related work

- Jaap A. Ottjes et. al 1996, 2006
- Prior presents simulation concepts for ITT, later presents a model and comparison of three vehicle systems
- Albert Douma focused barge handling in 2008
- Recently Tierney et. al presented mathematical model for ITT in 2014

MV area of Port of Rotterdam

Research Questions

How can operations of inter-terminal transportation be improved to meet future challenges of containerization?

- ✓ What are the challenges for container transportation at container terminals?
- ✓ What is state of the art for solving the problems identified in RQ1?
- ✓ How can we model ITT using a Multi-Agent system?
- ✓ How can we efficiently use resources involved in ITT?

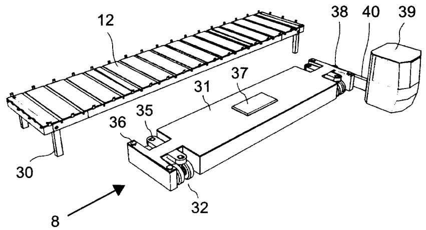
Modern Container Terminal

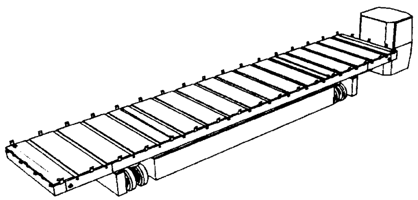
Operations in container handling

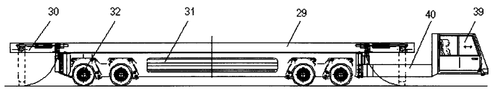
Horizontal Transport types

Cassette System is a floating buffer for decoupling and double stacking of containers

