The Green Yard Scheduler:

An Innovative Solution to Enhance the Sustainability and Performance of Container Terminals

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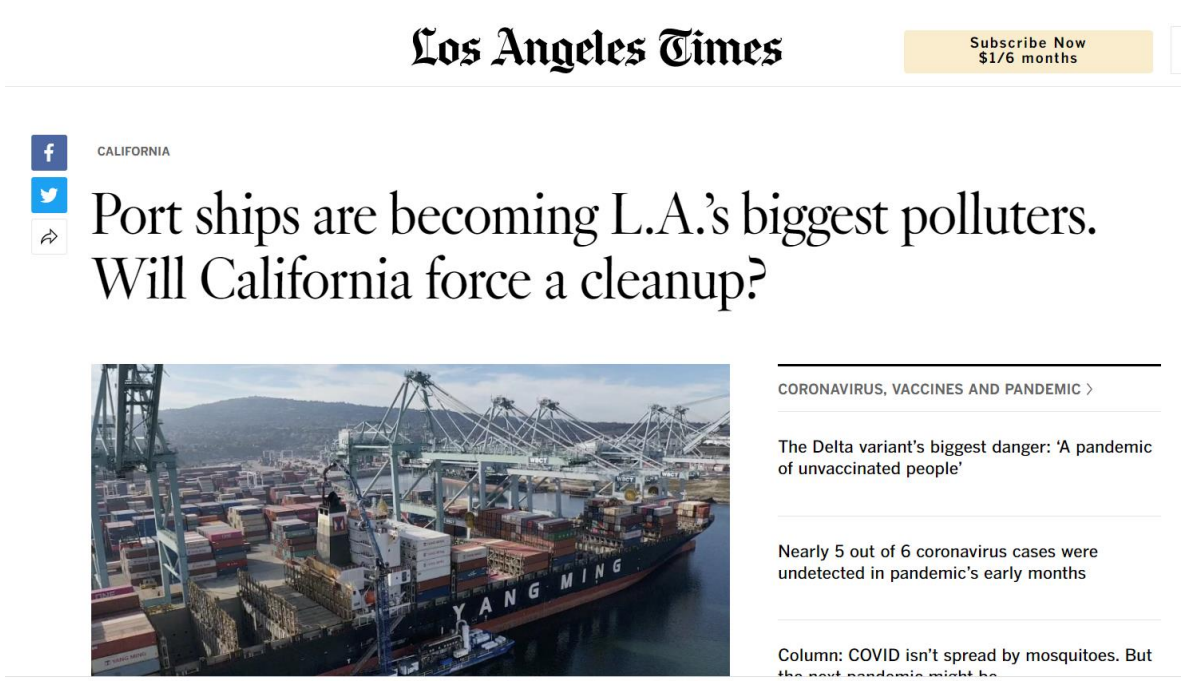
Green Energy Ports Conference
Port of Vigo, Spain
22-23 September 2021

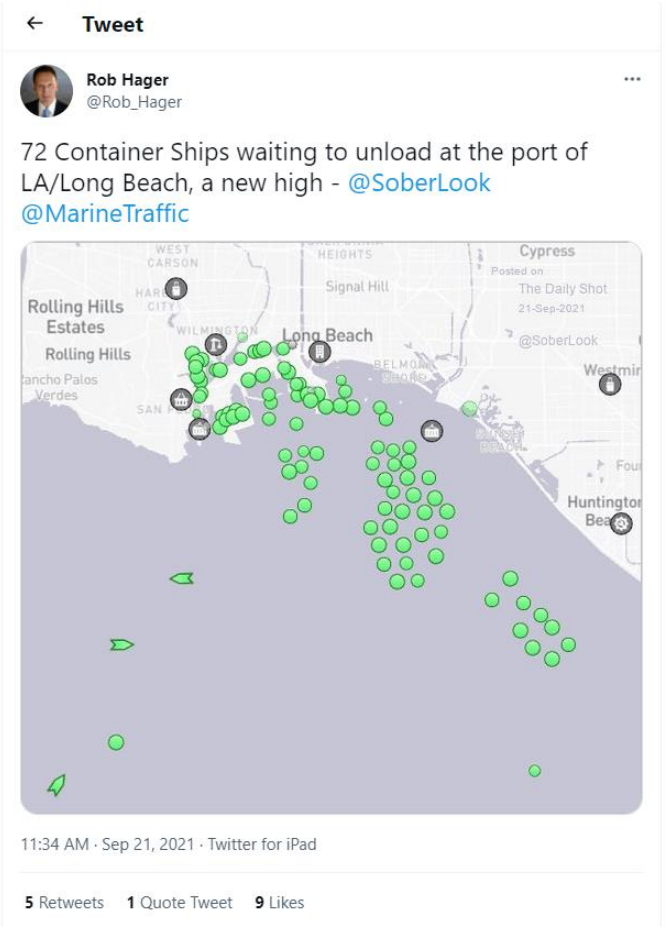
Maritime Shipping

- 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

The Port-City Relationship

- Ports are mostly integrated with cities, such as Shanghai, Rotterdam, Vancouver, Barcelona, Genoa, London, and Los Angeles:

