



# Gate congestion in container ports: causes and solutions

## — Optimizing Time Windows for Managing Truck Arrivals

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## Truck Congestion/Emission

### Causes

- Ever-increasing demand
- Limited supply of port capacity
- Fluctuation of truck arrivals

### Impacts

- Air pollution
- Limits terminal capacity and trucks'
- Safety
- Noise





## Existing solutions

### *In Europe and U.S.*

1. Terminal Gate Appointment System
2. Extended Gate Hours (Pier Pass)
3. Warehouse Hours
4. Chassis Exchange Terminal
5. Clean Truck Fee Policy
6. Visual Container Yard



## 1. Terminal Appointment System

### What is it?

- Appointment for truck entry
- Primarily for import containers
- Grounded operations
- Number of entries under control

- Fines the terminal \$250 for each truck idling 30 minutes in queue
- Waives if terminal either extends gate hours or uses appointment system

### When and where

Vancouver, 1999

LA/LB, 2003 (due to AB 2650)

Stated purpose: reduce vehicle emissions

Intended purpose: extend gate hours

### What happened?

LA/LB: delivered few benefits then be phased out

Vancouver: more successful

### Lessons

The biggest problem is Not technical but rather *human reluctance*

Commitment with terminal operators is important

## 2. Pier Pass

### **Another effort to extend terminal gate hours**

An industry response to legislative pressure

### **Provisions (Started July 2005)**

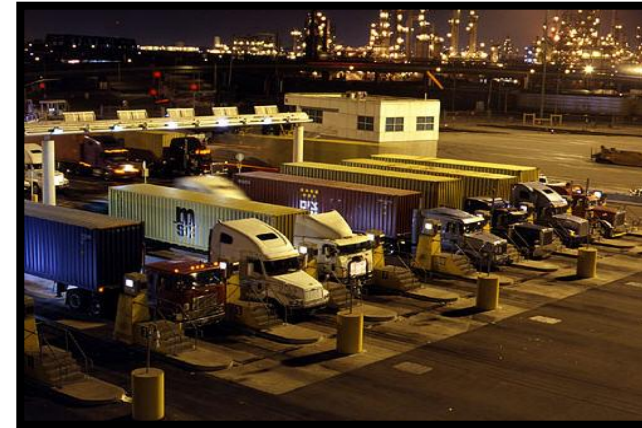
- Peak hours = M-F 3AM – 6 PM
- Fee of \$40/TEU for all road cargo entering/exiting during peak hours
- Net revenues allocated to terminals to offset costs

### **What happened in LA/LB in 2006**

- 40%-45% loaded trips moving OffPeak
- 60% of drivers have positive opinion, while 30% have negative.
- 67% of derivers see less congestion, 45% can do more trips per shift.

## 3. Warehouse Hours Coordination

To allow truckers to load and unload their containers during nights and weekends, coordination with warehouse hours is needed.





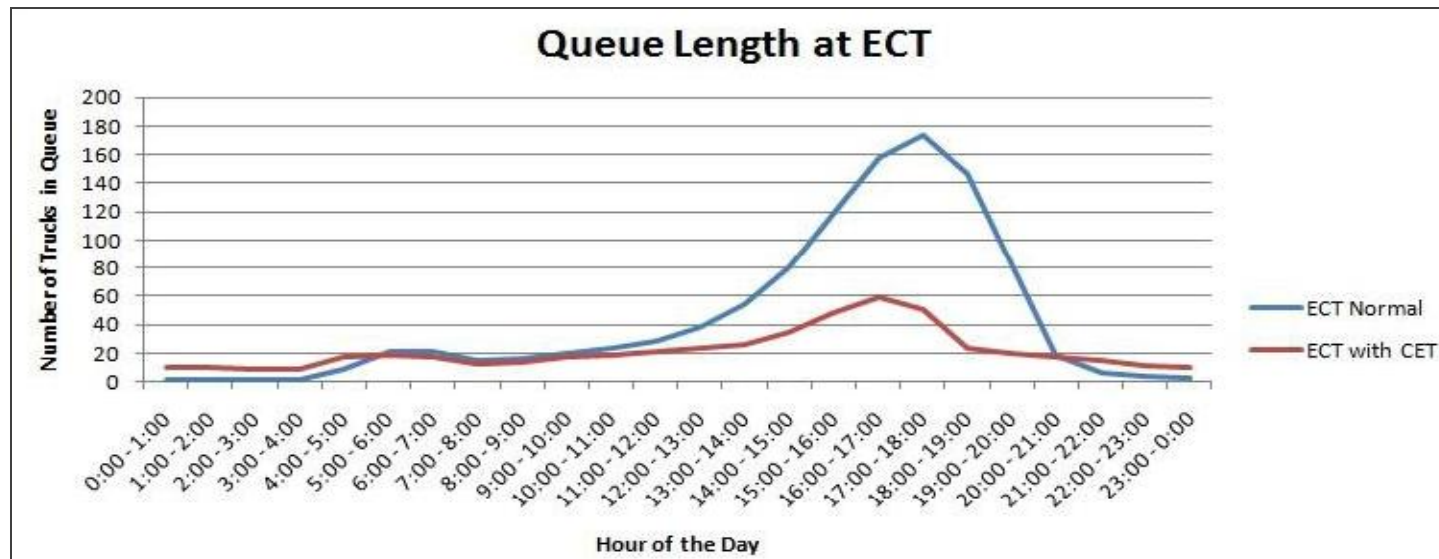
## 4. Chassis Exchange Terminal (Chassis Pool)

### How it works?

- Containers are ready on chassis
- Truckers switch chassis instead of containers
- Dropped containers are moved into the terminals at night.