Concepts & Designs







Man Driven Solutions

TTS Translifter

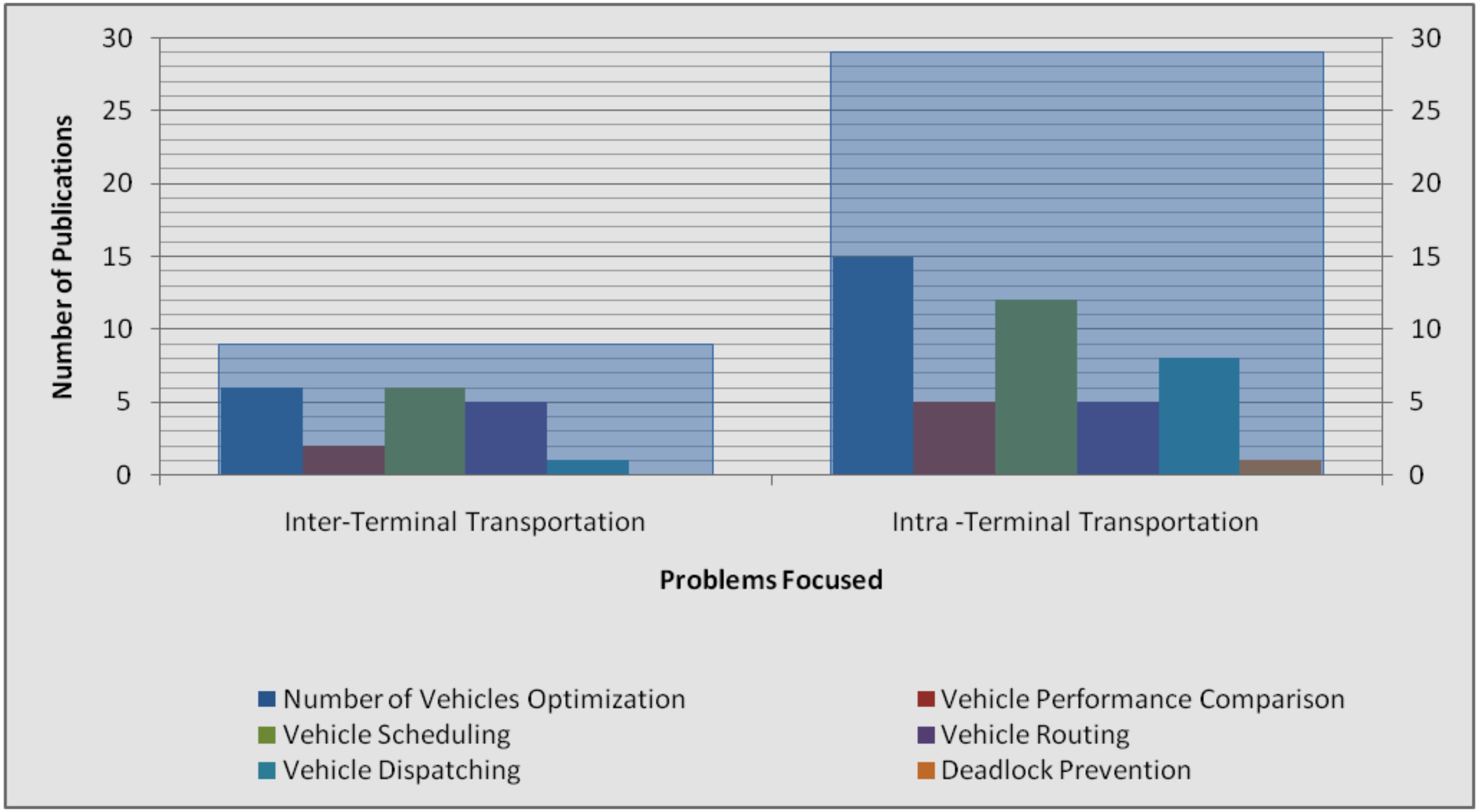
ATT Gaussin

Automated Solutions

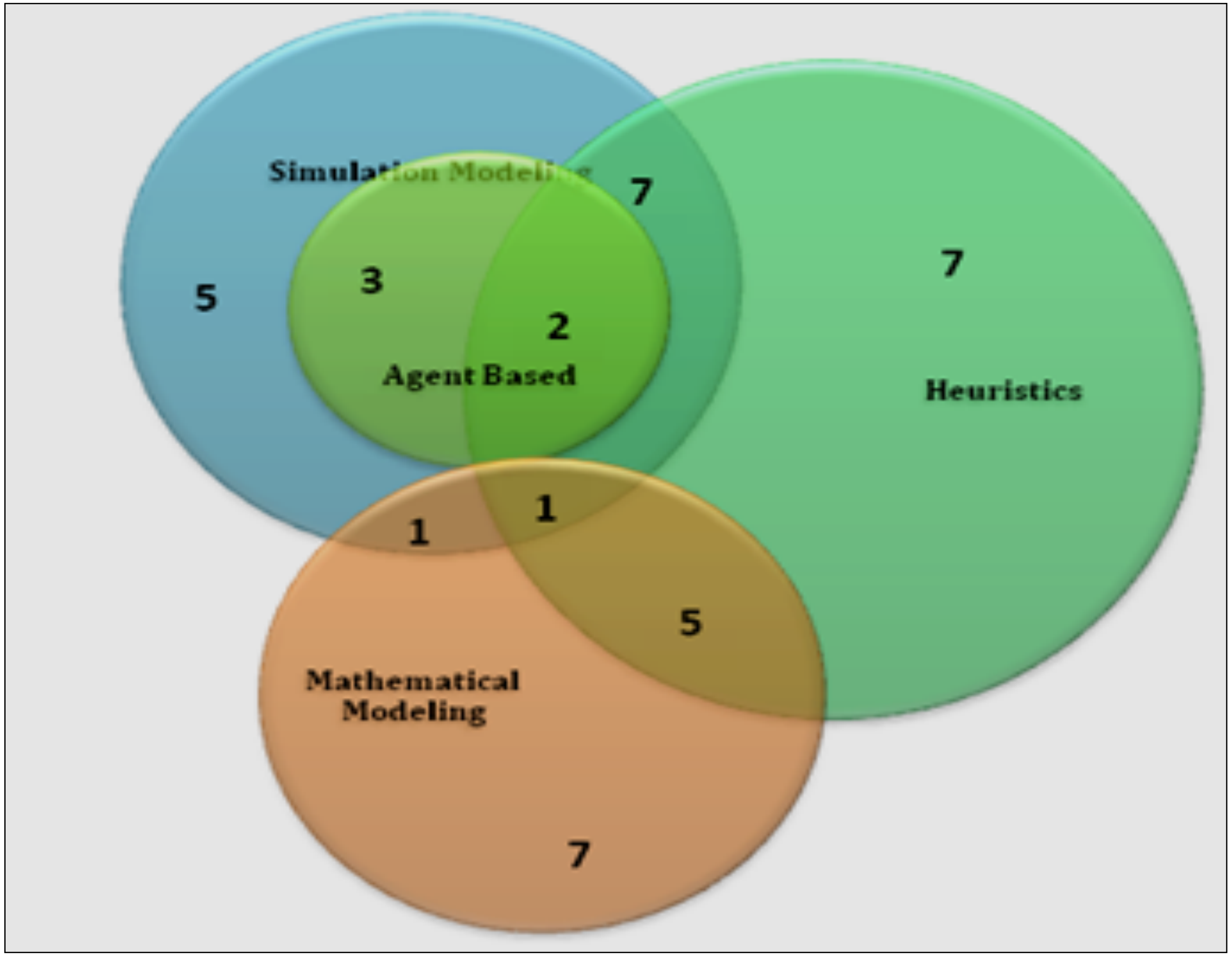
TTS Cassette AGV

Automated ATT Gaussin

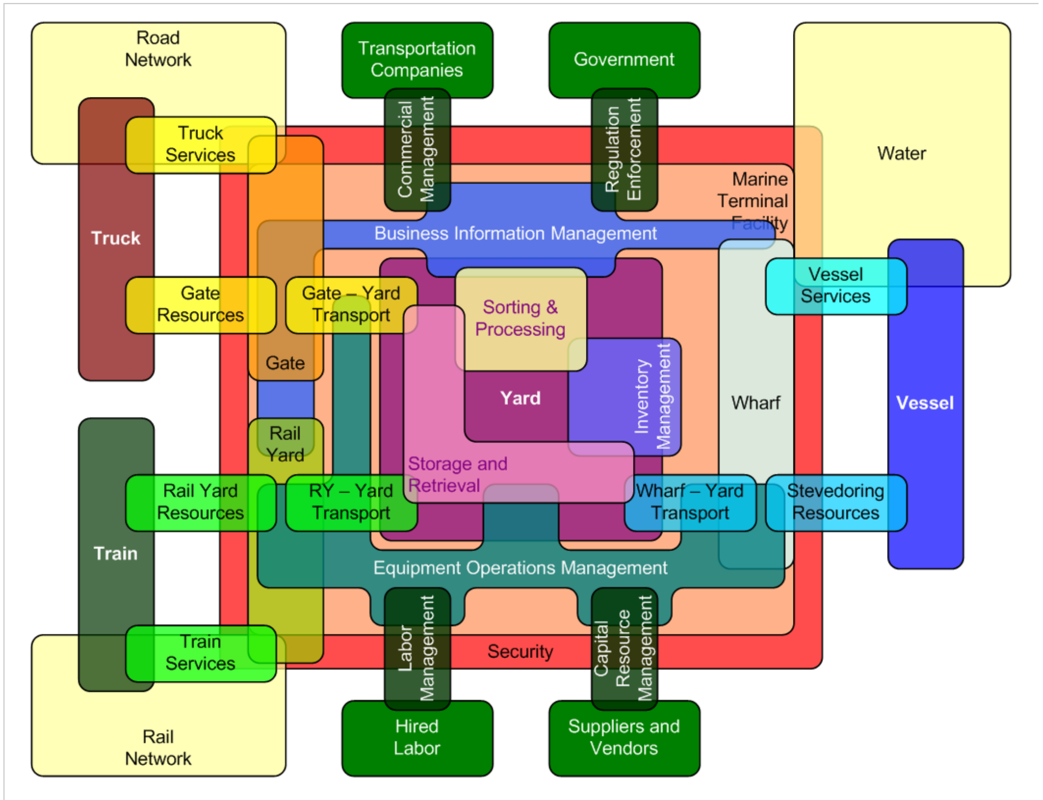
Problems Focused & Domain



Solution Approaches



Information Technology

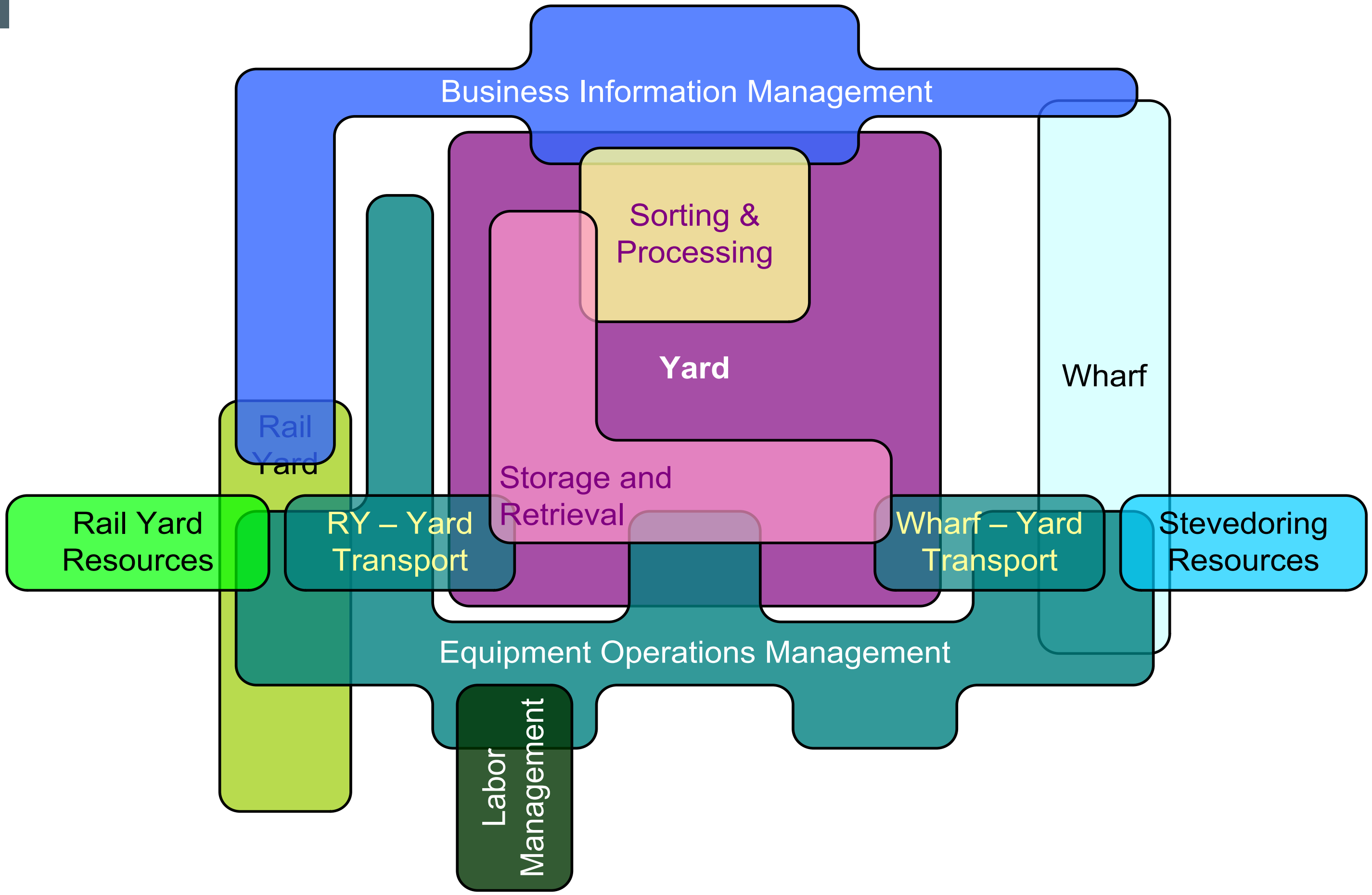


This diagram presents a general-purpose logical structure for any port operation

It's a bit scary, but gives some context

* Appreciation to Tom Ward – Next Generation Container Terminal, ORCHID®

TOS –Terminal Operating System



- The TOS is focused on logistics, business, transactions, and regulatory compliance
- It is not designed to handle “time and motion” problems in real time

TOS Limitations

The TOS determines:

- **What needs to move**
- **When it needs to have handling finished**