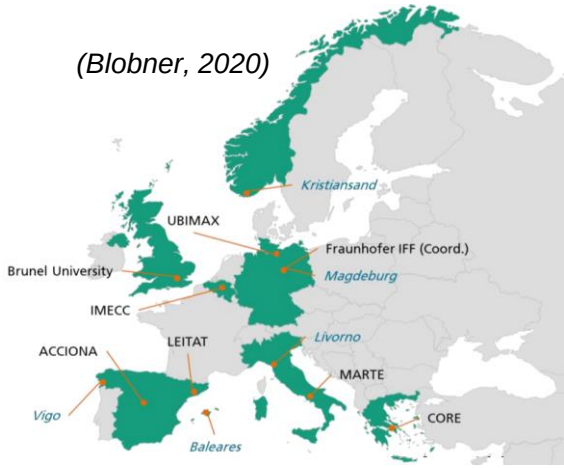




PortForward Project: 2018-2022

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

Puerto de Vigo

Autoridad Portuaria de Vigo

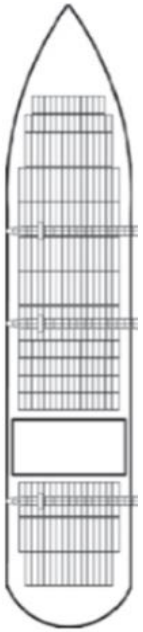
Container terminal

Cruise terminal

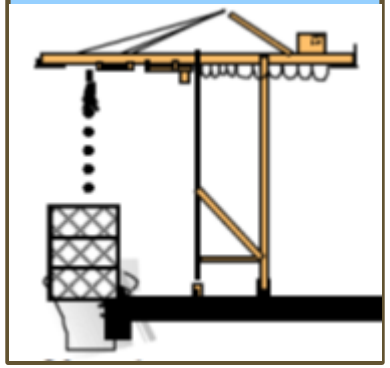
Fishing terminal

Ro-Ro terminal

Container Terminal Operations

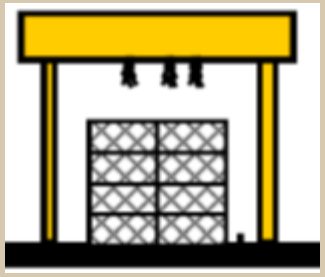


Berth
Vessel
Quay Crane
Yard Truck



Sea (Maritime) Side

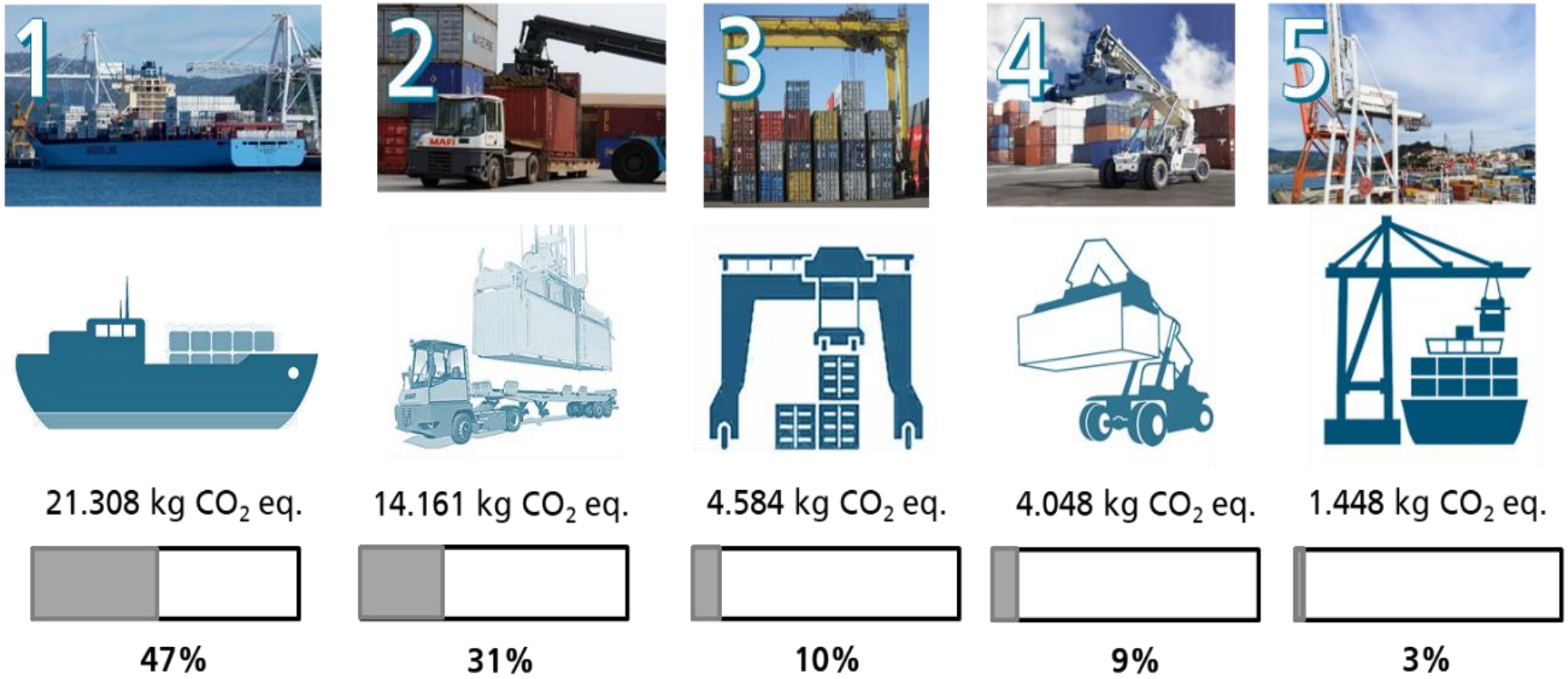
Storage Space
Yard Crane
Yard Truck
Drayage Truck



Land Side

Preliminary Sustainability Assessment

Carbon footprint: 45.549 kg CO_2 eq. / TEU



(Claret, 2019)

Container Terminal Equipment

Rubber Tyred Gantry crane (RTG)

Reach Stacker

Internal Movement Vehicles (IMV)

