

The Green Yard Scheduler:

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

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Green Energy Ports Conference
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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



The Port-City Relationship

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

Los Angeles Times [Subscribe Now \\$1/6 months](#)

CALIFORNIA

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




CORONAVIRUS, VACCINES AND PANDEMIC >

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

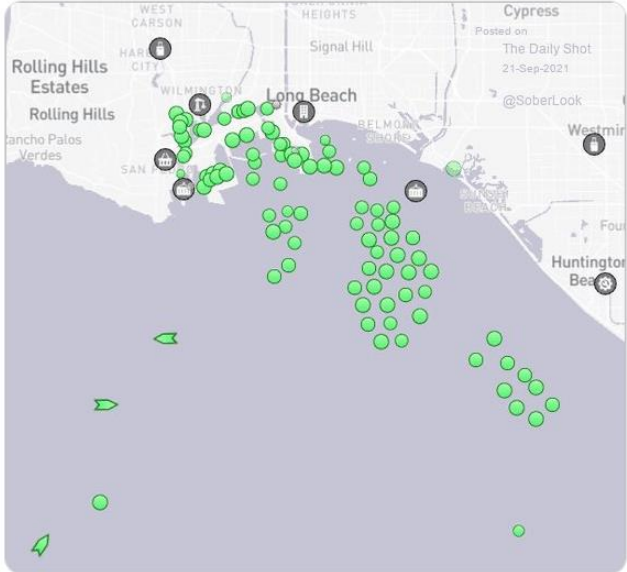
Nearly 5 out of 6 coronavirus cases were undetected in pandemic's early months

Column: COVID isn't spread by mosquitoes. But the next pandemic might be

← **Tweet**

 **Rob Hager**
@Rob_Hager

72 Container Ships waiting to unload at the port of LA/Long Beach, a new high - [@SoberLook](#)
[@MarineTraffic](#)



11:34 AM · Sep 21, 2021 · Twitter for iPad

5 Retweets 1 Quote Tweet 9 Likes

PortForward Project: 2018-2022

Main objectives

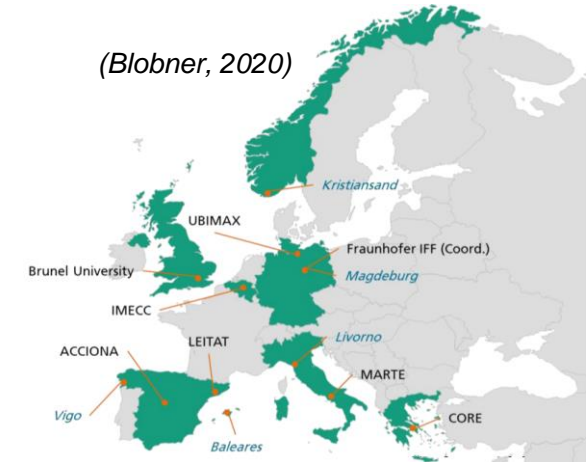
- **Smart Port Solutions:** Employing ICT solutions to improve information flows between ports and port communities
- **Green Port Solutions:** Adopting green technologies to reduce the environmental impacts of port operations and save resources
- **Interconnected Port Solutions:** Combining different modes of transport integrating of different technologies to better monitor and control freight flows

<https://www.portforward-project.eu>



PortForward

(Blobner, 2020)



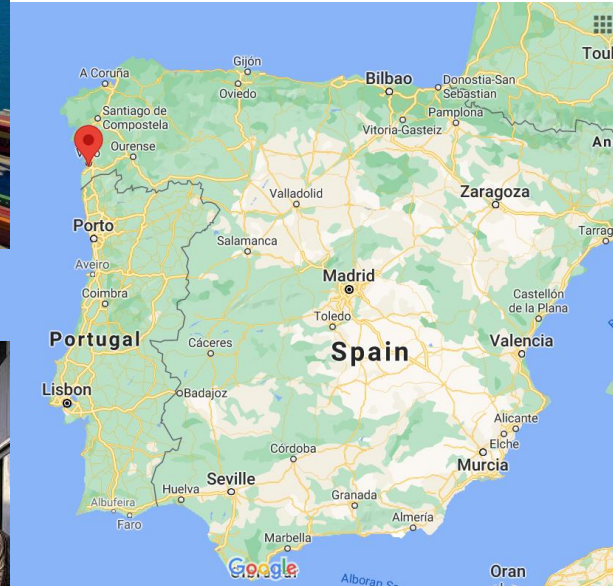
This project receives funding in the European Commission's Horizon 2020 Research Program under Grant Agreement Number 769267