- **What external data must be presented as work is done**

The TOS provides the target end-result of the operation, but is not naturally efficient at balancing all the competing needs

The same TOS should be used for all terminals, without the burden of automation control where it is not needed

We need something more robust and focused

Multi Agent Systems

The container terminal is "complex":

- **Too complicated for most humans to comprehend**
- **Too random for normal algorithmics to optimize**

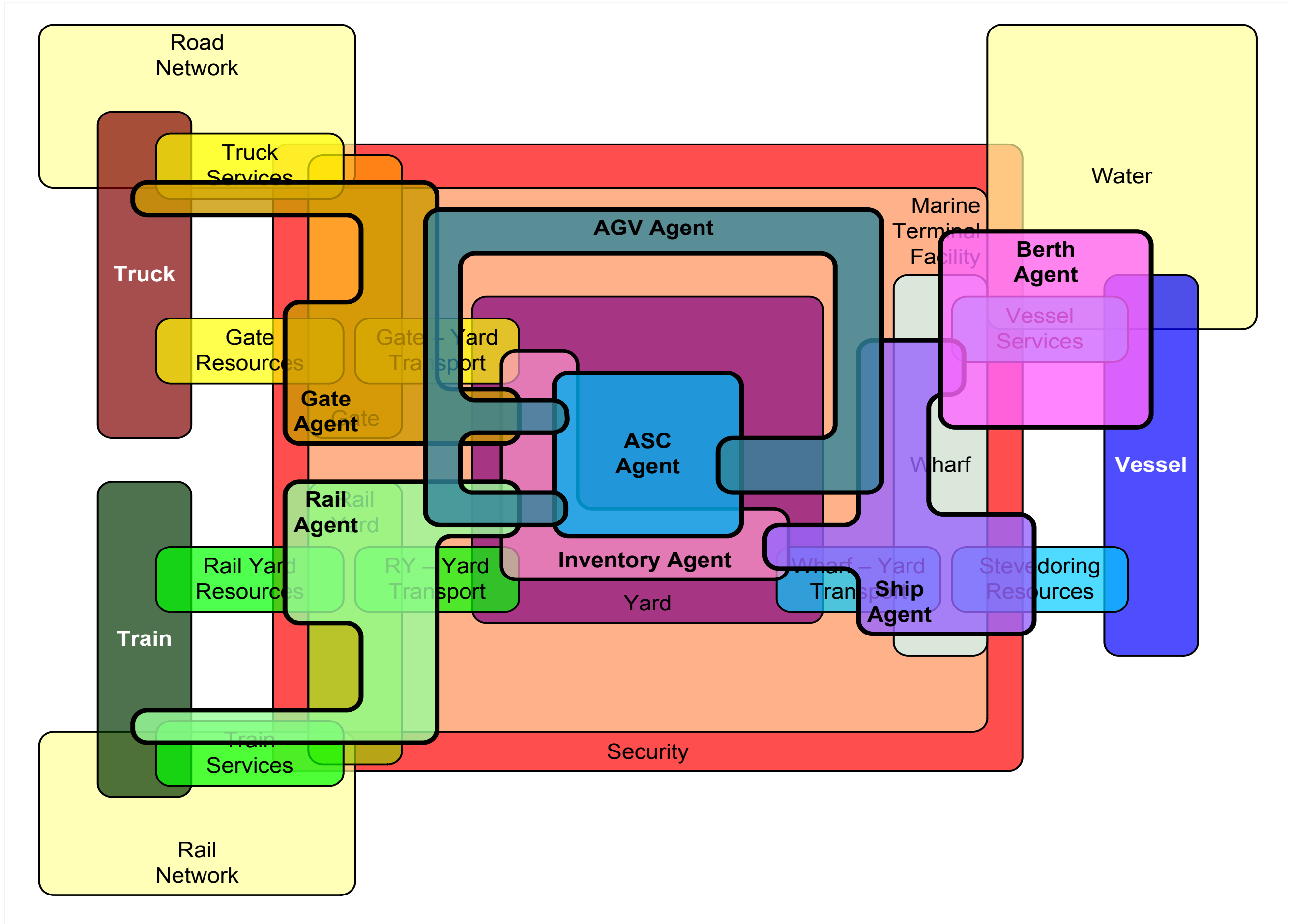
Multi Agent Systems (MAS) allow a layered, modular approach to rapidly getting to balanced solutions within complex systems

In an MAS, agents search, coordinate, communicate, and negotiate with other agents via a market based mechanism

Not "optimum" but "balanced"

* c.f ***Multi-Agent Container Terminal Management*** by L. Henesey, 2006, pp.1-271