External Truck

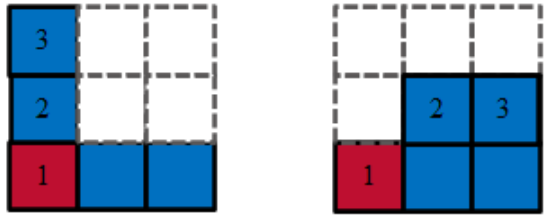
The Housekeeping Problem

- 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



Example of a reshuffle

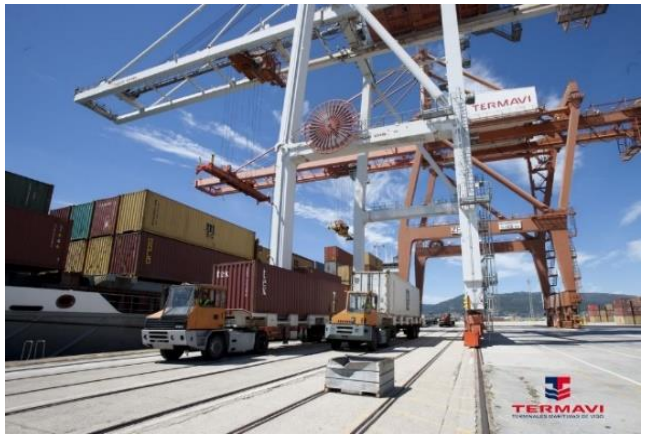
Ordering of a bay in two moves

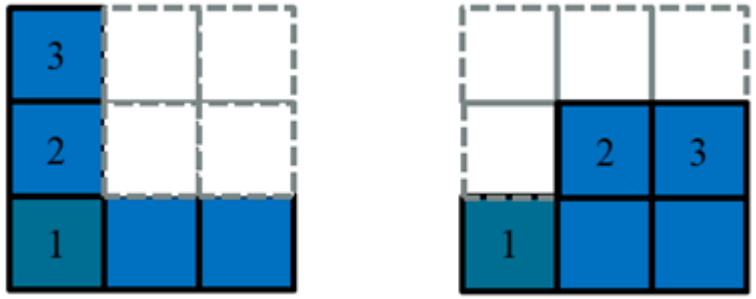
Container Positioning Problem

- **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





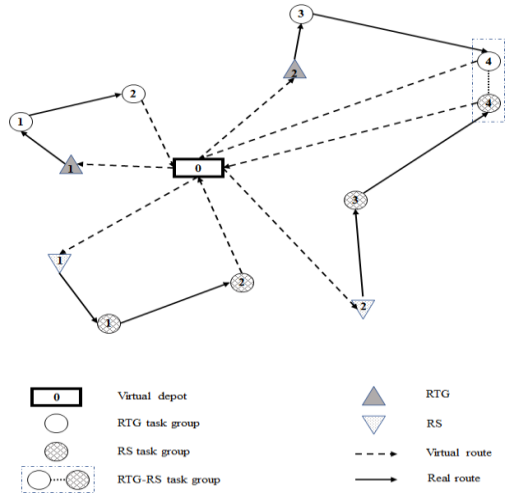
Example of a reshuffle

Yard Crane Scheduling Problem

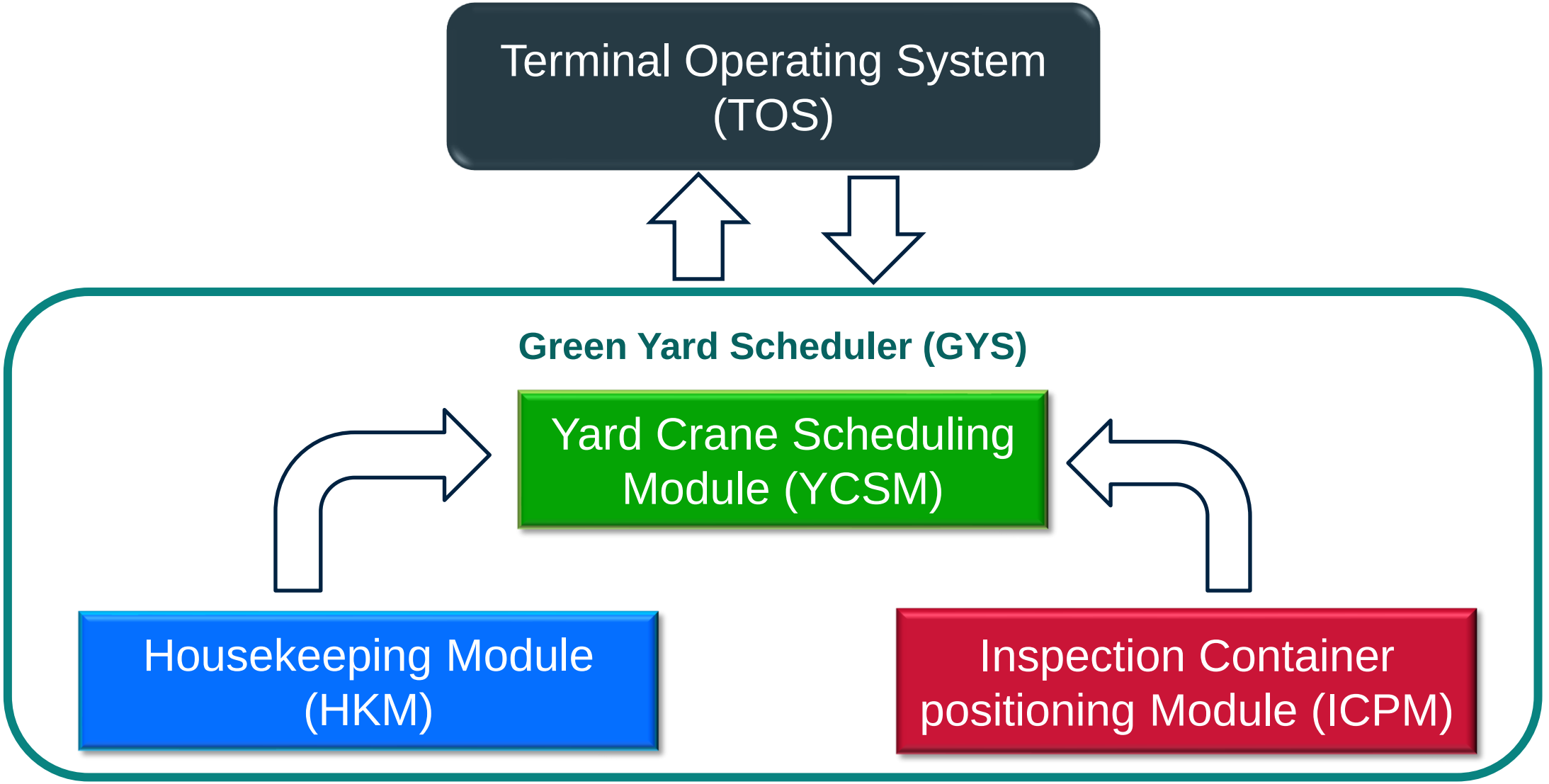
- Determine the allocation and schedule of the yard cranes (RTG's and RS's) to the pending operational jobs (e.g., movement of new containers from the Mafis (IMVs) to their allocated slots)

