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Green Scheduling of Container Terminals:

A new approach to enhance the sustainability of maritime shipping

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The OR Society Webinar
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Agenda

- Introduction to Green Scheduling
- The role of container terminals in maritime shipping
- Optimisation problems in container terminals
- The Green Yard Scheduler (GYS)
- Future research directions

Green Scheduling

- Classical scheduling focuses on performance- and/or cost-oriented objectives
- Green scheduling takes into account the environmental impact of operations as explicit objectives
- In most cases, involves conflicting objectives

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Green scheduling of a two-machine flowshop: Trade-off between makespan and energy consumption

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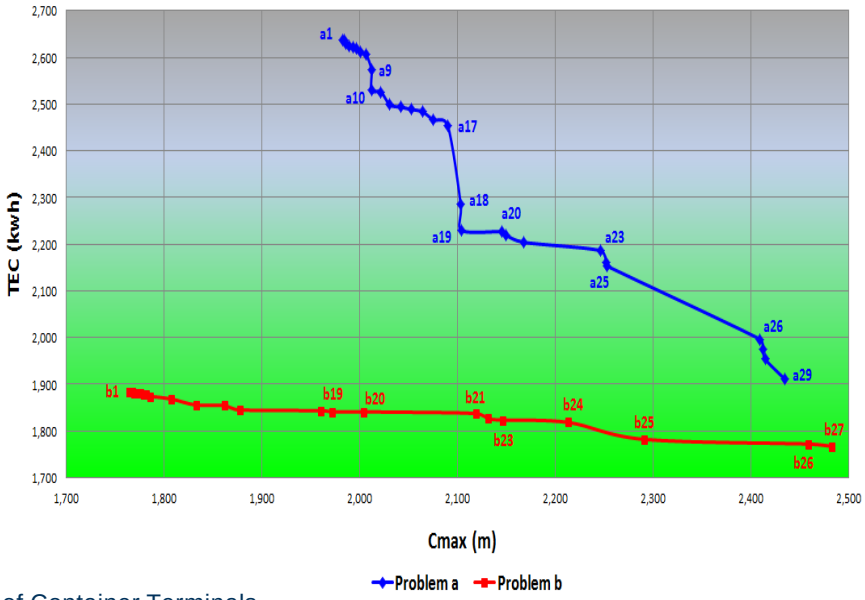
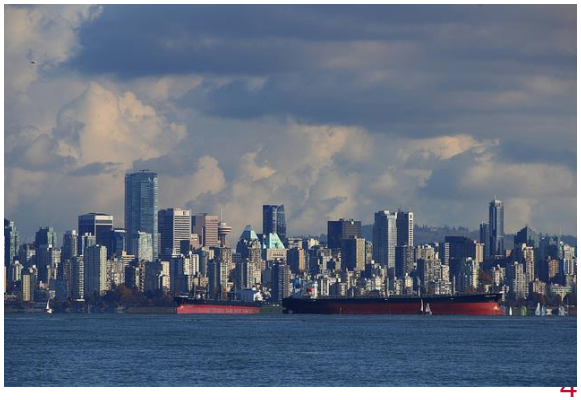


Maritime Shipping

- 80% of global trade is moved by sea transport
- Ports have environmental impacts (vessels, trucks, cranes)
- Container terminals handle over 60% of the cargo
- Involve complex operations with direct impact on the economy and the environment