### An research: proposing this idea for the ECT terminal in Rotterdam

- 12,000 truck trips a week
- 1,200 places for chassis



Source: LOGMS 2010 conference paper – A Chassis Exchange Terminal to Reduce Truck Congestion At Container Terminals by Rommert Dekker, Sander van der Heide, and Eelco van Asperen

## 5. Clean Truck Program (since 2005, LA/LB)

### Provisions (Effective Oct 1, 2008)

- Old Trucks (1988 or older) are banned
- Trucks (1989-2006) to pay \$35/TEU
- New trucks (2007- ) are free to enter.

### What's the fee used for?

- Match with state bond money for the purchase of new trucks



## 6. Virtual Container Yards

### What is it?

- An internet service to match empty import container with local exporters

Figure 1.

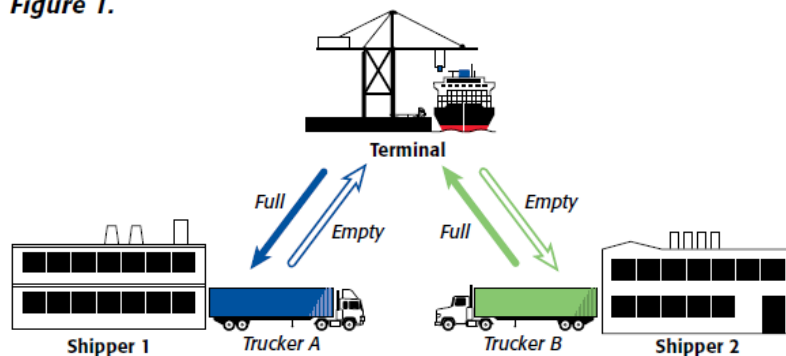
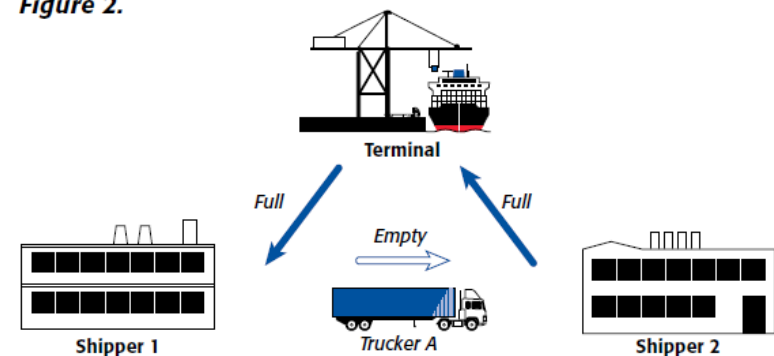


Figure 2.



## Existing solutions

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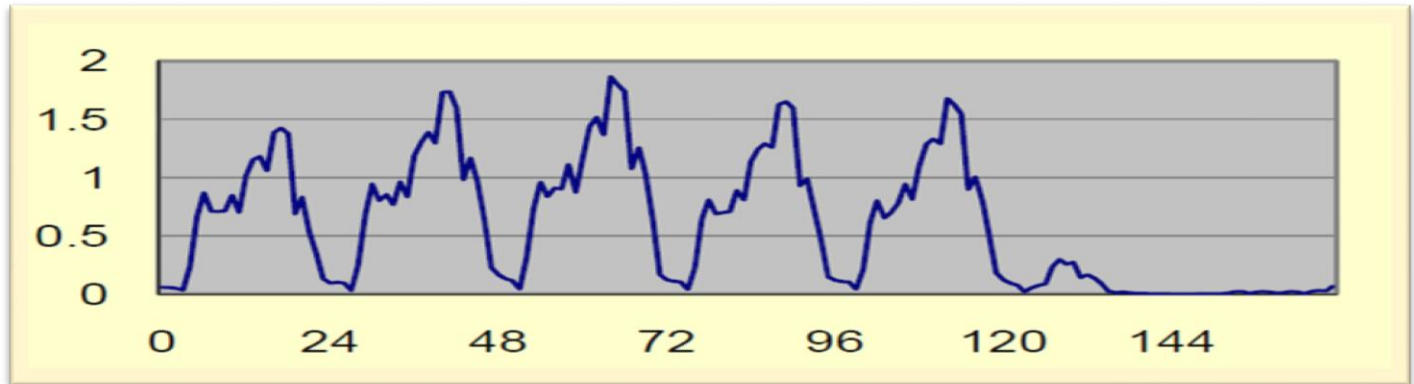
### *Transplant to the ports in China?*