- **Objectives (KPIs):**
  1) Minimise the total tardiness of all operations
  2) Minimise the total energy consumption of the yard cranes

- **Output:** Schedule of all pending operations on selected RTG's and RS's.



The Green Yard Scheduler (GYS)



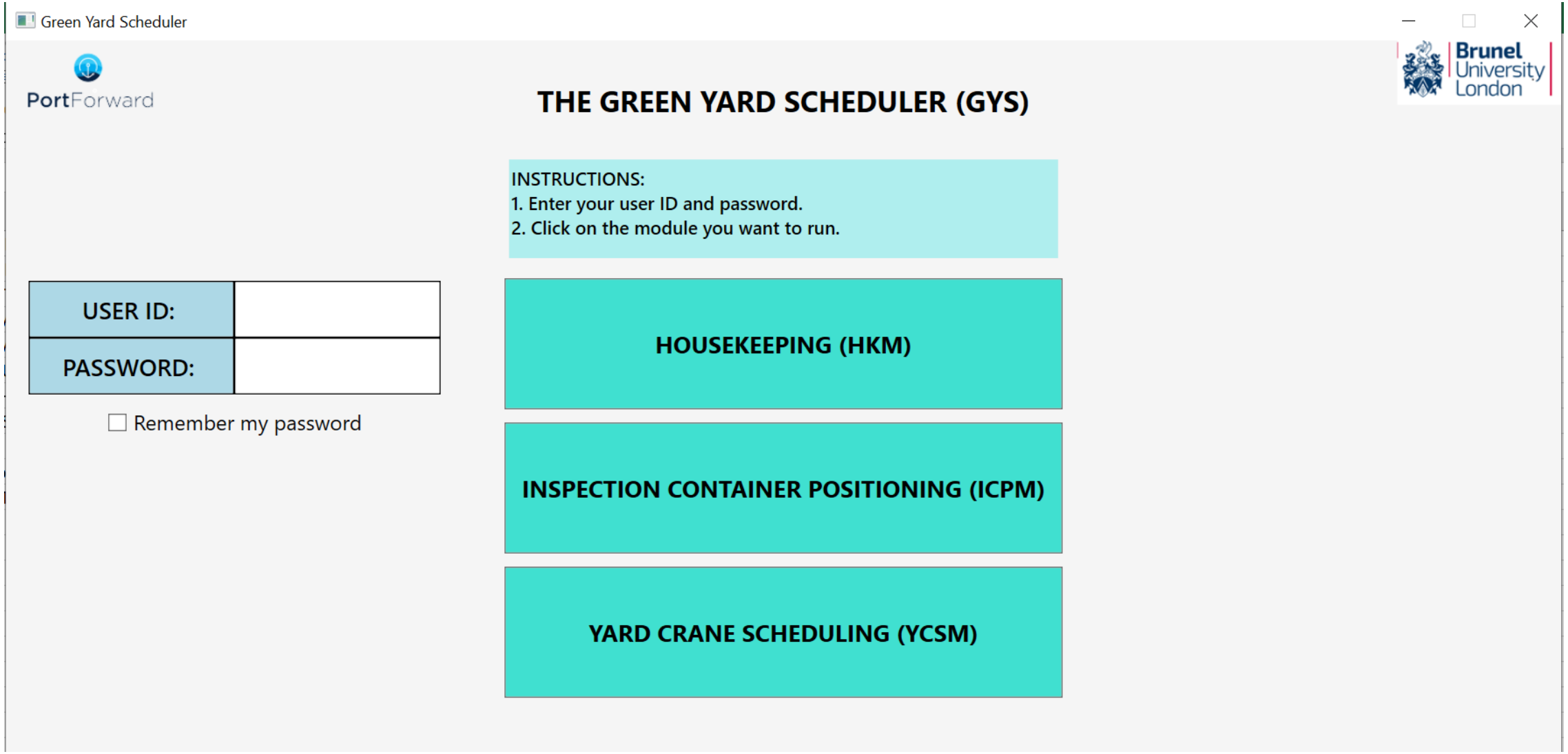
Preliminary Results

Housekeeping: Energy savings can be achieved without disrupting the operational efficiency of the terminal: **4-6%** energy reduction