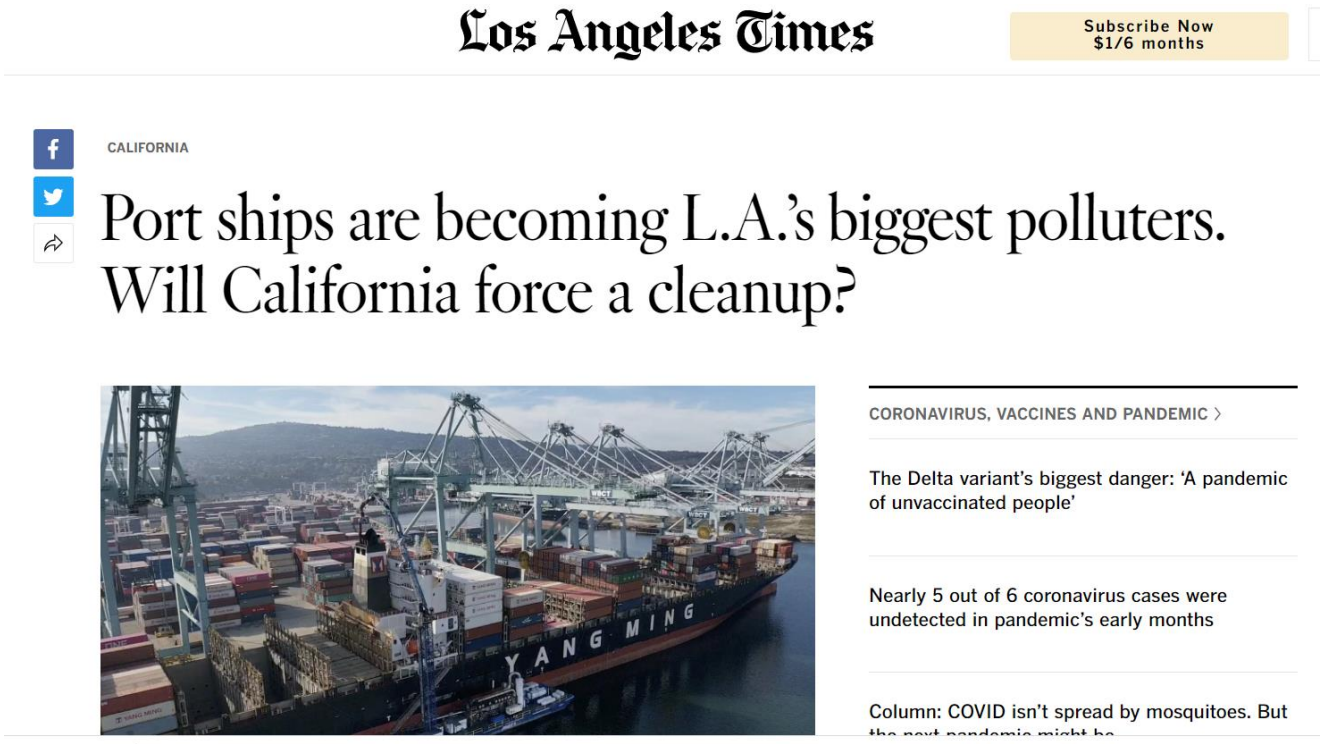
Container Vessels

10k-20k trucks!

~

The Port-City Relationship

- Ports are mostly integrated with cities:
  - Shanghai, Rotterdam, Vancouver, Los Angeles, Barcelona, Genoa, London, Southampton, Liverpool.



Los Angeles Times

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CALIFORNIA

Port ships are becoming L.A.'s biggest polluters. Will California force a cleanup?

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The Delta variant's biggest danger: 'A pandemic of unvaccinated people'

Nearly 5 out of 6 coronavirus cases were undetected in pandemic's early months

Column: COVID isn't spread by mosquitoes. But

PortForward Project: 2018-2022

PortForward

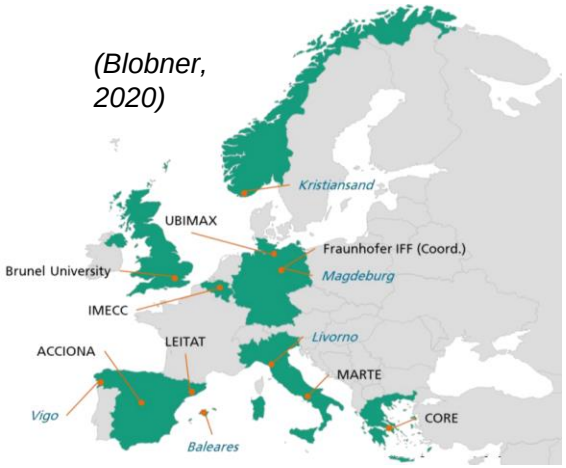
Main objectives

Smart Port Solutions: Employing ICT solutions to improve information flows between ports and port communities

Green Port Solutions: Adopting green technologies to reduce the environmental impacts of port operations and save resources