*Where export is more than import and 24x7 service is already provided*



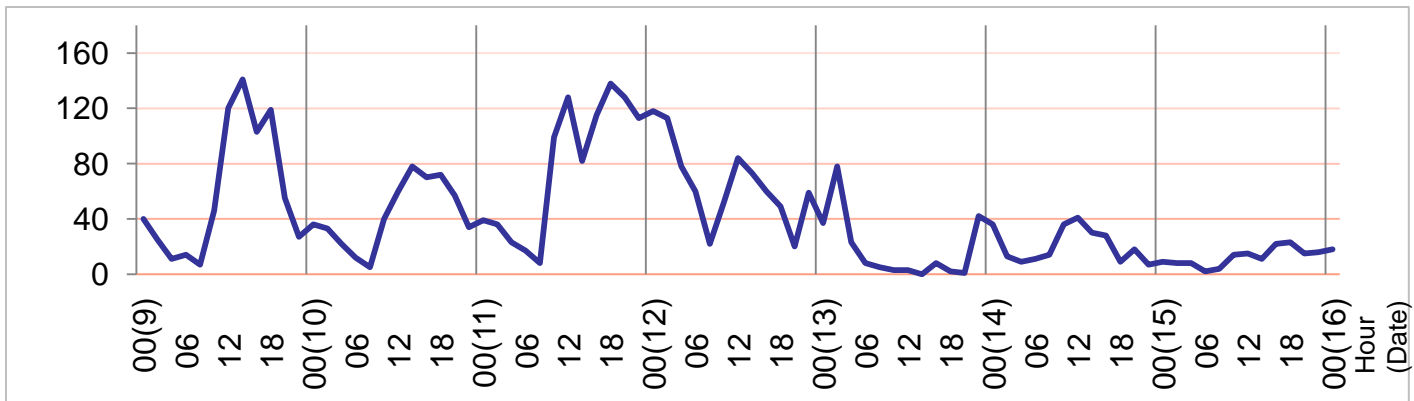
## Patterns of truck arrivals

A terminal in Rotterdam



Source: Voogd, P., Dekker, R., & Meersmans, P. J. M. (1999). *Famas-NewCon: A generator program for stacking in the reference case No. EI-9943/A* Erasmus University Rotterdam, Econometric Institute.

A terminal in Tianjin





## Research Questions

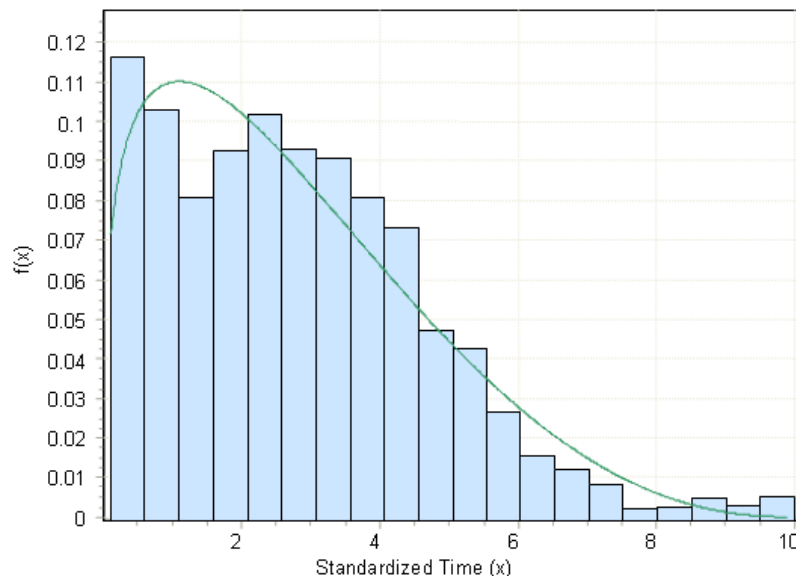
To find a new solution:

- 1. What is the pattern of the truck traffic demand?**
2. How to manage the truck traffic demand?
3. Strategies of the solution, from the practical perspective
4. How to integrate the solution into the whole terminal system?

## 1. Truck arrivals at Chinese terminals

*Time windows* are used to control container drop-offs;

Truck arrivals within a time window follow: ***Beta (1.29, 3.25)***



- 40% trucks will arrive within the first 20% of the time window;
- 85% trucks will arrive within the first half of the time window.

