

# Yard Crane Scheduling Problem

30 June 2021

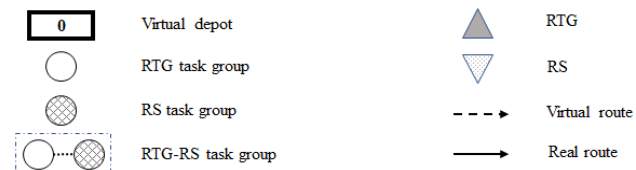
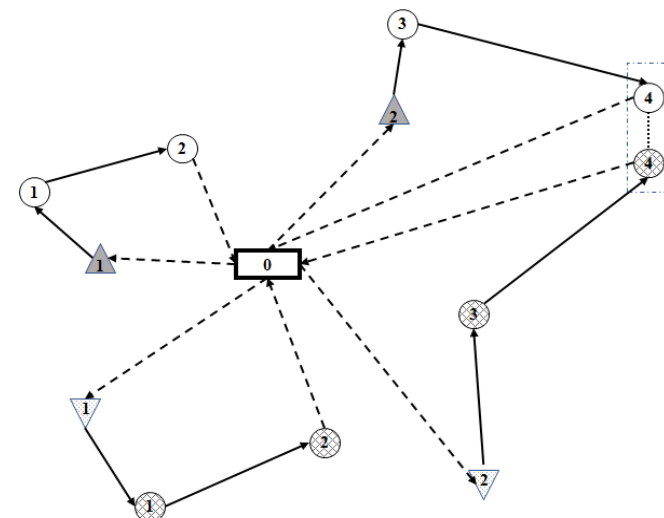
- Determine the **allocation and schedule of the yard cranes** (RTG's and RS's) to the pending operational jobs (e.g., movement of new containers from the Mafis to their allocated slots)
- **Objectives (KPIs):**
  - 1) Minimise the total **tardiness** of all operations
  - 2) Minimise the total **energy consumption of the yard cranes**
- **Output:** Schedule of all pending operations on selected RTG's and RS's.



# Solution Methods

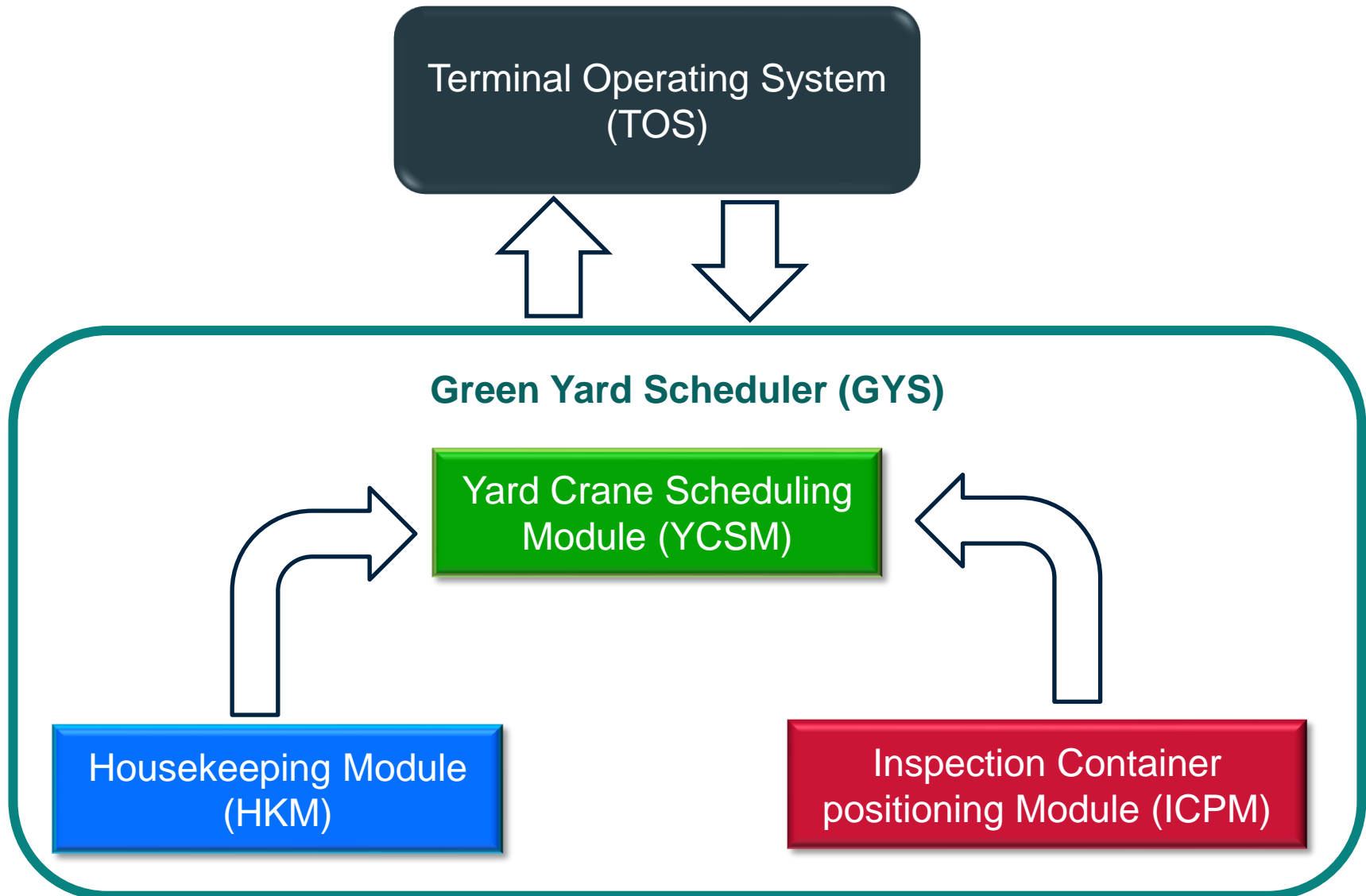
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- **Housekeeping Problem:** Hybrid A\* algorithm to seek the shortest path from the initial bay configuration to the desired configuration with the minimum container movements
- **Container Positioning Problem:** Pareto Archived Evolution Strategy (PAES) searching for the Pareto frontier of the bi-objective problem
- **Yard Crane Scheduling Problem:** Formulated as a Vehicle Routing Problem with Time Windows (VRPTW). A hybrid metaheuristic comprising of PAES and Simulated Annealing (SA)