Interconnected Port Solutions: Combining different modes of transport integrating of different technologies to better monitor and control freight flows

https://www.portforward-project.eu

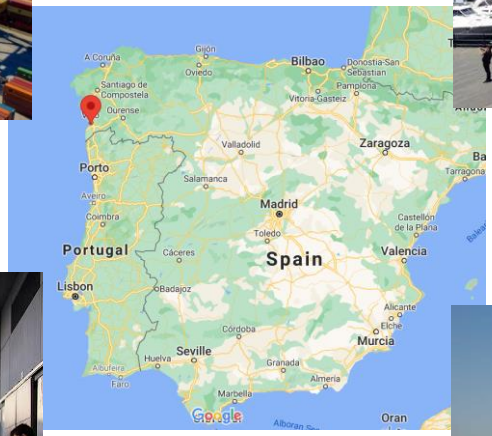


This project receives funding in the European Commission's Horizon 2020 Research Program under Grant Agreement Number 769267

Port of Vigo

Container terminal

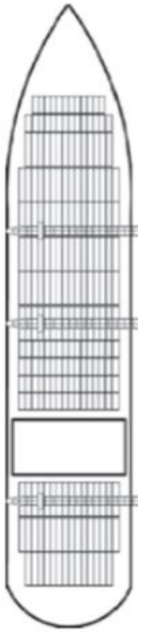
Cruise terminal



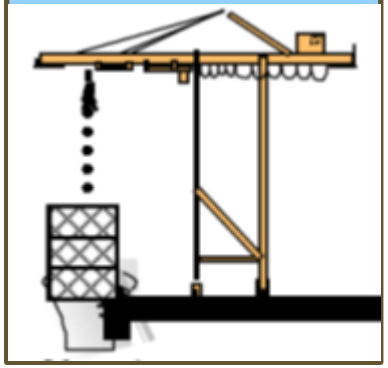
Fishing terminal

Ro-Ro terminal

Container Terminal Operations

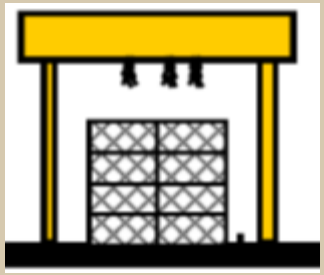


Berth
Vessel
Quay Crane
Yard Truck



Sea (Maritime) Side

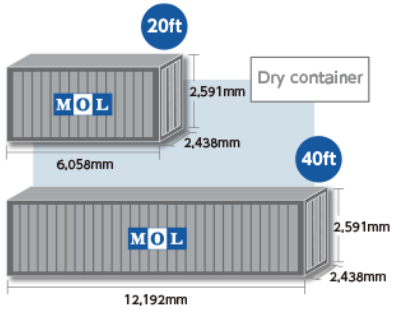
Storage Space
Yard Crane
Yard Truck
Drayage Truck