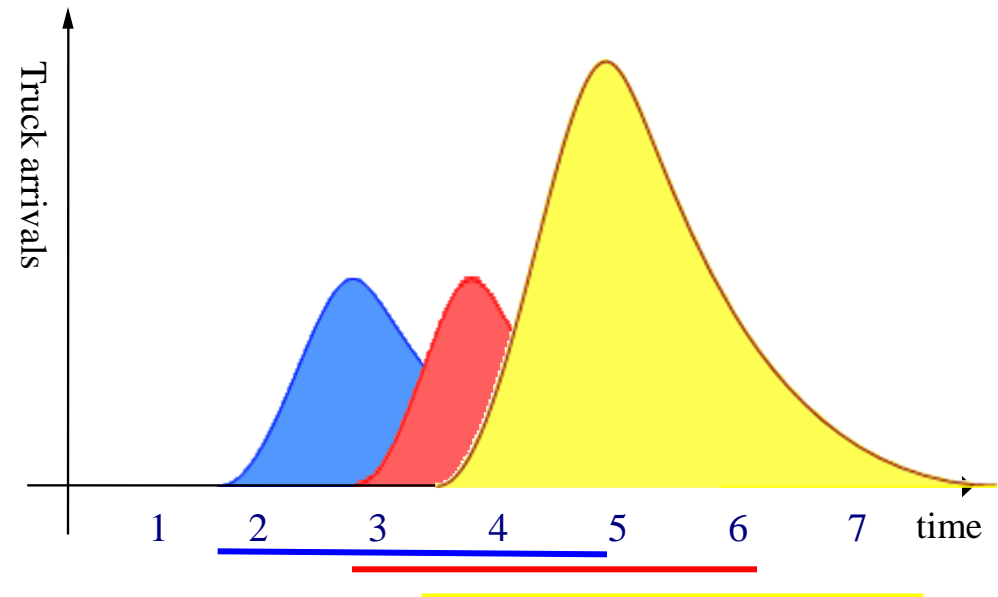


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To find a new solution:

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- 2. How to manage the truck traffic demand?**
3. How to manage the truck traffic demand? From the *practical perspective*
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## 2.1 Adjust time windows to control truck arrivals



The questions are:

- ❖ Can it reduce the congestion and the cost?
- ❖ Does a terminal operator have willingness?