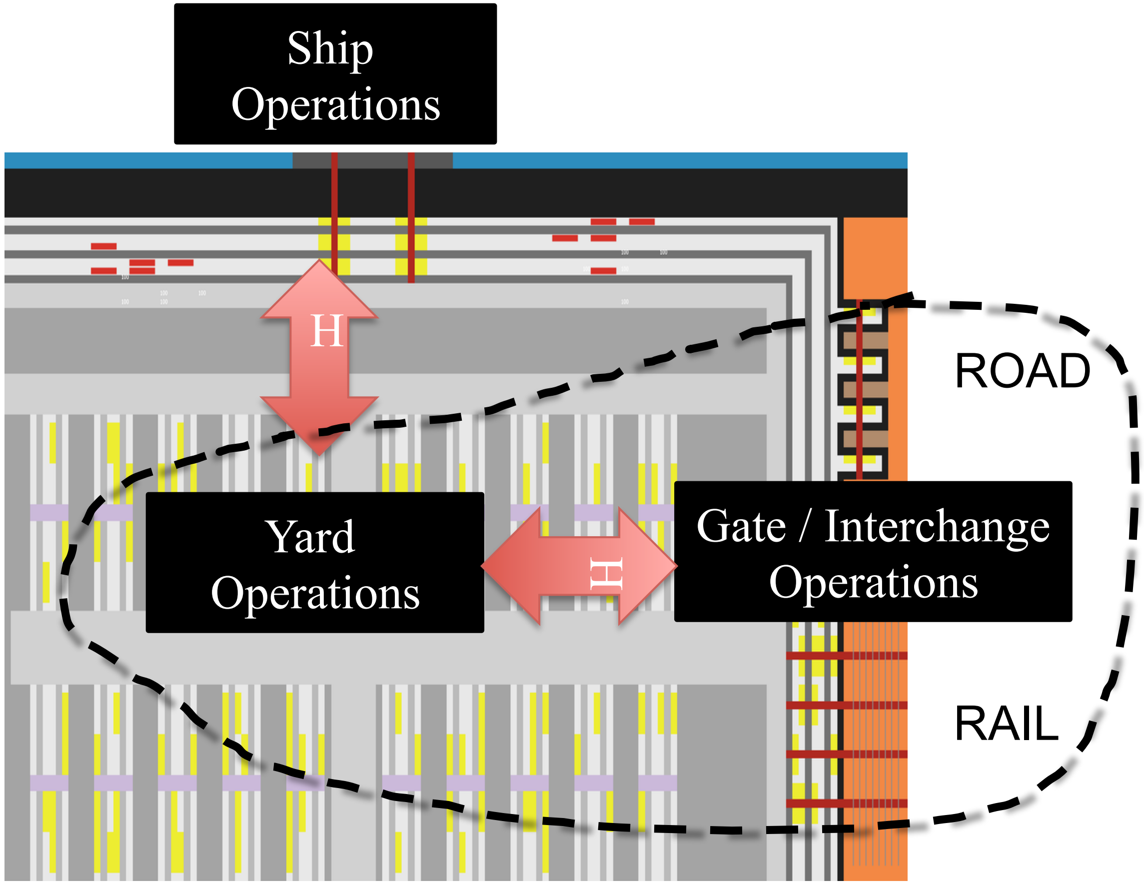
Agents in the Port Logical Model

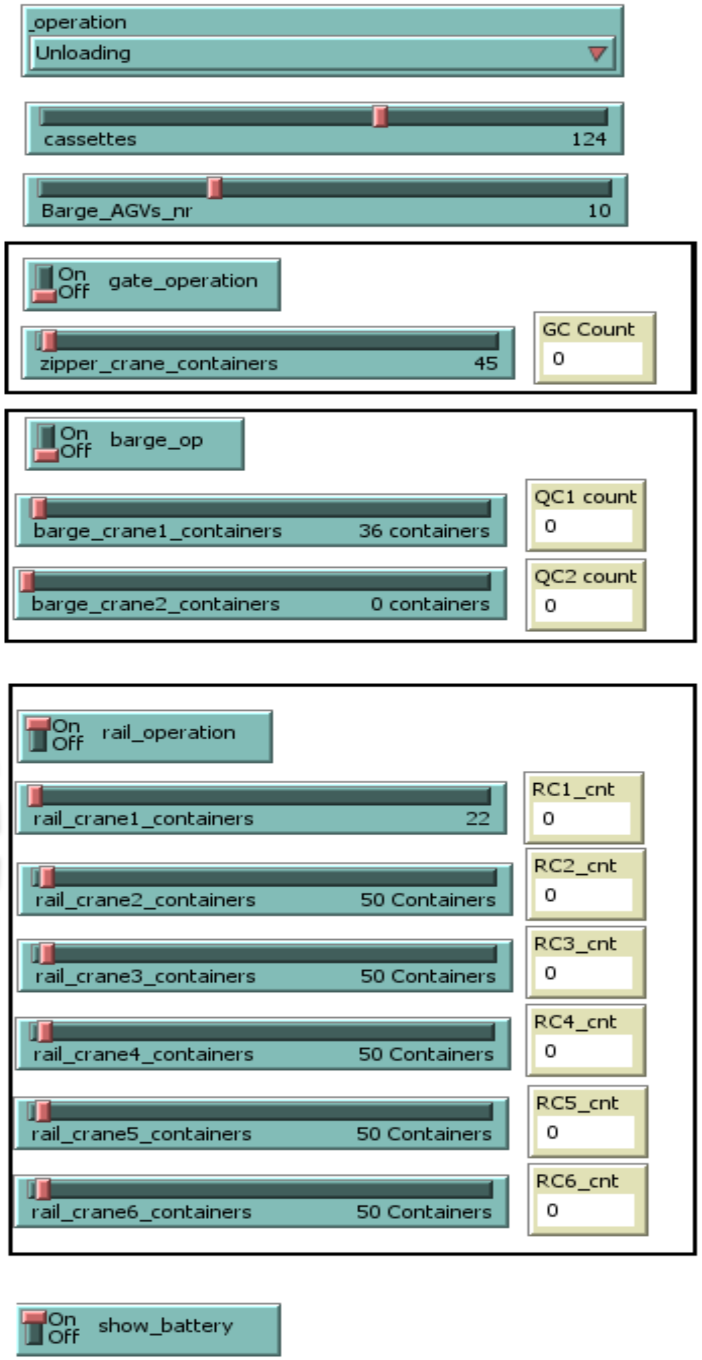


•This diagram depicts the scope of a number of Agents in a Port MAS: Berth, Ship, Gate, Rail, Inventory; ASC and AGV fleets; individual CHEs