Land Side

Preliminary Sustainability Assessment

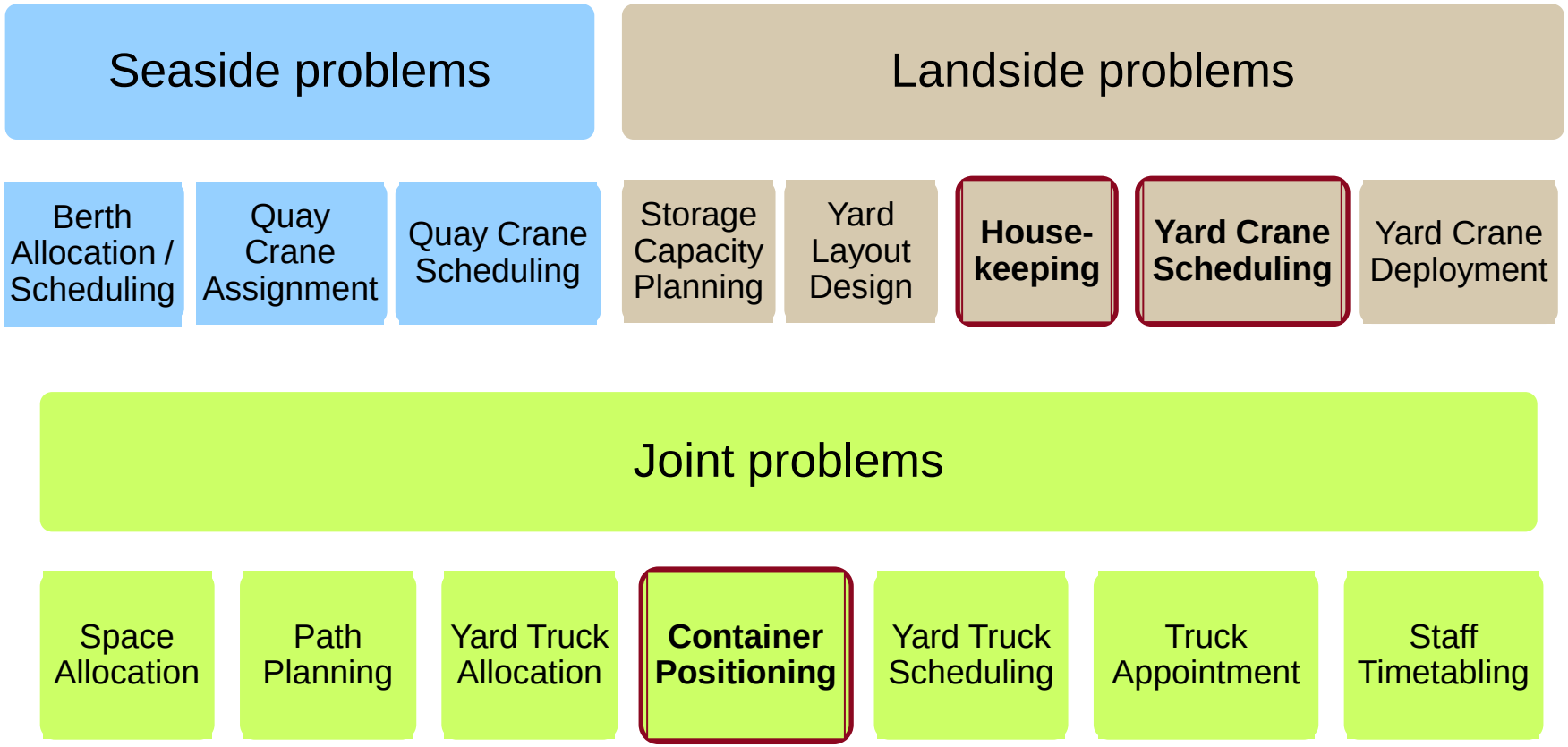
Unit of analysis: TEU (Twenty-foot Equivalent Unit)



Carbon footprint: 45.549 kg CO_2 eq. / TEU

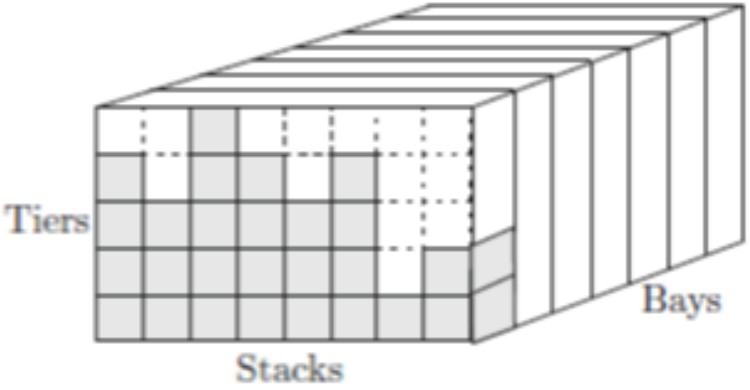
21.308 kg CO_2 eq.	14.161 kg CO_2 eq.	4.584 kg CO_2 eq.	4.048 kg CO_2 eq.	1.448 kg CO_2 eq.
47%	31%	10%	9%	3%

Container Terminal Decision Problems



Container Terminal Terminology

A container block (Caserta et al., 2011)



Container Terminal Terminology (contd.)