Port of Vigo



Container terminal



Cruise terminal

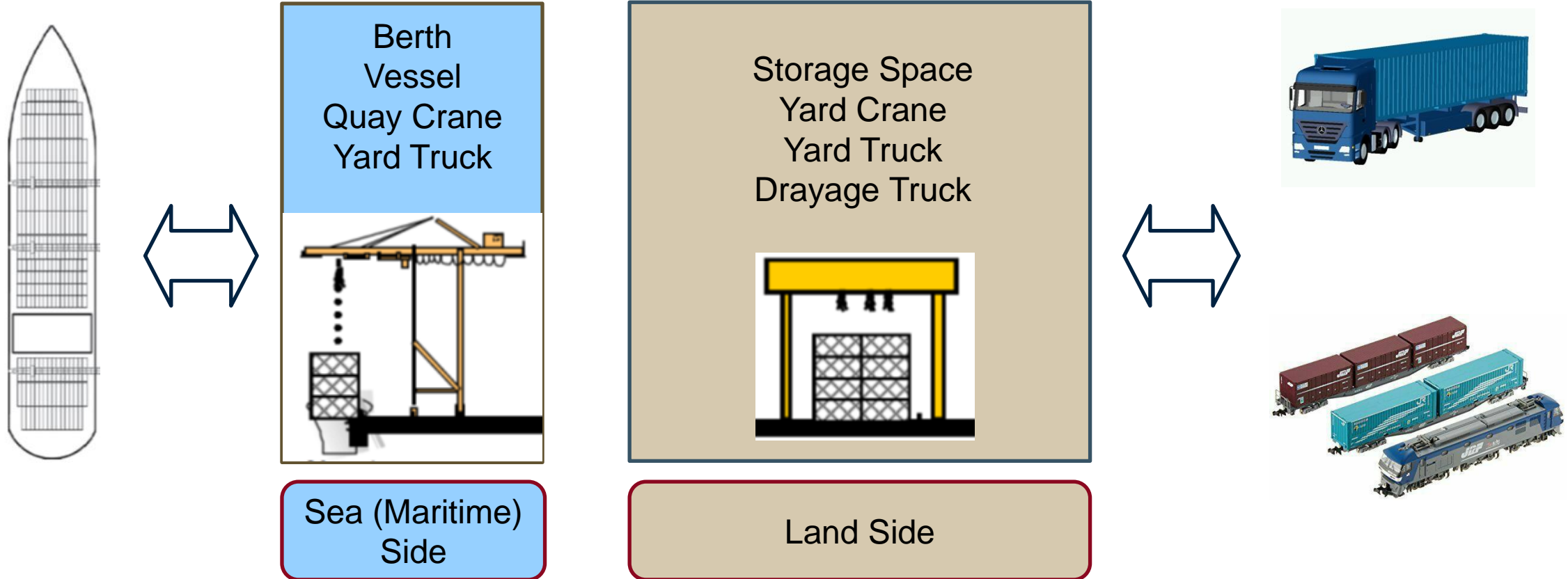


Fishing terminal



Ro-Ro terminal

Container Terminal Operations



Preliminary Sustainability Assessment



Carbon footprint: 45.549 kg CO₂eq. / TEU



21.308 kg CO₂ eq.



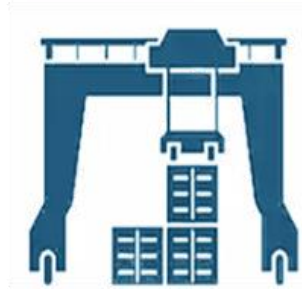
47%



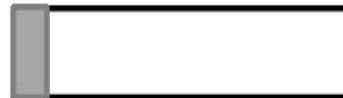
14.161 kg CO₂ eq.



31%



4.584 kg CO₂ eq.



10%



4.048 kg CO₂ eq.



9%



1.448 kg CO₂ eq.