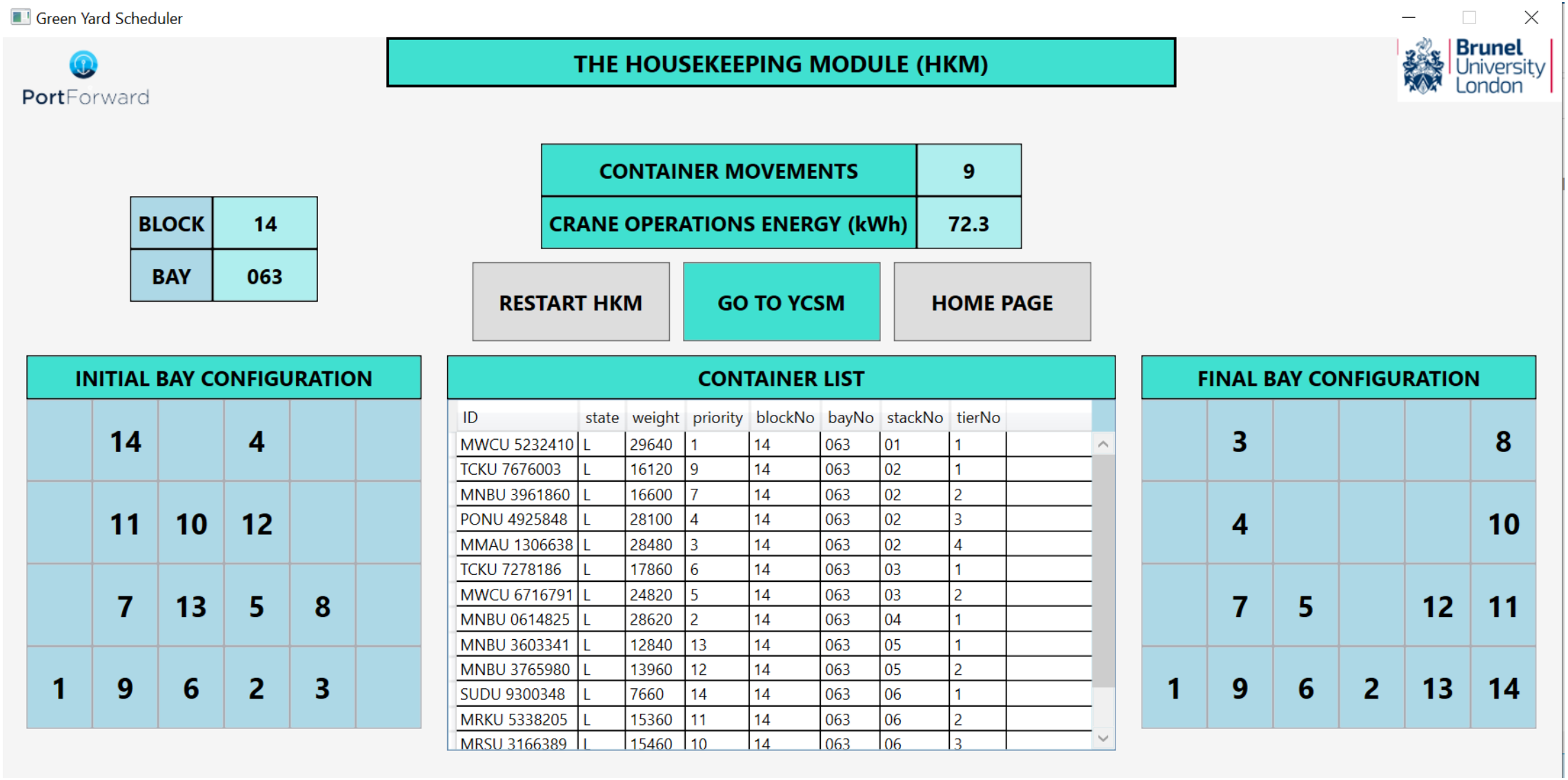
Container Positioning: The performance- and sustainability-oriented objectives conflict with each other. **13-34%** energy reduction at the expense of more reshuffles

Yard Crane Scheduling: The performance- and sustainability-oriented objectives conflict with each other. Up to **38%** energy reduction at the expense of greater delays