•The MAS allows parallel balancing of complex issues in real time

A Simulated Container Terminal





Netlogo® Simulation tool

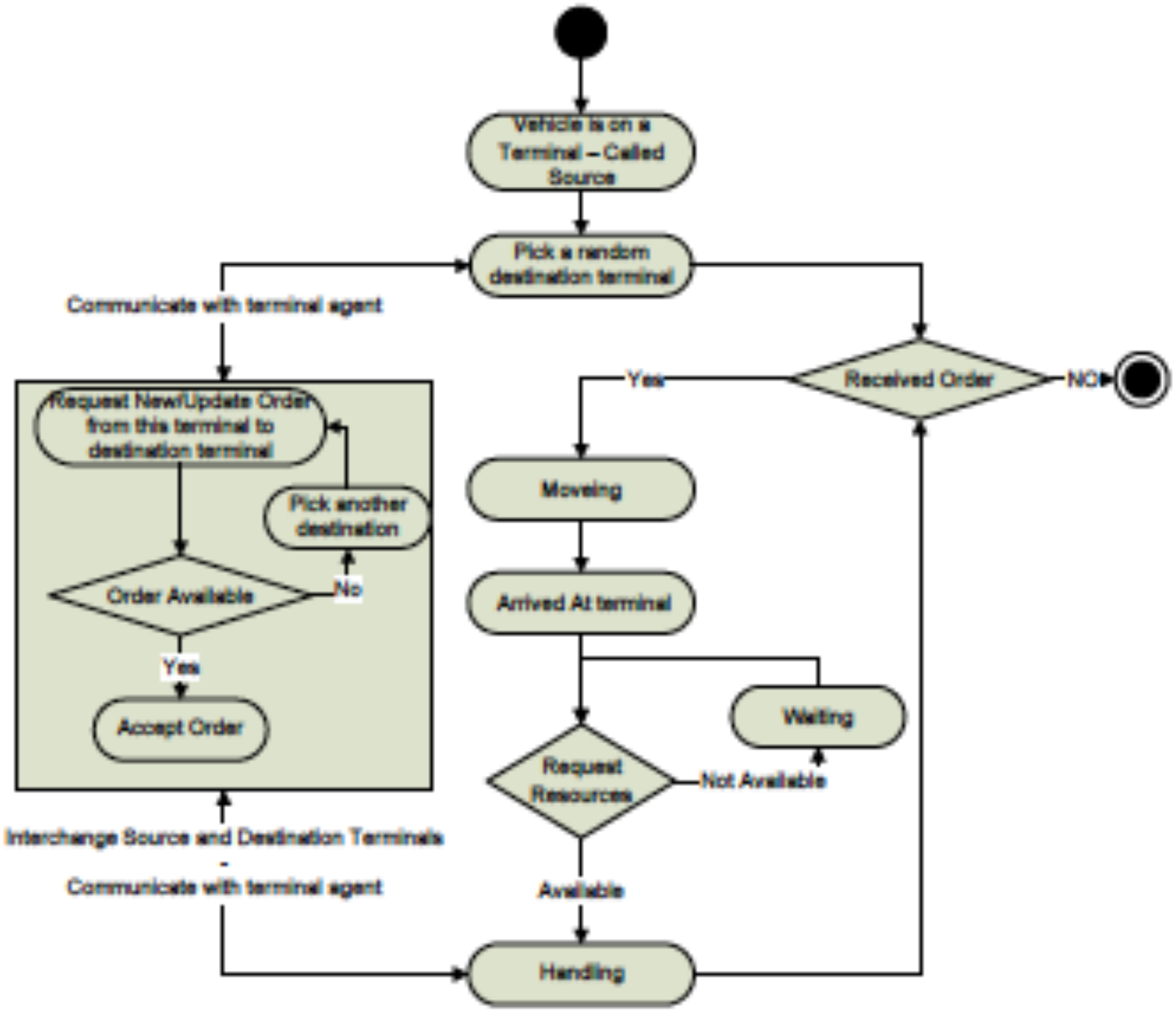
Conceptual Modeling

Terminal Agents

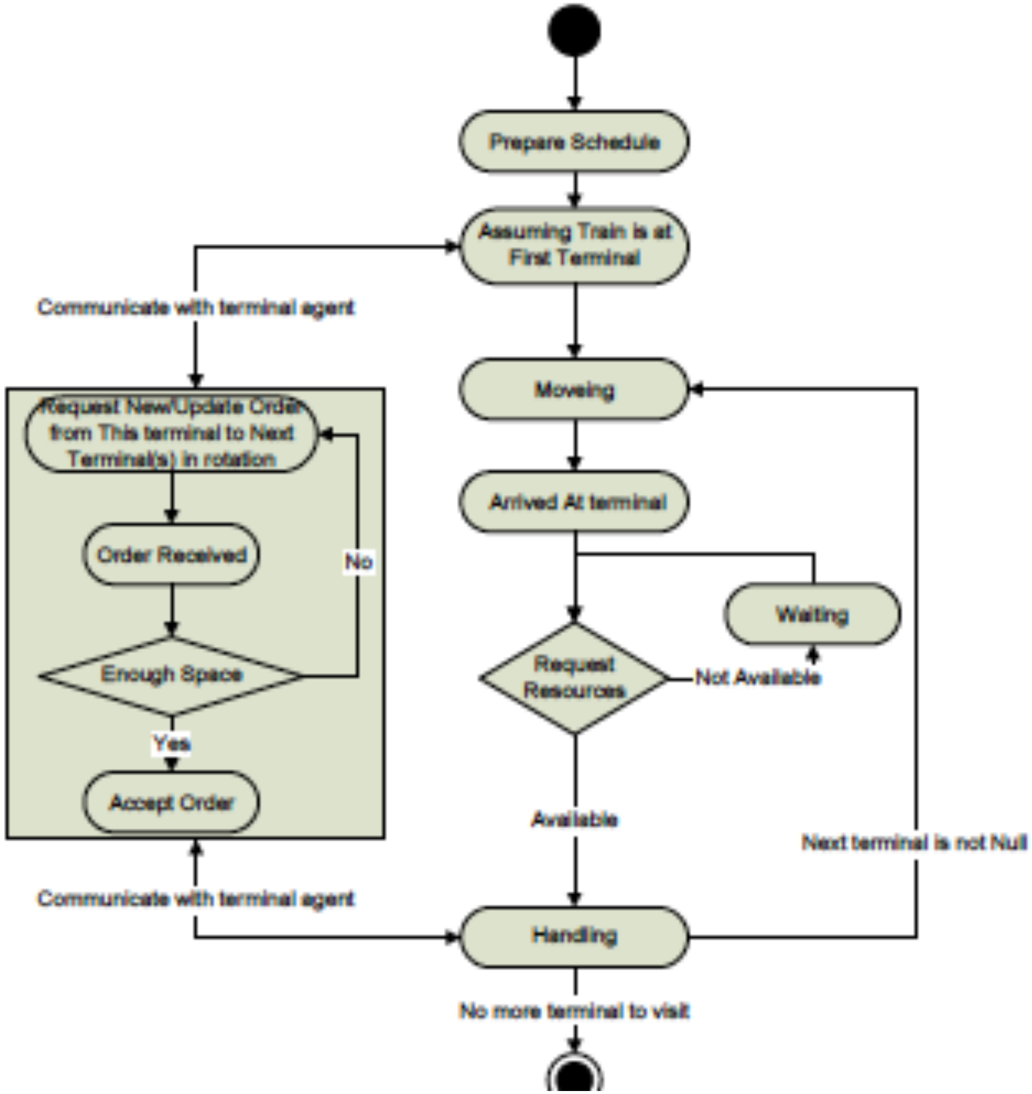
Transport Agents (Vehicles)

- Road Vehicle Agents
  1. Automated Guided Vehicle (AGV)
  2. Multi-trailer system (MTS)
  3. Truck
- Rail Agents
- Barge Agents