3%

(Claret, 2019) **LEITAT**
managing technologies

Container Terminal Equipment



Rubber Tyred Gantry crane (RTG)



Reach Stacker



Internal Movement Vehicles (IMV)



External Truck

The Housekeeping Problem

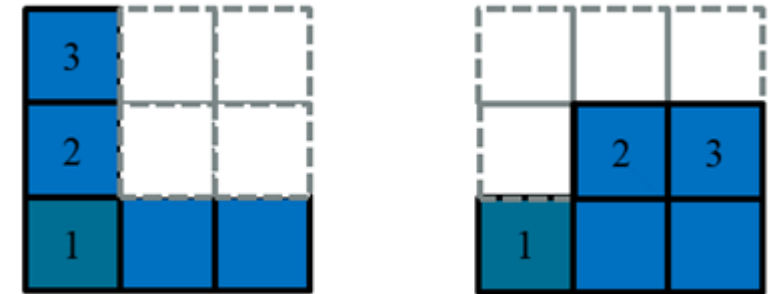
- Determine the **sequence of container movements** in a bay area selected for pre-marshalling to eliminate any further reshuffles to reduce the vessels waiting time
- **Objectives (KPIs):**
 - 1) Minimise the number of **container movements**
 - 2) Minimise the estimated **energy consumption of the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



Ordering of a bay in two moves

Container Positioning Problem

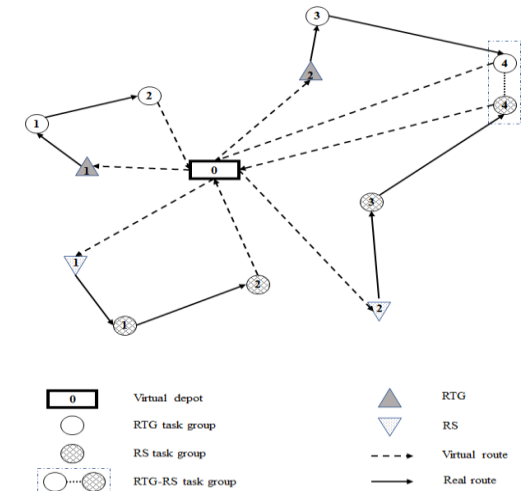
- **Determine the slot allocations of:**
 - Import containers discharged from vessels
 - Containers coming back from inspection
 - Export containers arrived at the terminal gate
- **Objectives (KPIs):**
 - 1) Minimise the energy consumption of the internal and external trucks
 - 2) Minimise the number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