# The Green Yard Scheduler (GYS)

30 June 2021



**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

30 June 2021

Green Yard Scheduler

PortForward

**THE GREEN YARD SCHEDULER (GYS)**

**INSTRUCTIONS:**

1. Enter your user ID and password.
2. Click on the module you want to run.

USER ID:	
PASSWORD:	

Remember my password

**HOUSEKEEPING (HKM)**

**INSPECTION CONTAINER POSITIONING (ICPM)**

**YARD CRANE SCHEDULING (YCSM)**

Brunel University London

# An example of Housekeeping (HKM)

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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](#)
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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	

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

30 June 2021

Green Yard Scheduler
— □ ×

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

GO BACK TO YCSM

CONFIRM THE SCHEDULE

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# Inspection Container Positioning (ICPM) → YCSM: A Pareto frontier

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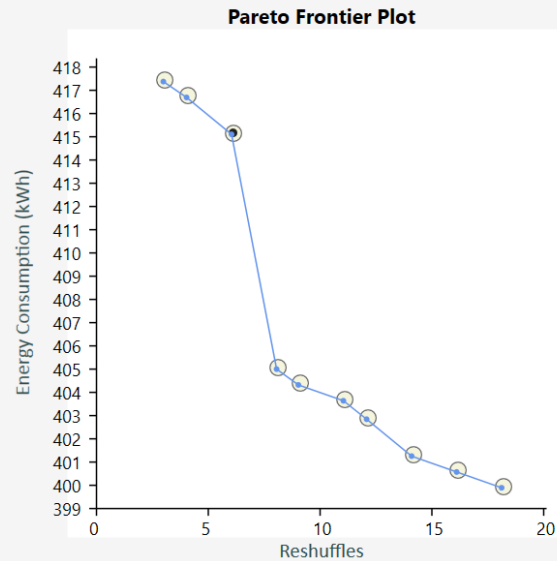
Green Yard Scheduler



## THE INSPECTION CONTAINER POSITIONING MODULE (ICPM)



<b>RESTOWS</b>	<b>6</b>
<b>TRUCK TRAVEL ENERGY (kWh)</b>	<b>415</b>



DISPLAY THE SOLUTION

GO TO YCSM

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# Inspection Container Positioning (ICPM) → YCSM: A Pareto frontier (contd.)