Road Vehicle Flow

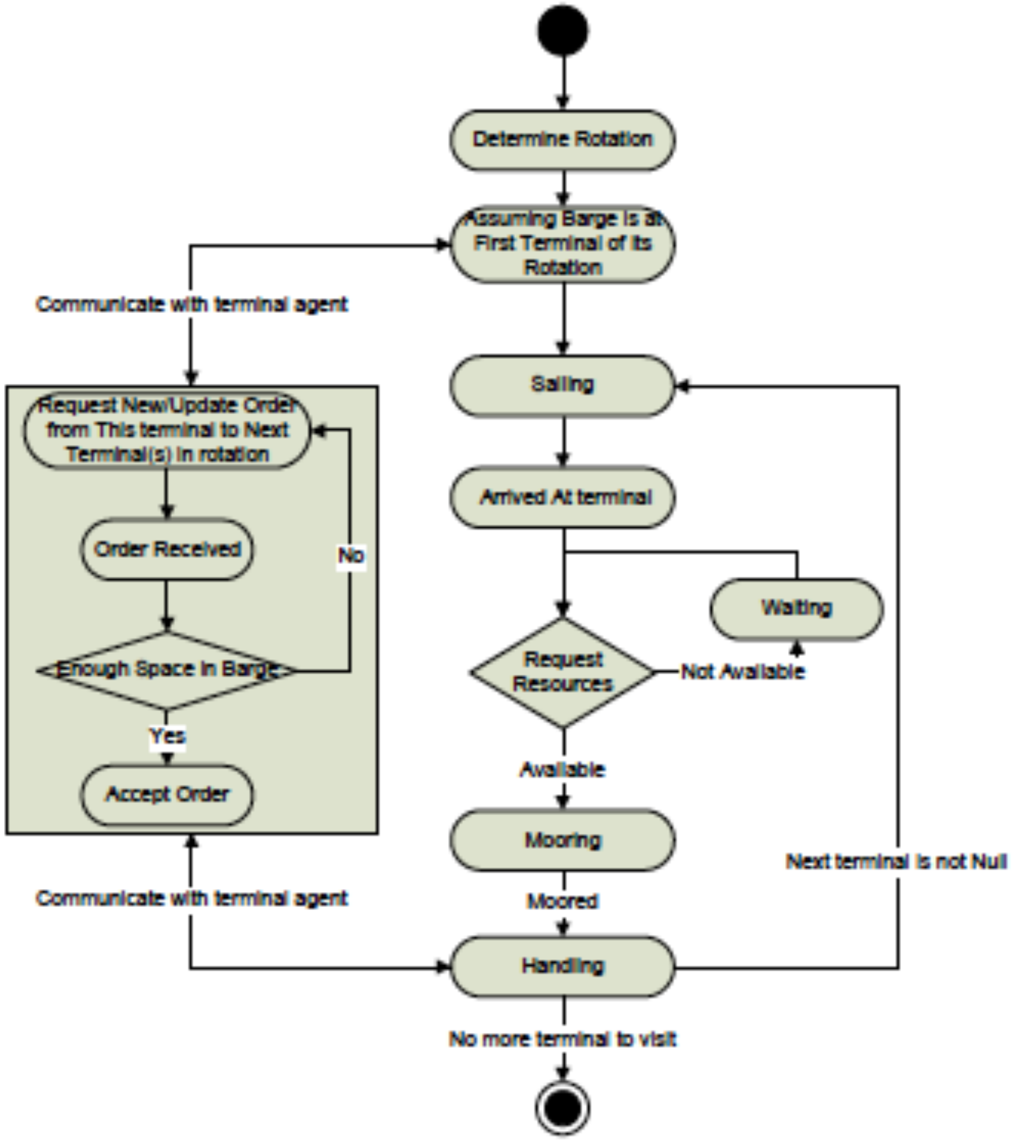


Train Flow



Prepare Schedule
Assuming Train is at First Terminal
Communicate with terminal agent
Request New/Update Order from This terminal to Next Terminal(s) in rotation
Order Received
No
Enough Space
Yes
Accept Order
Communicate with terminal agent
Moveing
Arrived At terminal
Waiting
Request Resources
Not Available
Available
Next terminal is not Null
Handling
No more terminal to visit

Barge Flow

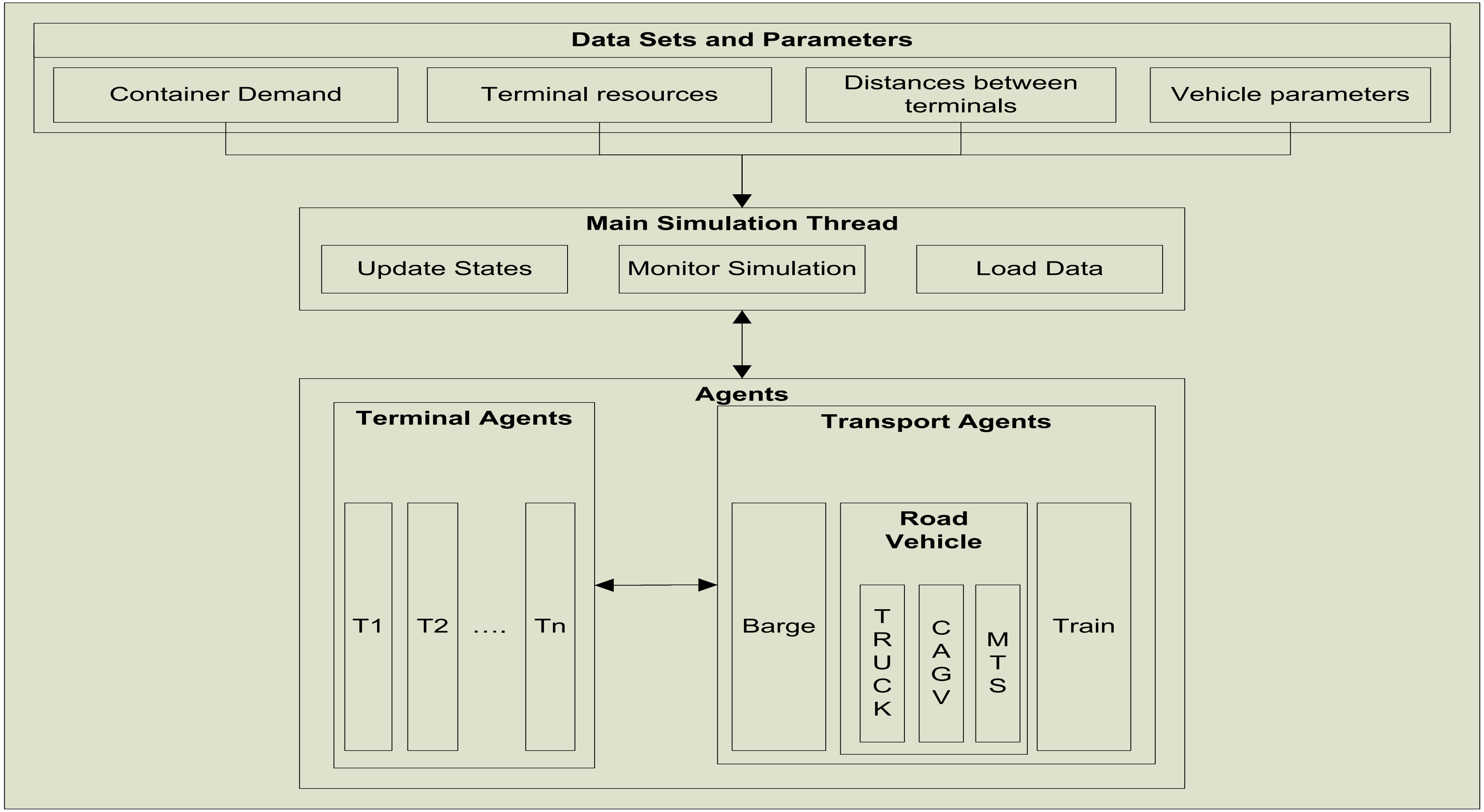


Determine Rotation
Assuming Barge is at First Terminal of its Rotation
Communicate with terminal agent
Request New/Update Order from This terminal to Next Terminal(s) in rotation
Order Received
No
Enough Space in Barge
Yes
Accept Order
Communicate with terminal agent
Sailing
Arrived At terminal
Waiting
Request Resources
Not Available
Available
Mooring
Moored
Handling
Next terminal is not Null
No more terminal to visit