## 2.2 The model

Objective: to minimize the cost of export container transport operations

$$\min TC = \sum_i \sum_t (WC_{it} + FC_{it} + SC_{it} + YC_{it})$$

Subject to

$$\sum_t a_{it} = V_i$$

$$T_i^E \leq ETA_i$$

$$T_i^E - T_i^S \geq 6$$

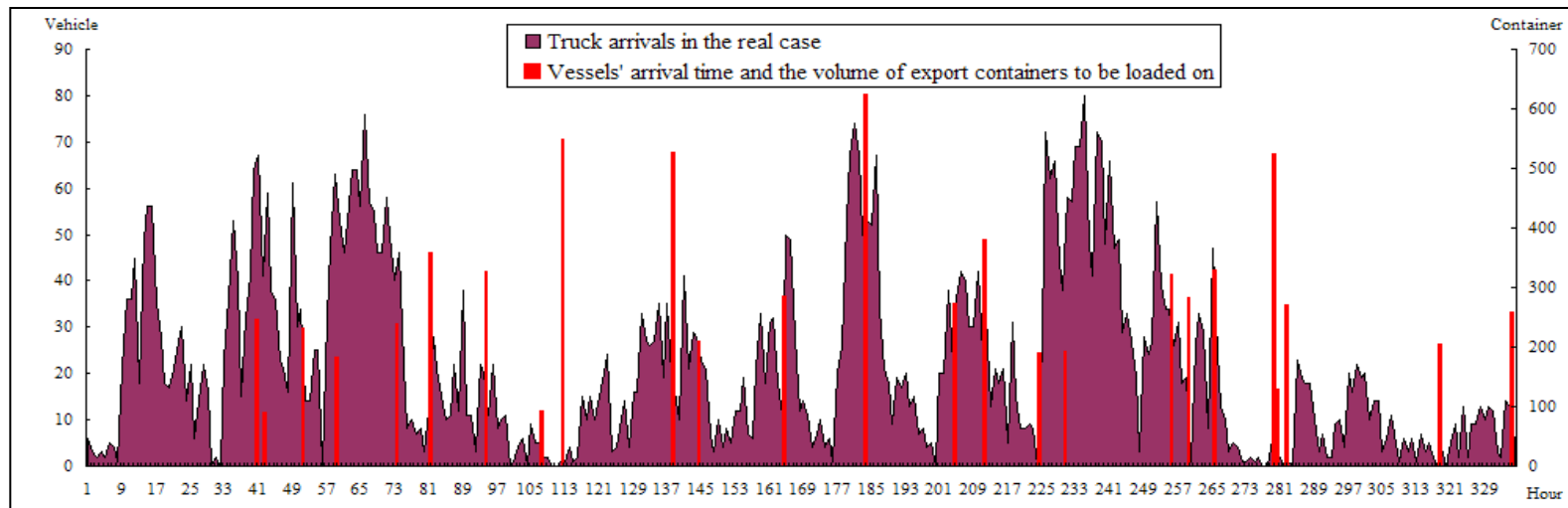
Fuel consumption of trucks' idling

Yard fee for containers

Waiting time of trucks and drivers

Storage time value of container cargos

## 2.3 The case study – Data



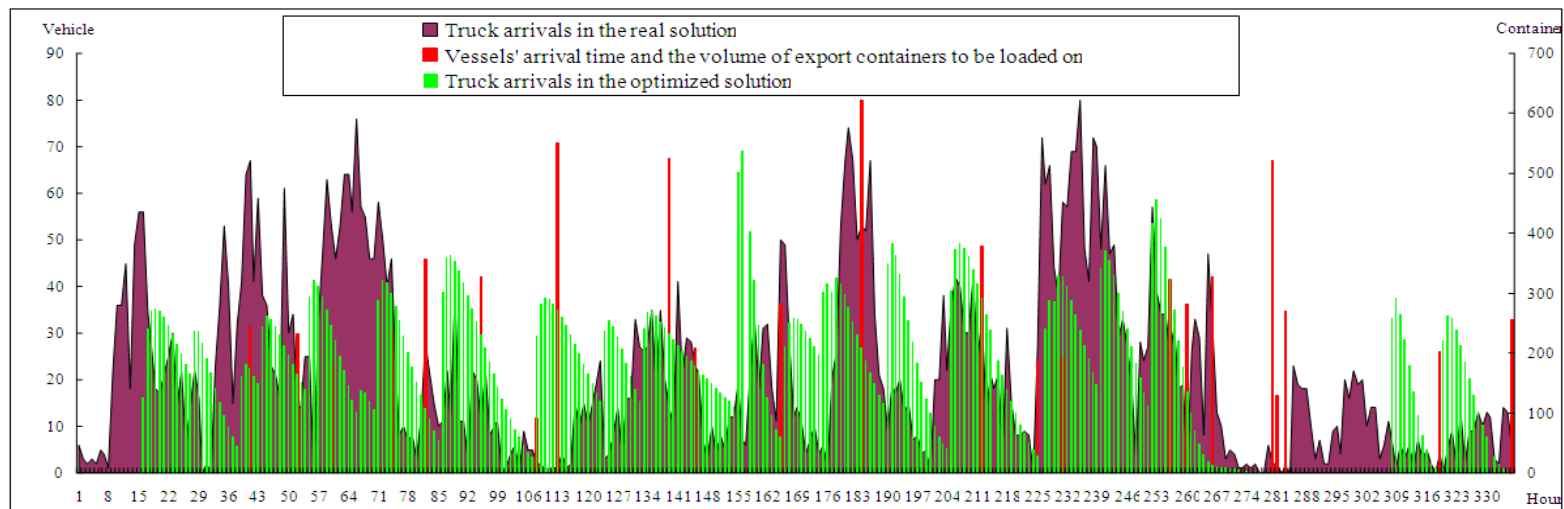
## 2.4 The case study – Result

Comparison 1: shorter time windows and less overlaps

Comparison 2: reduced total cost and queue length

	Real solution	Optimized solution
Total cost (RMB 1,000)	1,854	667
Average truck waiting time (min)	106	9
Maximum queue length (vehicle)	336	62
Average container storage time (hour)	32	18

Comparison 3: peaks flatten down

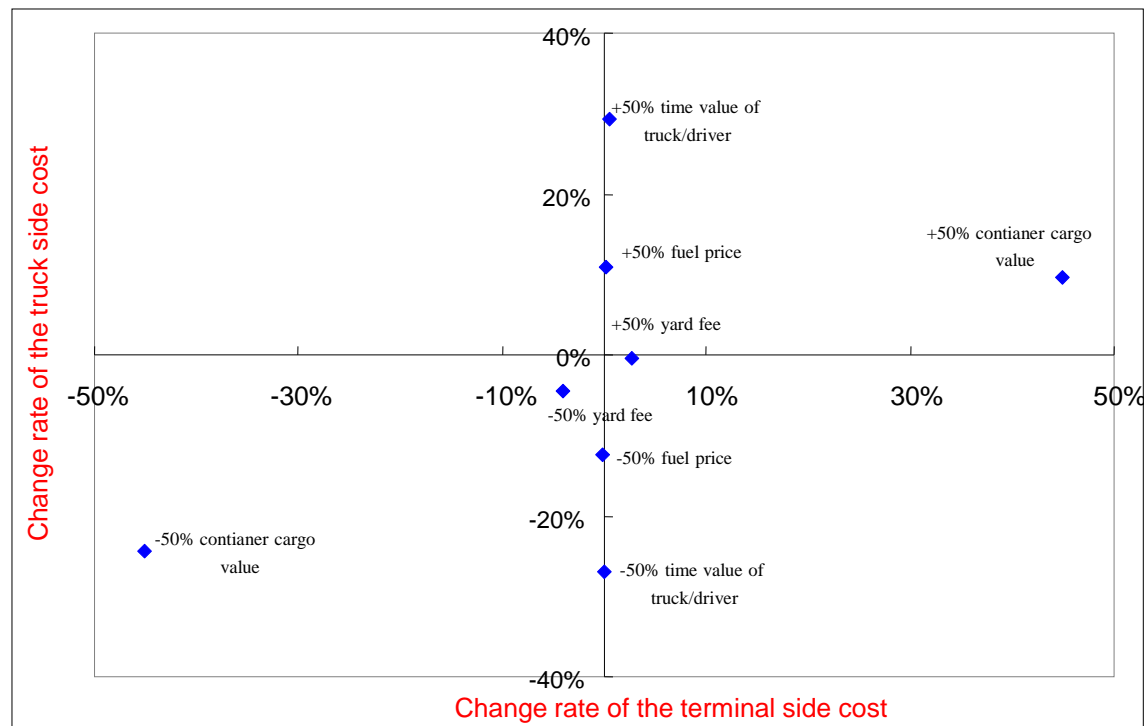


## 2.5 The case study – Terminal operators’ willingness

Eight scenarios (each cost factor increases/decreases 50% respectively)

**Truck-side Cost** = Costs of Truck/Driver Waiting Time + Diesel Idling Consumption

**Terminal-side Cost** = Costs of Container Cargo Storage Time + Yard Fee



- ❖ Result: Terminals don't need to drop their own benefit to compensate trucks' lose.