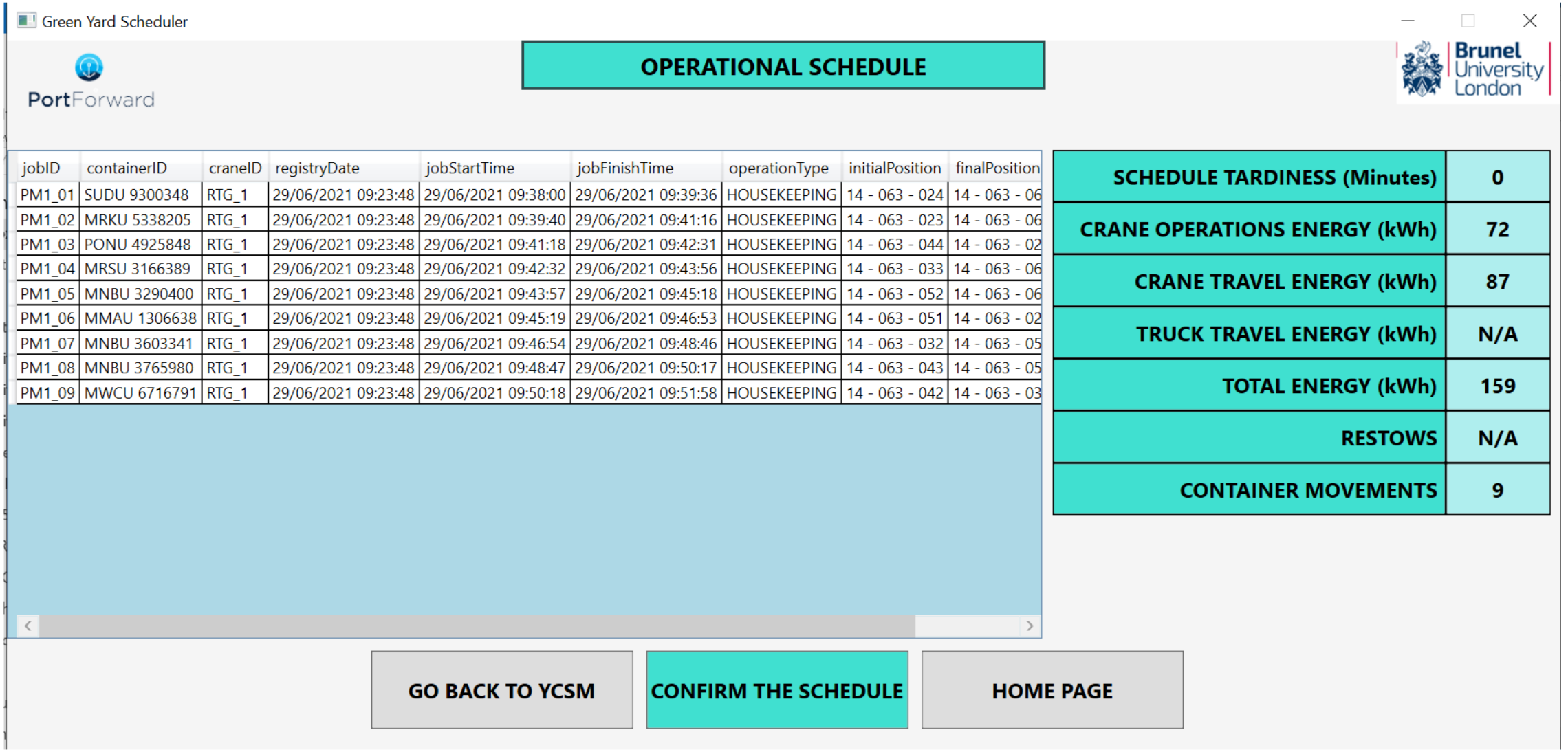
Beta Version of the GYS



An example of Housekeeping (HKM)



HKM → Yard Crane Scheduling (YCSM): A single solution



jobID	containerID	craneID	registryDate	jobStartTime	jobFinishTime	operationType	initialPosition	finalPosition
PM1_01	SUDU 9300348	RTG_1	29/06/2021 09:23:48	29/06/2021 09:38:00	29/06/2021 09:39:36	HOUSEKEEPING	14 - 063 - 024	14 - 063 - 06
PM1_02	MRKU 5338205	RTG_1	29/06/2021 09:23:48	29/06/2021 09:39:40	29/06/2021 09:41:16	HOUSEKEEPING	14 - 063 - 023	14 - 063 - 06
PM1_03	PONU 4925848	RTG_1	29/06/2021 09:23:48	29/06/2021 09:41:18	29/06/2021 09:42:31	HOUSEKEEPING	14 - 063 - 044	14 - 063 - 02
PM1_04	MRSU 3166389	RTG_1	29/06/2021 09:23:48	29/06/2021 09:42:32	29/06/2021 09:43:56	HOUSEKEEPING	14 - 063 - 033	14 - 063 - 06
PM1_05	MNBU 3290400	RTG_1	29/06/2021 09:23:48	29/06/2021 09:43:57	29/06/2021 09:45:18	HOUSEKEEPING	14 - 063 - 052	14 - 063 - 06
PM1_06	MMAU 1306638	RTG_1	29/06/2021 09:23:48	29/06/2021 09:45:19	29/06/2021 09:46:53	HOUSEKEEPING	14 - 063 - 051	14 - 063 - 02
PM1_07	MNBU 3603341	RTG_1	29/06/2021 09:23:48	29/06/2021 09:46:54	29/06/2021 09:48:46	HOUSEKEEPING	14 - 063 - 032	14 - 063 - 05
PM1_08	MNBU 3765980	RTG_1	29/06/2021 09:23:48	29/06/2021 09:48:47	29/06/2021 09:50:17	HOUSEKEEPING	14 - 063 - 043	14 - 063 - 05
PM1_09	MWCU 6716791	RTG_1	29/06/2021 09:23:48	29/06/2021 09:50:18	29/06/2021 09:51:58	HOUSEKEEPING	14 - 063 - 042	14 - 063 - 03

SCHEDULE TARDINESS (Minutes)	0
CRANE OPERATIONS ENERGY (kWh)	72
CRANE TRAVEL ENERGY (kWh)	87
TRUCK TRAVEL ENERGY (kWh)	N/A
TOTAL ENERGY (kWh)	159
RESTOWS	N/A
CONTAINER MOVEMENTS	9

Inspection Container Positioning (ICPM)→YCSM: Pareto frontier

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THE INSPECTION CONTAINER POSITIONING MODULE (ICPM)

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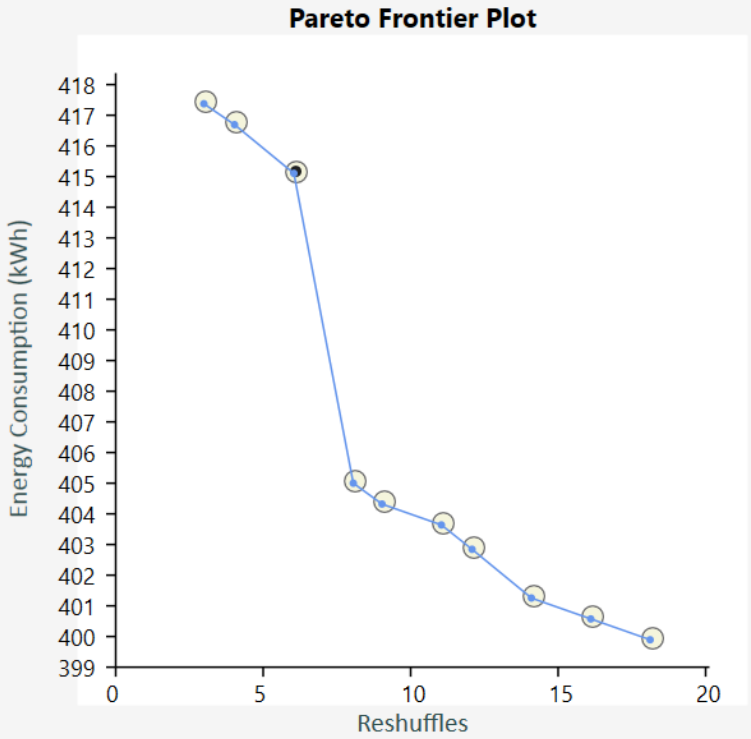
RESTOWS	**6**
TRUCK TRAVEL ENERGY (kWh)	**415**