Tool Selection

AnyLogic and NetLogo Comparison		
	AnyLogic	**NetLogo**
Programming Language	Java	Scripting
Programming Paradigm	Object Oriented	Procedural
3D animation	Yes (Powerful)	Yes (Limited)
Drag and Drop Components	Yes	NO
Data Analysis	Yes (Powerful)	Yes (Limited)
Data Import/ Export	Easy and several methods	Limited (Text Files Only)
Model Export	Java Applet (Paid Version)	Java Applet (Third Party)
Developer Guide	Yes	Yes
Help	Training videos, Paid training sessions, Descriptive Documentation	Online Social media Community

Structure of Simulation



Container volume demand / flow

Weekly ITT Volume (in TEU) Distribution for Scenario 3											
	RWG	**APMTMII**	**ETR**	**RCT**	**APMTR**	**DCS**	**ECTDT**	**ECTD-BFT**	**VDCD**	**KDD**	**Total**
RWG	0	1048	16348	743	220	22	20	4467	3720	5054	**31640**
APMTMII		0	3063	1404	41	4	0	840	701	952	**7008**
ETR			0	2179	644	64	58	13106	10915	14829	**41795**
RCT				0	29	0	0	1536	496	674	**2741**
APMTR					0	0	0	176	147	199	**524**
DCS						0	0	18	15	20	**52**
ECTDT							0	16	13	18	**47**
ECTD-BFT								0	2987	4057	**7044**
VDCD									0	3379	**3379**
Total											**94231**

Experiment Setup

Transport Settings			
Mode/ Vehicles	**Maximum Capacity (TEU)**	**Average Speed (m/s)**	**# of Vehicles**
AGV	4 (Double Stacking)	6	Variable
MTS	10	6	Variable
Truck	2	6	Variable
Train	70	20	6
Barge	50	3	6

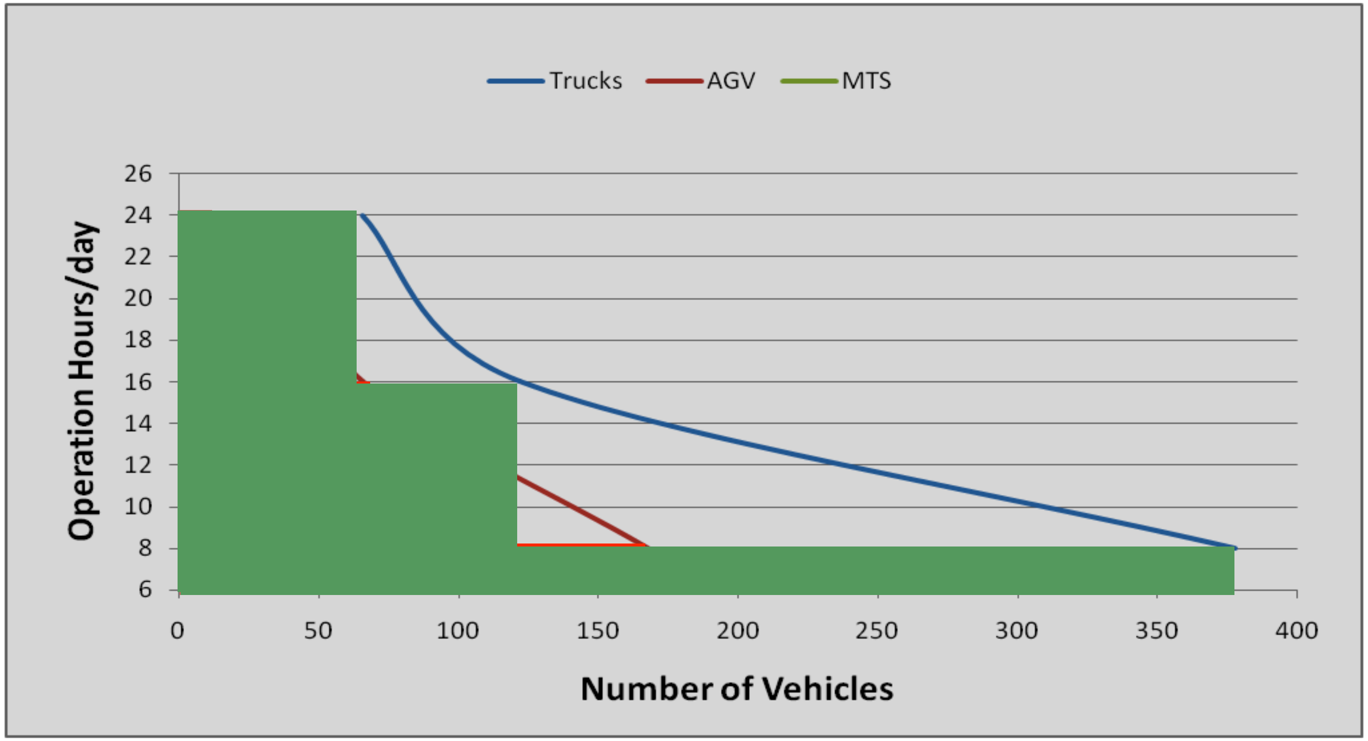
Experiment Setup

Terminal Settings						
Terminal Name	Gate		Barge		Train Terminal	
	Cranes	Loading/ unloading Time per Container (Minutes)	Cranes	Loading/ unloading Time per Container (Minutes)	Capacity in terms of Trains	Train Change over Time (Minutes)
RWG	20	2	2	2	3	45
APMTII	8	2	2	2	3	45
ETR	25	2	2	2	3	45
RCT	7	2	2	2	3	45
APMTR	5	2	2	2	3	45
DCS	5	2	2	2	0	NA
ECTDT	5	2	2	2	3	45
ECT-BFT	20	2	2	2	3	45
VDCD	10	2	0	NA	0	NA
KDD	20	2	2	2	0	NA