Rubber Tyred Gantry crane (RTG)

Reach stacker

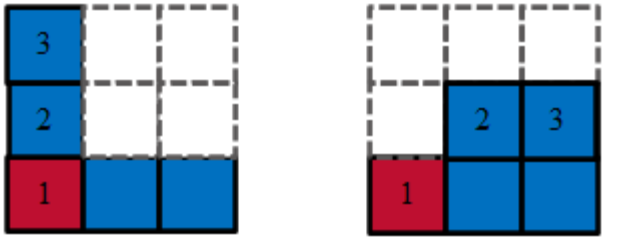
Internal Movement Vehicles (IMV)

External Truck

The Housekeeping Problem

- Determine the sequence of container movements in a bay area selected for pre-marshalling to eliminate any further reshuffles to reduce the vessels waiting time
- **Objectives (KPIs):**
  1) Minimise the number of container movements
  2) Minimise the estimated energy consumption of the RTGs
- **Output:** List of container movements

The Housekeeping Problem (contd.)

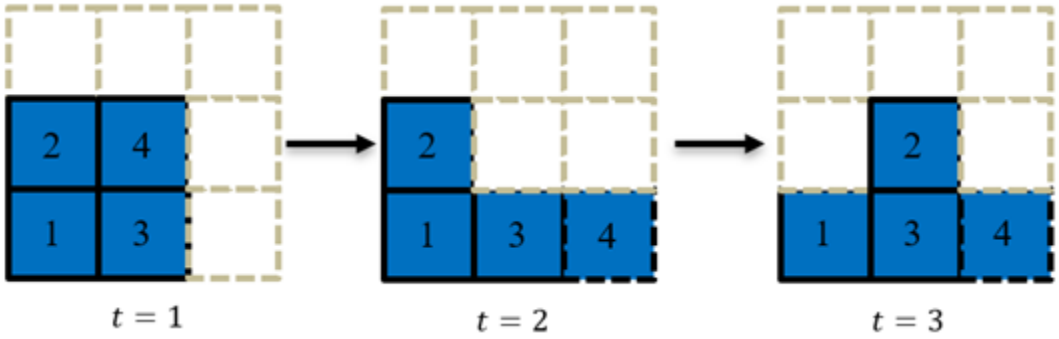


Example of a reshuffle

Ordering of a bay in two moves

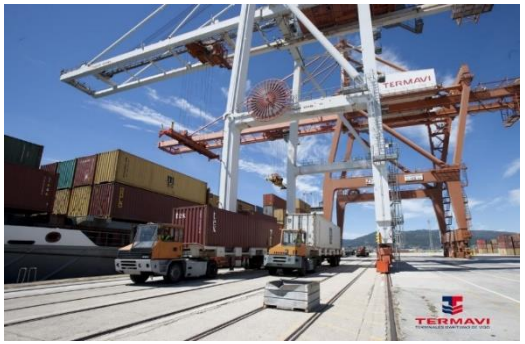
Formulation as a Mixed integer Programming (MIP) model

Y_{shkept}	**1 if a container of priority p is moved from stack s tier h to stack k tier e at time t , 0 otherwise**

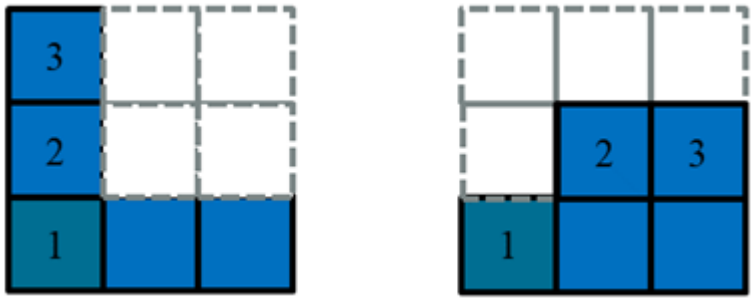


$$Y_{223141} = 1 \quad Y_{122222} = 1$$

Container Positioning Problem



- **Determine the slot allocations of:**
  - Import containers discharged from vessels
  - Containers coming back from inspection
  - Export containers arrived at the terminal gate
- **Objectives (KPIs):**
  1) Minimise the energy consumption of the internal and external trucks
  2) Minimise the number of future container reshuffles
- **Output:** List of new container operations with final slot positions



Example of a reshuffle