DISPLAY THE SOLUTION

GO TO YCSM

HOME PAGE

Inspection Container Positioning (ICPM)→YCSM: Pareto frontier

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THE INSPECTION CONTAINER POSITIONING MODULE (ICPM)

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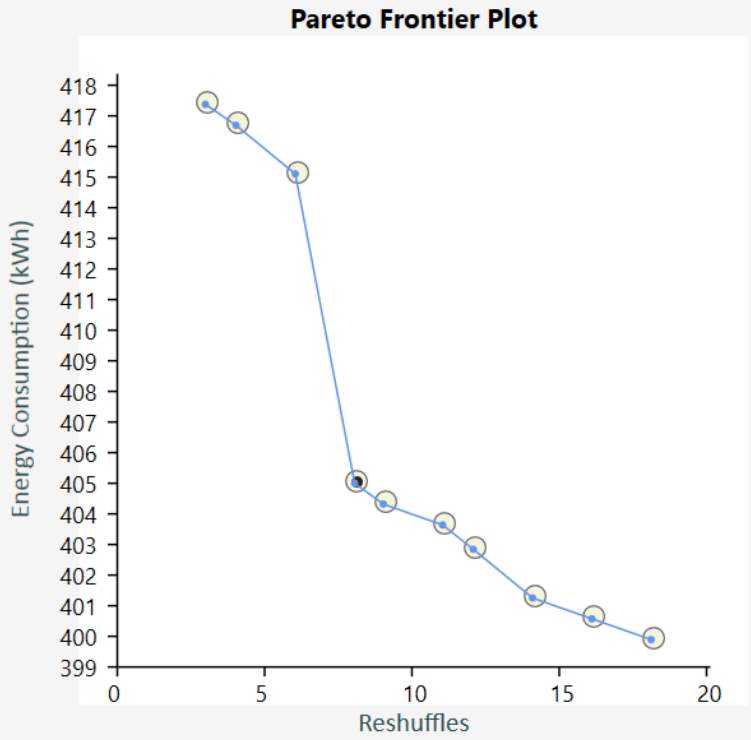
RESTOWS	**8**
TRUCK TRAVEL ENERGY (kWh)	**405**



DISPLAY THE SOLUTION

GO TO YCSM

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An example of YCSM for other jobs

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THE YARD CRANE SCHEDULING MODULE (YCSM)

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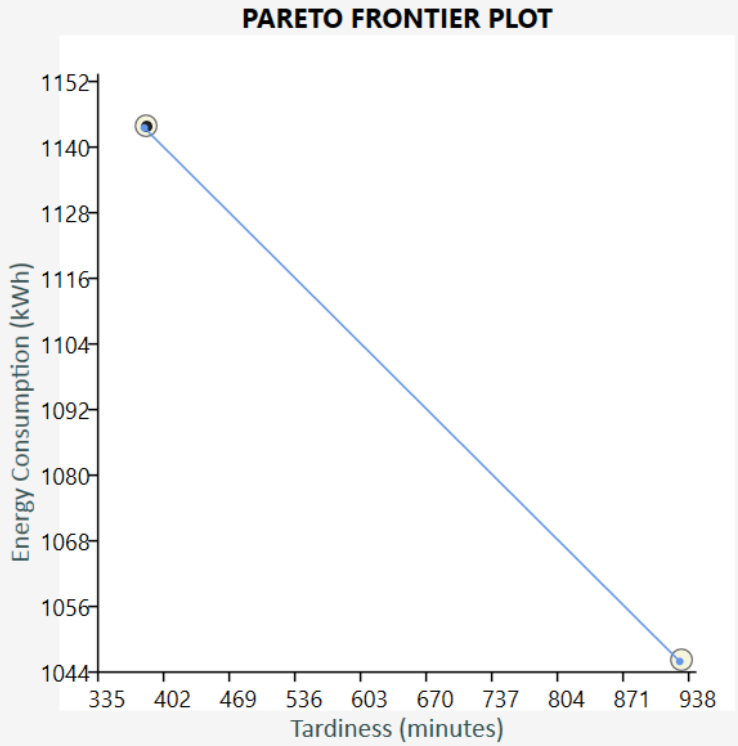
SCHEDULE TARDINESS (Minutes)	382
CRANE OPERATIONS ENERGY (kWh)	230
CRANE TRAVEL ENERGY (kWh)	913
TRUCK TRAVEL ENERGY (kWh)	N/A
TOTAL ENERGY (kWh)	1143
RESTOWS	N/A
CONTAINER MOVEMENTS	N/A



DISPLAY THE SOLUTION

REVIEW THE SCHEDULE

HOME PAGE

An example of YCSM for other jobs (contd.)

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THE YARD CRANE SCHEDULING MODULE (YCSM)

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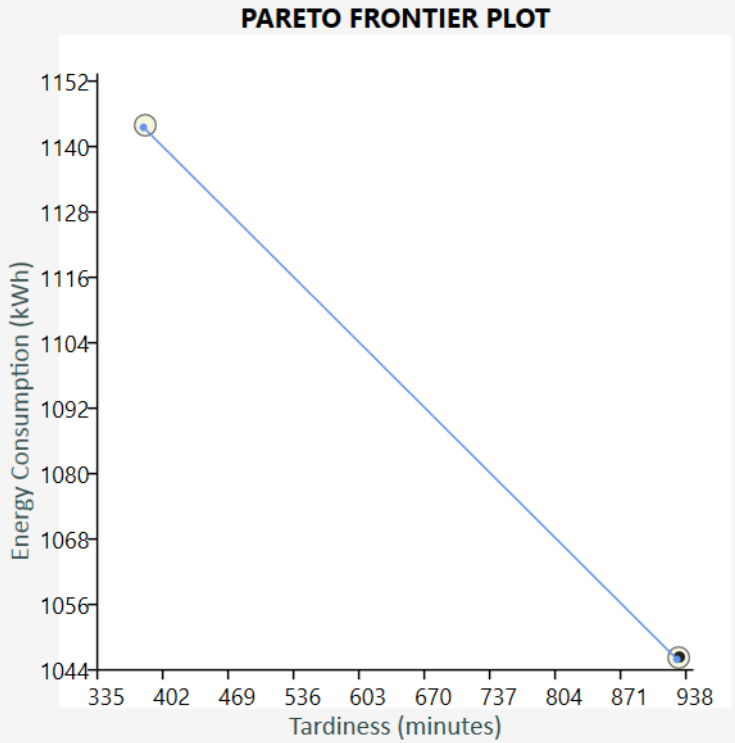
SCHEDULE TARDINESS (Minutes)	921
CRANE OPERATIONS ENERGY (kWh)	230
CRANE TRAVEL ENERGY (kWh)	816
TRUCK TRAVEL ENERGY (kWh)	N/A
TOTAL ENERGY (kWh)	1046
RESTOWS	N/A
CONTAINER MOVEMENTS	N/A