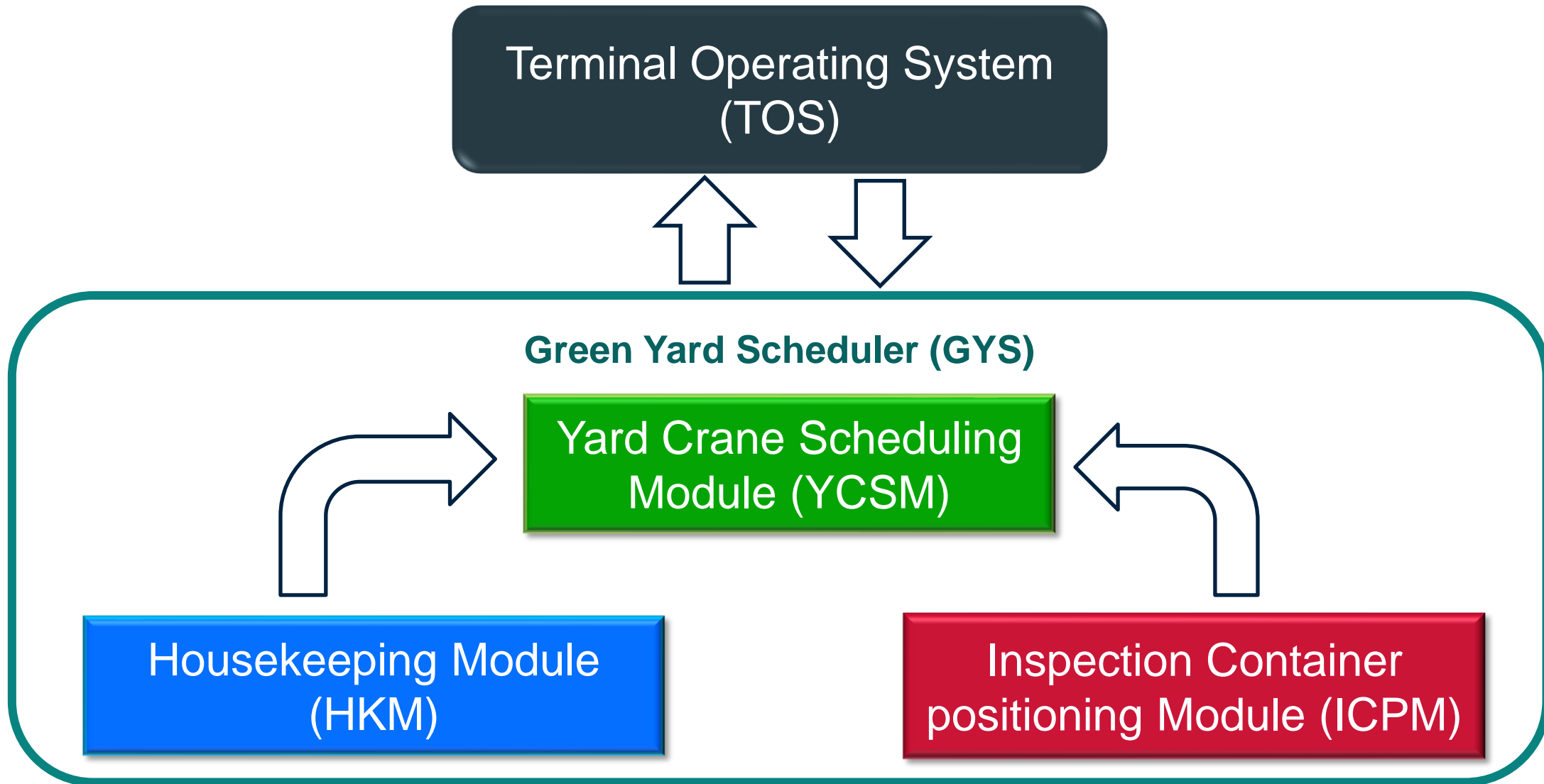
Example of a reshuffle

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

Green Yard Scheduler


PortForward

USER ID:

PASSWORD:

☐ Remember my password

THE GREEN YARD SCHEDULER (GYS)

INSTRUCTIONS:


1. Enter your user ID and password.

2. Click on the module you want to run.

HOUSEKEEPING (HKM)

INSPECTION CONTAINER POSITIONING (ICPM)

YARD CRANE SCHEDULING (YCSM)


Brunel
University
London

An example of Housekeeping (HKM)

Green Yard Scheduler



THE HOUSEKEEPING MODULE (HKM)

BLOCK	14
BAY	063

CONTAINER MOVEMENTS	9
CRANE OPERATIONS ENERGY (kWh)	72.3

RESTART HKM

GO TO YCSM

HOME PAGE

INITIAL BAY CONFIGURATION

	14		4		
	11	10	12		
	7	13	5	8	
1	9	6	2	3	


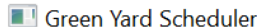
CONTAINER LIST

ID	state	weight	priority	blockNo	bayNo	stackNo	tierNo	
MWCU 5232410	L	29640	1	14	063	01	1	^
TCKU 7676003	L	16120	9	14	063	02	1	
MNBU 3961860	L	16600	7	14	063	02	2	
PONU 4925848	L	28100	4	14	063	02	3	
MMAU 1306638	L	28480	3	14	063	02	4	
TCKU 7278186	L	17860	6	14	063	03	1	
MWCU 6716791	L	24820	5	14	063	03	2	
MNBU 0614825	L	28620	2	14	063	04	1	
MNBU 3603341	L	12840	13	14	063	05	1	
MNBU 3765980	L	13960	12	14	063	05	2	
SUDU 9300348	L	7660	14	14	063	06	1	
MRKU 5338205	L	15360	11	14	063	06	2	
MRSU 3166389	L	15460	10	14	063	06	3	v