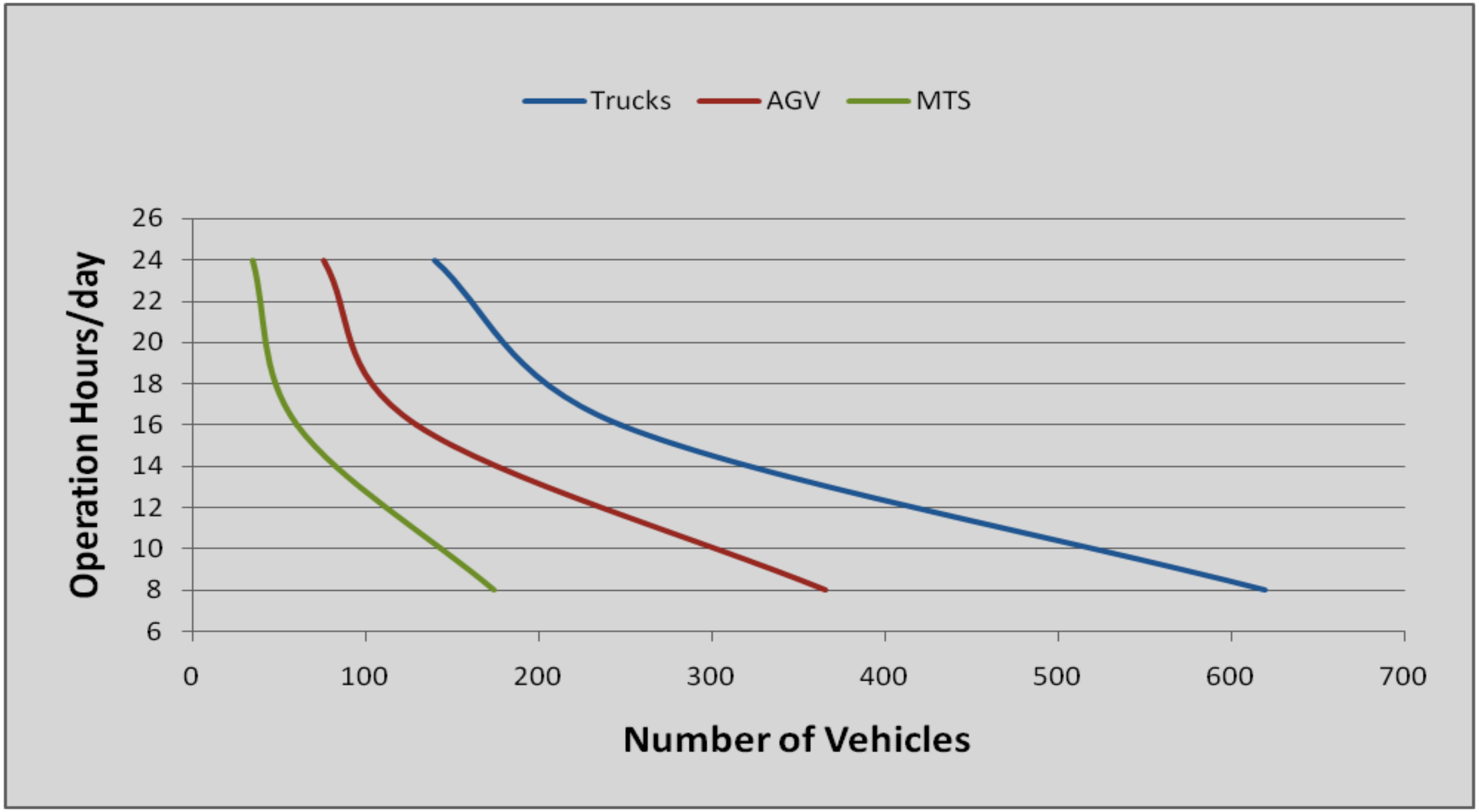
Summarizing all scenarios

Road Vehicles Required for All Scenarios				
		Operational Hours/week		
Scenario Name	Road Vehicles	56	112	168
Scenario 1	Trucks	378	122	66
	AGV	168	66	30
	MTS	93	29	14
Scenario 2	Trucks	620	248	140
	AGV	366	130	76
	MTS	174	61	35
Scenario 3	Trucks	1221	407	236
	AGV	622	212	126
	MTS	276	99	60

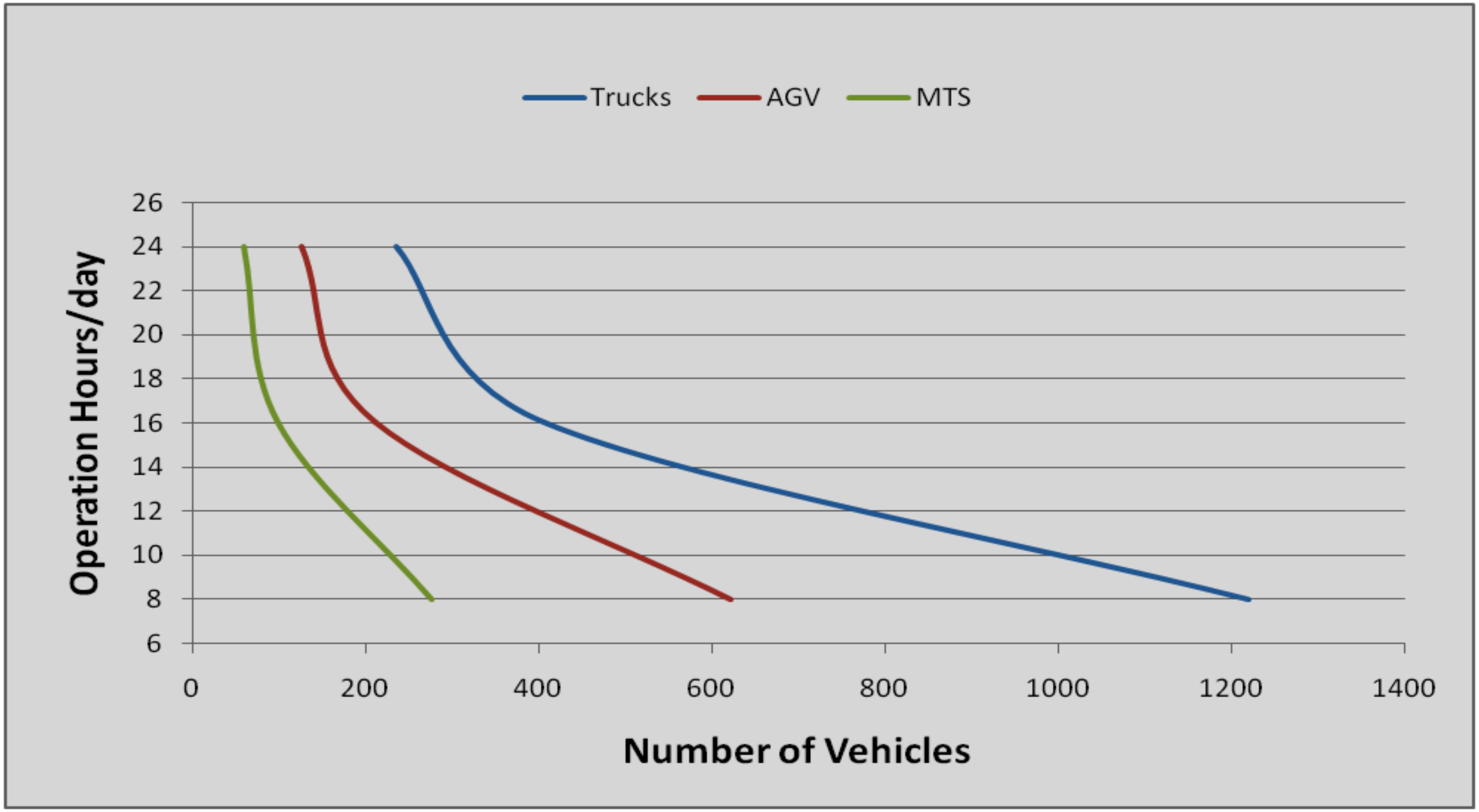
Summarizing Scenario 1



Summarizing Scenario 2



Summarizing Scenario 3



Strengths & Weaknesses

Simulation Model

- Did not change more than one variable at a time during simulations
- Validation and verification functions
- Model does not perform as good as required for barges and trains in 56 hours/week scenario
- One scenario shows unexpected service time for AGVs

Concluding remarks

- Designed and implemented ITT model to help ITT planners in planning and estimation
- Explored different combinations of transport vehicles for different scenarios
- Discussed utilization of terminal resources

Future Work

- Model can be improved by working on its current limitations
- Model can be evaluated with variable number of barges and trains
- Model can be extended to consider Intra-terminal operations
- Additional automated vehicles to be considered, i.e., Automated lifting vehicles or Automated Multi-trailer System,

Thank you

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