## Research Questions

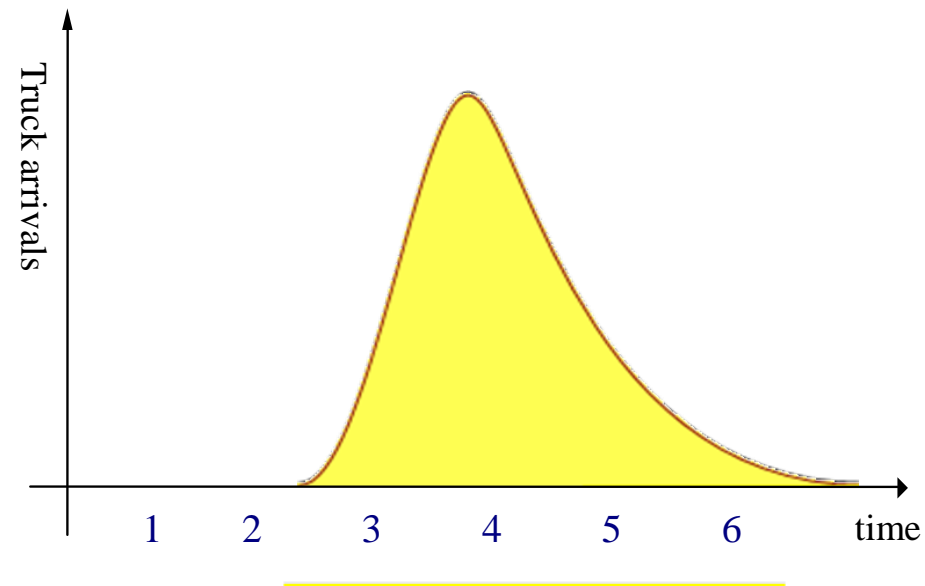
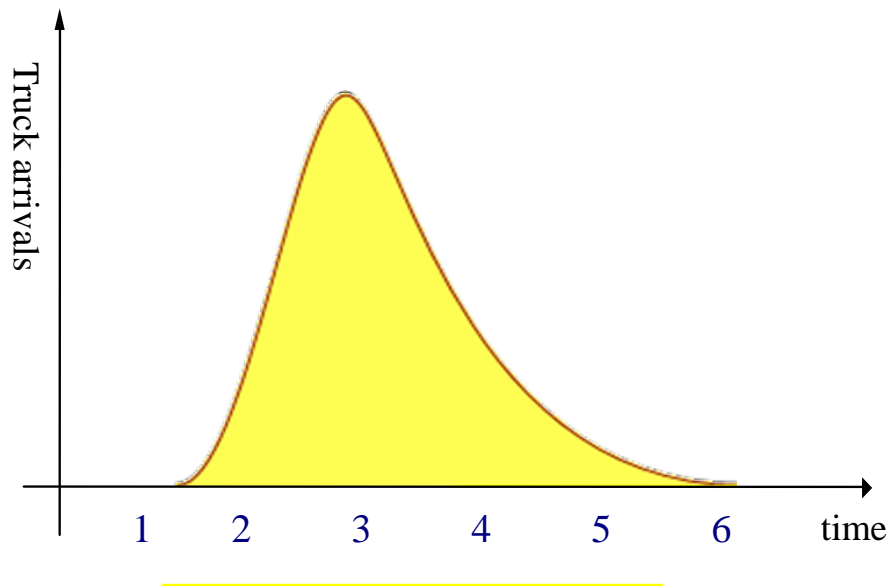
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### 3.1 Vessel-dependent time window method