FINAL BAY CONFIGURATION

	3				8
	4				10
	7	5		12	11
1	9	6	2	13	14

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

**PortForward**

OPERATIONAL SCHEDULE



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

GO BACK TO YCSM

CONFIRM THE SCHEDULE

HOME PAGE

Inspection Container Positioning (ICPM)→YCSM: Pareto frontier

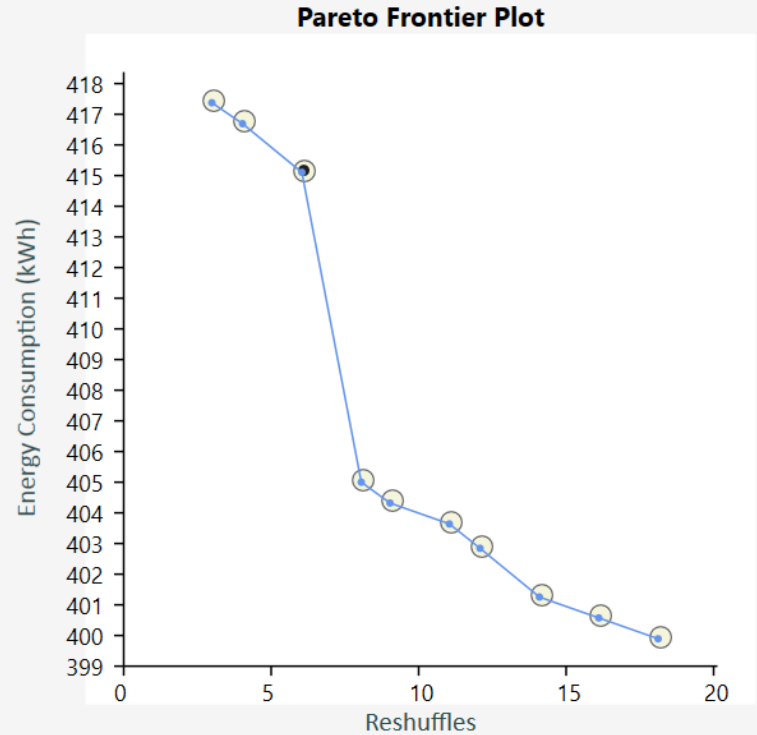
Green Yard Scheduler



THE INSPECTION CONTAINER POSITIONING MODULE (ICPM)



RESTOWS	6
TRUCK TRAVEL ENERGY (kWh)	415



DISPLAY THE SOLUTION

GO TO YCSM

HOME PAGE



Inspection Container Positioning (ICPM)→YCSM: Pareto frontier

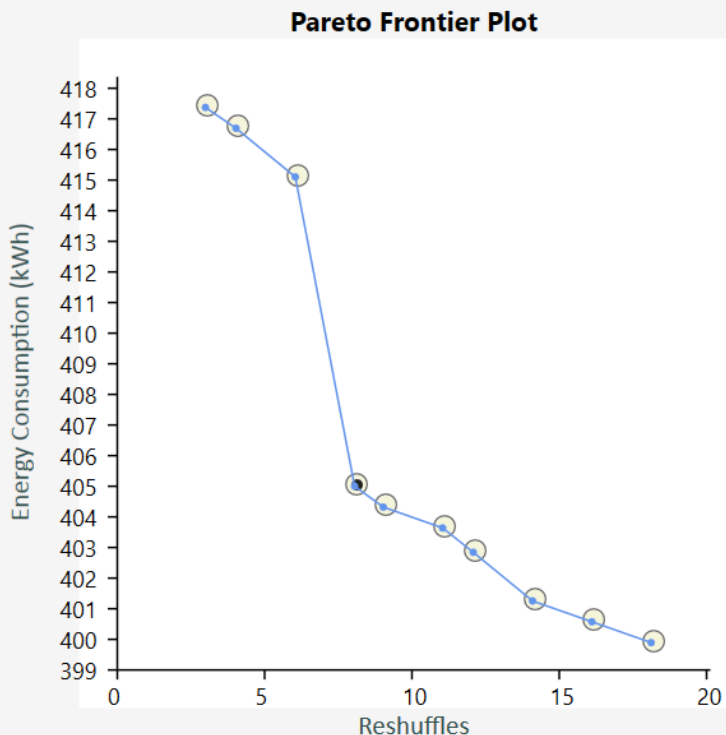
Green Yard Scheduler



THE INSPECTION CONTAINER POSITIONING MODULE (ICPM)