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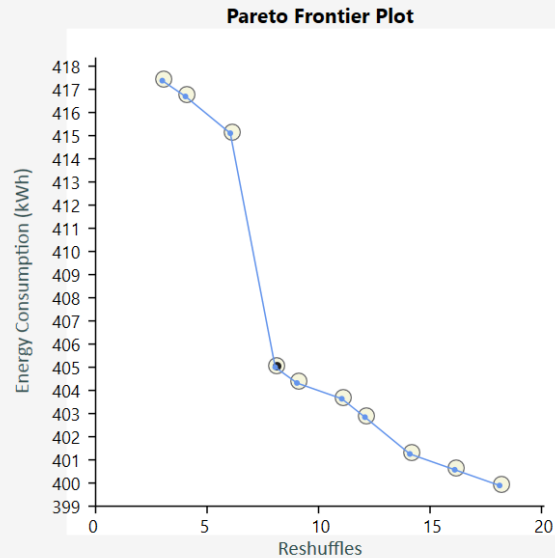
Green Yard Scheduler



## THE INSPECTION CONTAINER POSITIONING MODULE (ICPM)



<b>RESTOWS</b>	<b>8</b>
<b>TRUCK TRAVEL ENERGY (kWh)</b>	<b>405</b>



- DISPLAY THE SOLUTION
- GO TO YCSM
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# An example of YCSM alone

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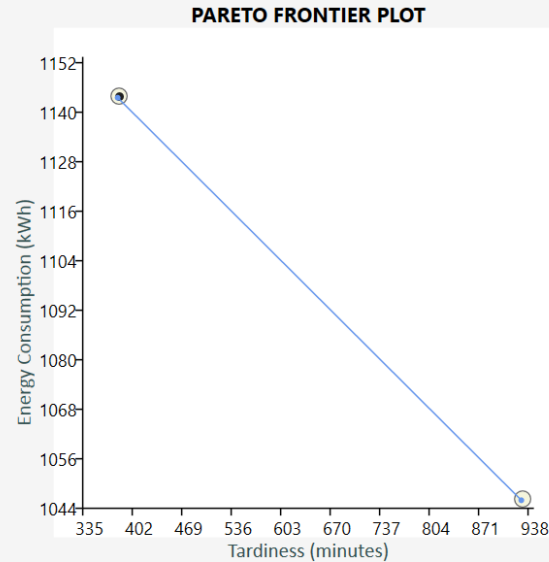
Green Yard Scheduler



## THE YARD CRANE SCHEDULING MODULE (YCSM)



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



DISPLAY THE SOLUTION

REVIEW THE SCHEDULE

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# An example of YCSM alone (contd.)

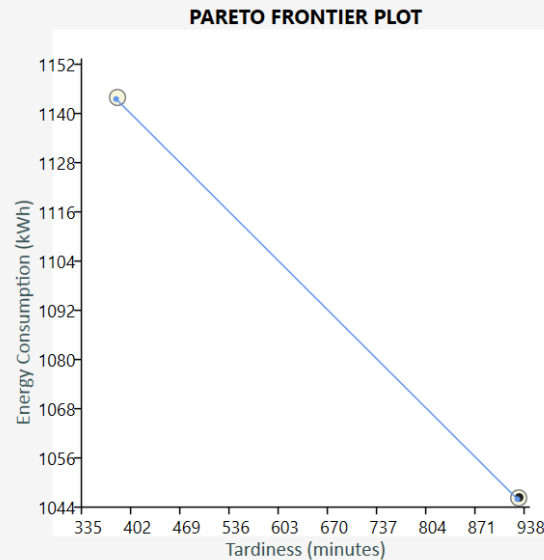
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## THE YARD CRANE SCHEDULING MODULE (YCSM)



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



DISPLAY THE SOLUTION

REVIEW THE SCHEDULE

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# An example of the YCSM output

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**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

**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

**RUN YCSM** **HOME PAGE** **GO TO HKM** **GO TO ICPM**

# A TRL View of the GYS

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- **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

# Future Research: How can the OR community help promote sustainability?

- Embedding the sustainability agenda in classical optimisation models
- Research and development for:
  - Efficient and scalable solution methods
  - Data-driven decision models
- Multidisciplinary research
  - Interfaces with environmental science and sustainability
  - Integration with IT platforms and cloud-computing

# Acknowledgements

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  - Dr Navid Sahebjamnia, Dr Ramin Raeesi, Dr Trung Hieu tran



# Thank you for your attention!

## Questions, comments?

30 June 2021



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