Three strategies: GRA *VS* VEP *VS* FEP

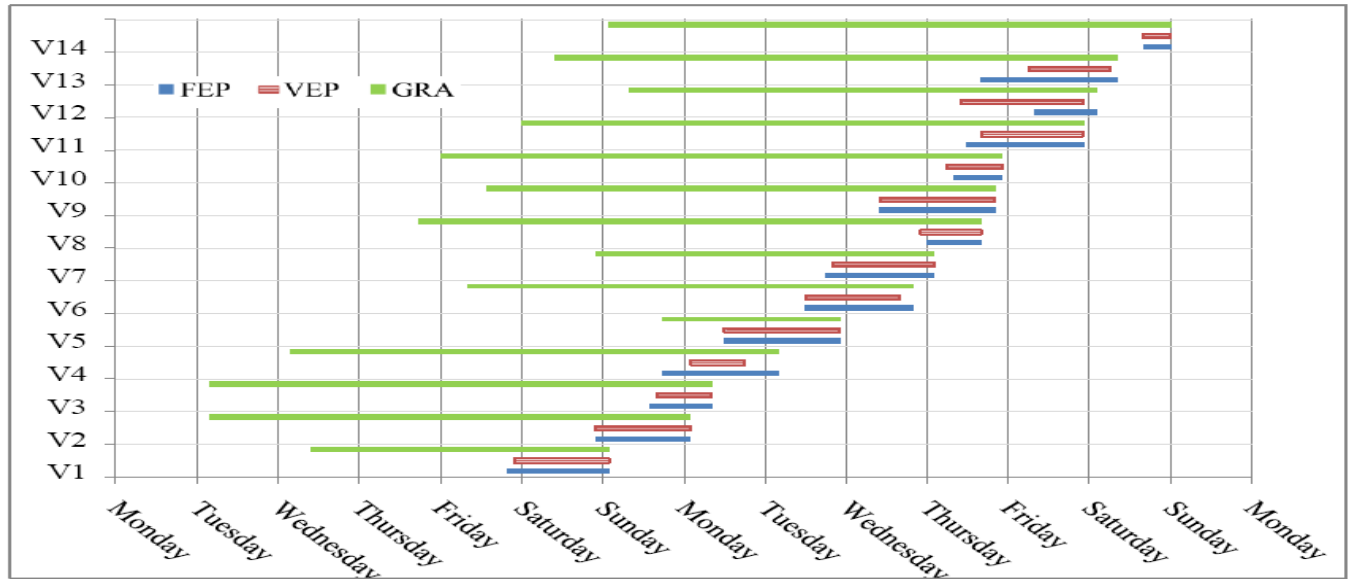
- ❖ GRA– Greedy algorithm strategy (as long as possible)
- ❖ VEP– variable end-point time windows
- ❖ FEP – fixed end-point time windows