RESTOWS	8
TRUCK TRAVEL ENERGY (kWh)	405



DISPLAY THE SOLUTION

GO TO YCSM

HOME PAGE

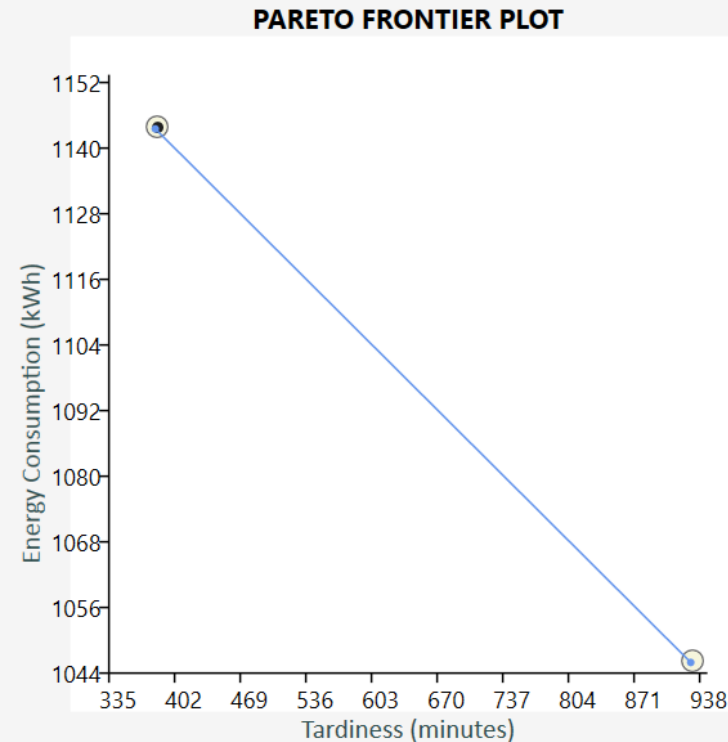
An example of YCSM for other jobs

Green Yard Scheduler

THE YARD CRANE SCHEDULING MODULE (YCSM)



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

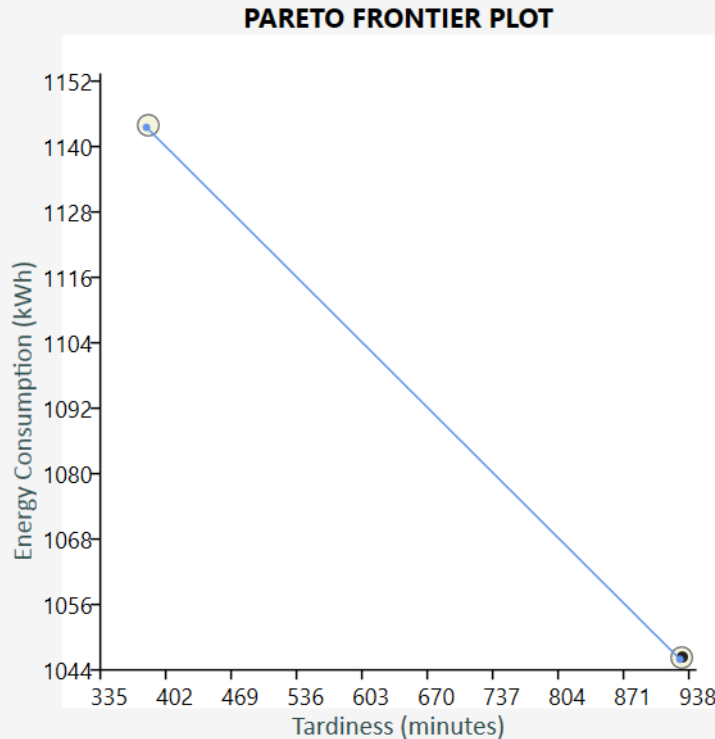
An example of YCSM for other jobs (contd.)