DISPLAY THE SOLUTION

REVIEW THE SCHEDULE

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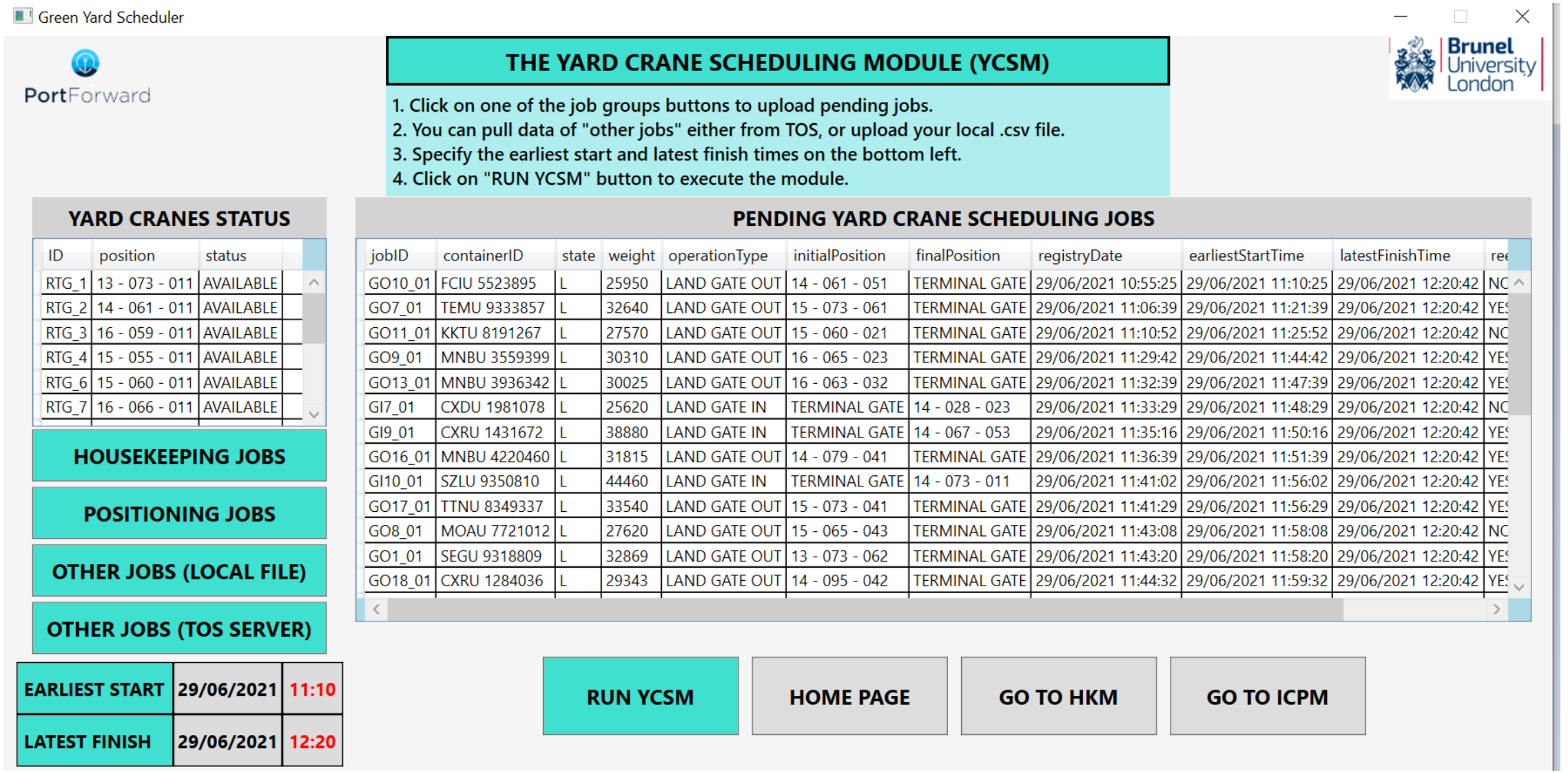
An example of the YCSM output



A TRL View of the GYS

- **TRL 1.** Basic principles observed → Green scheduling 2011-2015
- **TRL 2.** Technology concept formulated → 2018-2019 (PortForward)
- **TRL 3.** Experimental proof of concept → 2018-2019 (PortForward)
- **TRL 4.** Technology validated in lab → 2019-2020 (Portforward)
- **TRL 5.** Technology validated in relevant environment → 2020 (Portforward)
- **TRL 6.** Technology demonstrated in relevant environment → 2020-2021 Testing at Brunel using remote connection to the port of Vigo's TOS

- **TRL 7**. System prototype demonstration in operational environment → beta version of the GYS released end of June 2021. Testing and improvement planned by end of summer 2021 in the Port of Vigo (PortForward)
- **TRL 8**. System complete and qualified → By the end of 2021
- **TRL 9**. Actual system proven in operational environment → By Jun 2022

Thank you for your attention!
Questions, comments?

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