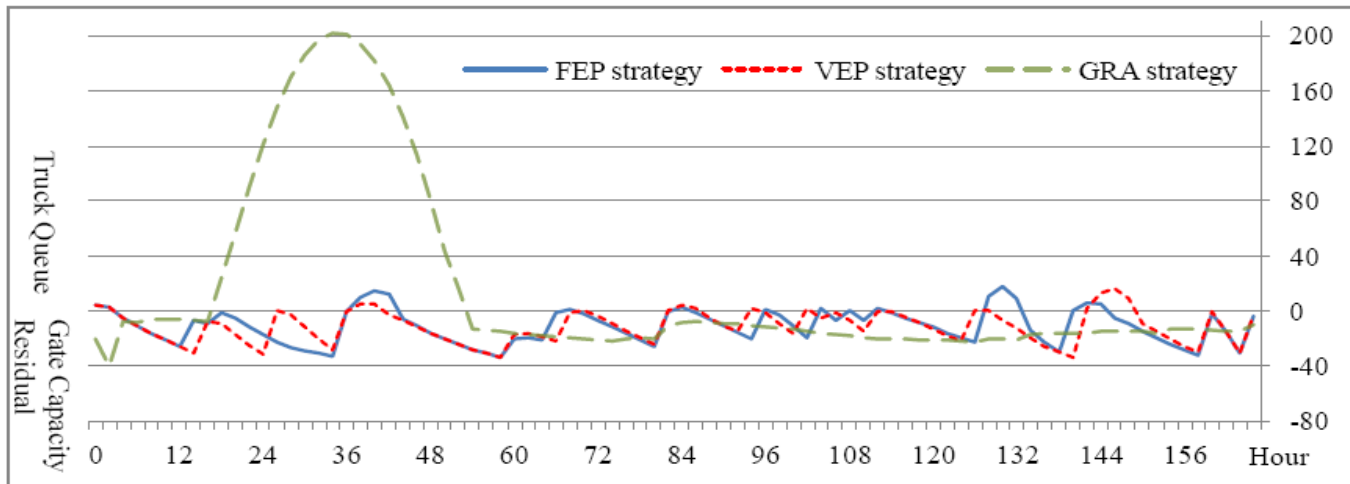


### 3.2 The case study

#### Time windows



#### Queue length





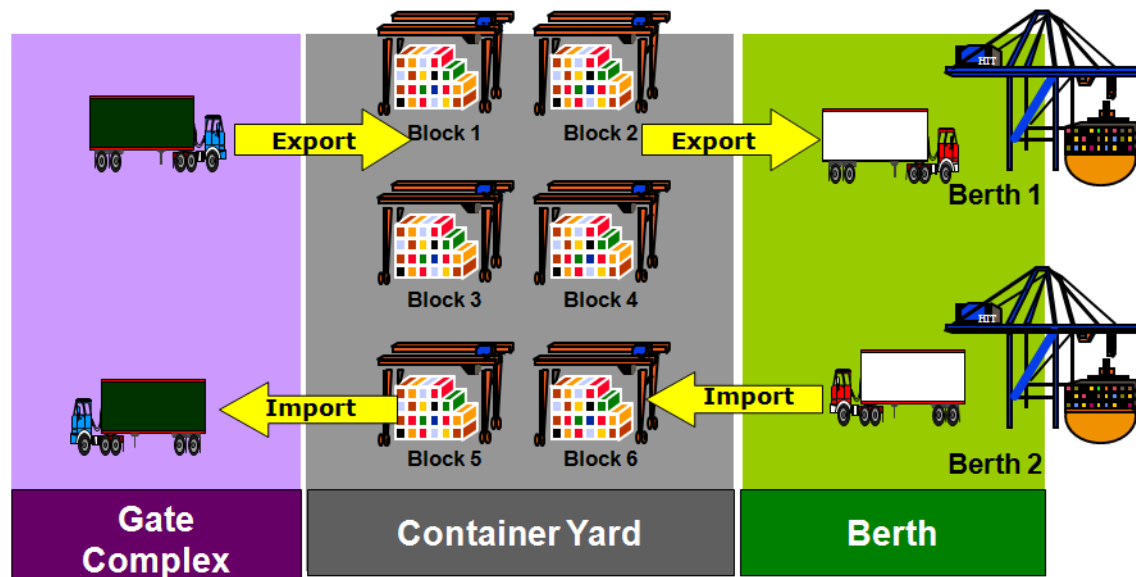
## Research Questions

To find a new solution:

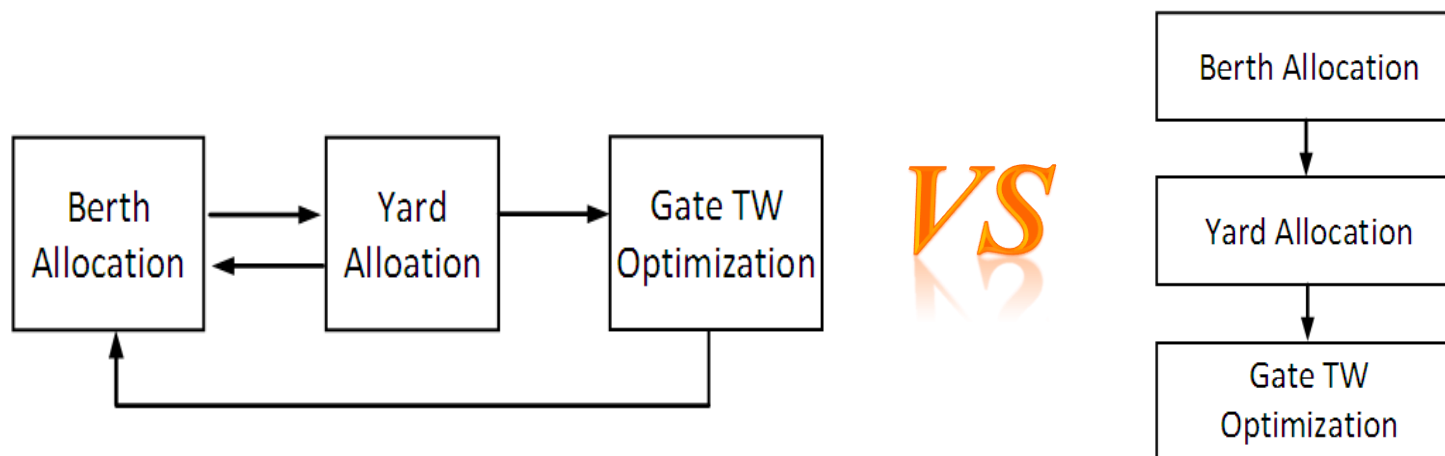
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*‘improved terminal performance cannot necessarily be obtained by solving isolated problems but by an integration of various operations connected to each other’ (Stahlbock & Voß, 2008, pp.33).*

## 4.1 How to integrate



Source of the picture: Katta G. Murty Industrial and Operations Engineering University of Michigan [www-personal.umich.edu/~murty/container1r.ppt](http://www-personal.umich.edu/~murty/container1r.ppt)



Integrated model structure

Top-down model structure



## 4.2 Finding

Trade-off between ship turn time and truck waiting time:

**3,200 truck-hours VS 2 ship-hours ?**

Yard( $\times 10^3$ ) \ Gate	Gate congestion				
	200	210	220	230	240
	Average truck waiting (h)				
30	2.9	0.9	0.5	0.3	0.2
32	2.9	0.9	0.5	0.3	0.2
34	1.1	0.5	0.3	<b>0.1</b>	0.1
36	<b>0.7</b>	0.6	0.2	0.1	0.1
38	<b>0.9</b>	<b>0.5</b>	0.2	0.1	0.1
40	0.9	0.6	0.2	0.1	0.1
42	0.9	0.6	0.2	0.1	0.1
44	0.9	0.6	0.2	0.1	0.1
46	0.9	0.6	0.2	0.1	0.1
48	0.9	0.6	0.2	0.1	0.1

Total ship turn time  
**195**  
**193**



## **Conclusions for the new solution**

- Truckers prefer to come early during a time window.
- Time window optimization can be used to reduce truck congestion.
- Terminal operators will be willing to accept.
- Fix end-point strategy (FEP) is a better choice.
- It is important to integrate the new solution with the other planning.



## **In order to reduce truck congestion/emission?**

Extend gate opening hours;

Manage truck arrivals by either appointment systems or time windows;

Encourage the usage of new trucks: set a fast lane at terminal gate for new vehicles, or charge for the old trucks;

Develop near-port truck parking areas with plug-in electrification technology to reduce idling emissions.



# Thanks for your attention!

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