Green Yard Scheduler

THE YARD CRANE SCHEDULING MODULE (YCSM)



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

HOME PAGE

An example of the YCSM output

Green Yard Scheduler



THE YARD CRANE SCHEDULING MODULE (YCSM)

1. Click on one of the job groups buttons to upload pending jobs.
2. You can pull data of "other jobs" either from TOS, or upload your local .csv file.
3. Specify the earliest start and latest finish times on the bottom left.
4. Click on "RUN YCSM" button to execute the module.

YARD CRANES STATUS

ID	position	status	
RTG_1	13 - 073 - 011	AVAILABLE	^
RTG_2	14 - 061 - 011	AVAILABLE	
RTG_3	16 - 059 - 011	AVAILABLE	
RTG_4	15 - 055 - 011	AVAILABLE	
RTG_6	15 - 060 - 011	AVAILABLE	
RTG_7	16 - 066 - 011	AVAILABLE	v

HOUSEKEEPING JOBS

POSITIONING JOBS

OTHER JOBS (LOCAL FILE)

OTHER JOBS (TOS SERVER)

EARLIEST START	29/06/2021	11:10
LATEST FINISH	29/06/2021	12:20

PENDING YARD CRANE SCHEDULING JOBS

jobID	containerID	state	weight	operationType	initialPosition	finalPosition	registryDate	earliestStartTime	latestFinishTime	rec
GO10_01	FCIU 5523895	L	25950	LAND GATE OUT	14 - 061 - 051	TERMINAL GATE	29/06/2021 10:55:25	29/06/2021 11:10:25	29/06/2021 12:20:42	NC ^
GO7_01	TEMU 9333857	L	32640	LAND GATE OUT	15 - 073 - 061	TERMINAL GATE	29/06/2021 11:06:39	29/06/2021 11:21:39	29/06/2021 12:20:42	YES
GO11_01	KKTU 8191267	L	27570	LAND GATE OUT	15 - 060 - 021	TERMINAL GATE	29/06/2021 11:10:52	29/06/2021 11:25:52	29/06/2021 12:20:42	NC
GO9_01	MNBU 3559399	L	30310	LAND GATE OUT	16 - 065 - 023	TERMINAL GATE	29/06/2021 11:29:42	29/06/2021 11:44:42	29/06/2021 12:20:42	YES
GO13_01	MNBU 3936342	L	30025	LAND GATE OUT	16 - 063 - 032	TERMINAL GATE	29/06/2021 11:32:39	29/06/2021 11:47:39	29/06/2021 12:20:42	YES
GI7_01	CXDU 1981078	L	25620	LAND GATE IN	TERMINAL GATE	14 - 028 - 023	29/06/2021 11:33:29	29/06/2021 11:48:29	29/06/2021 12:20:42	NC
GI9_01	CXRU 1431672	L	38880	LAND GATE IN	TERMINAL GATE	14 - 067 - 053	29/06/2021 11:35:16	29/06/2021 11:50:16	29/06/2021 12:20:42	YES
GO16_01	MNBU 4220460	L	31815	LAND GATE OUT	14 - 079 - 041	TERMINAL GATE	29/06/2021 11:36:39	29/06/2021 11:51:39	29/06/2021 12:20:42	YES
GI10_01	SZLU 9350810	L	44460	LAND GATE IN	TERMINAL GATE	14 - 073 - 011	29/06/2021 11:41:02	29/06/2021 11:56:02	29/06/2021 12:20:42	YES
GO17_01	TTNU 8349337	L	33540	LAND GATE OUT	15 - 073 - 041	TERMINAL GATE	29/06/2021 11:41:29	29/06/2021 11:56:29	29/06/2021 12:20:42	YES
GO8_01	MOAU 7721012	L	27620	LAND GATE OUT	15 - 065 - 043	TERMINAL GATE	29/06/2021 11:43:08	29/06/2021 11:58:08	29/06/2021 12:20:42	NC
GO1_01	SEGU 9318809	L	32869	LAND GATE OUT	13 - 073 - 062	TERMINAL GATE	29/06/2021 11:43:20	29/06/2021 11:58:20	29/06/2021 12:20:42	YES
GO18_01	CXRU 1284036	L	29343	LAND GATE OUT	14 - 095 - 042	TERMINAL GATE	29/06/2021 11:44:32	29/06/2021 11:59:32	29/06/2021 12:20:42	YES v

RUN YCSM

HOME PAGE

GO TO HKM

GO TO ICPM

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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