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# A Hybrid Metaheuristic For Yard Crane Scheduling Problem considering Energy Consumption

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# Problem introduction



**Yard crane scheduling problem (YCSP)** determines the allocation and schedule of the yard cranes (RTG's and RS's) to the pending operational jobs.

Rubber Tyred Gantry crane (RTG)


Reach Stacker (RS)

*(Source: https://www.termavi.com/en/multimedia-2/)*

# Problem introduction

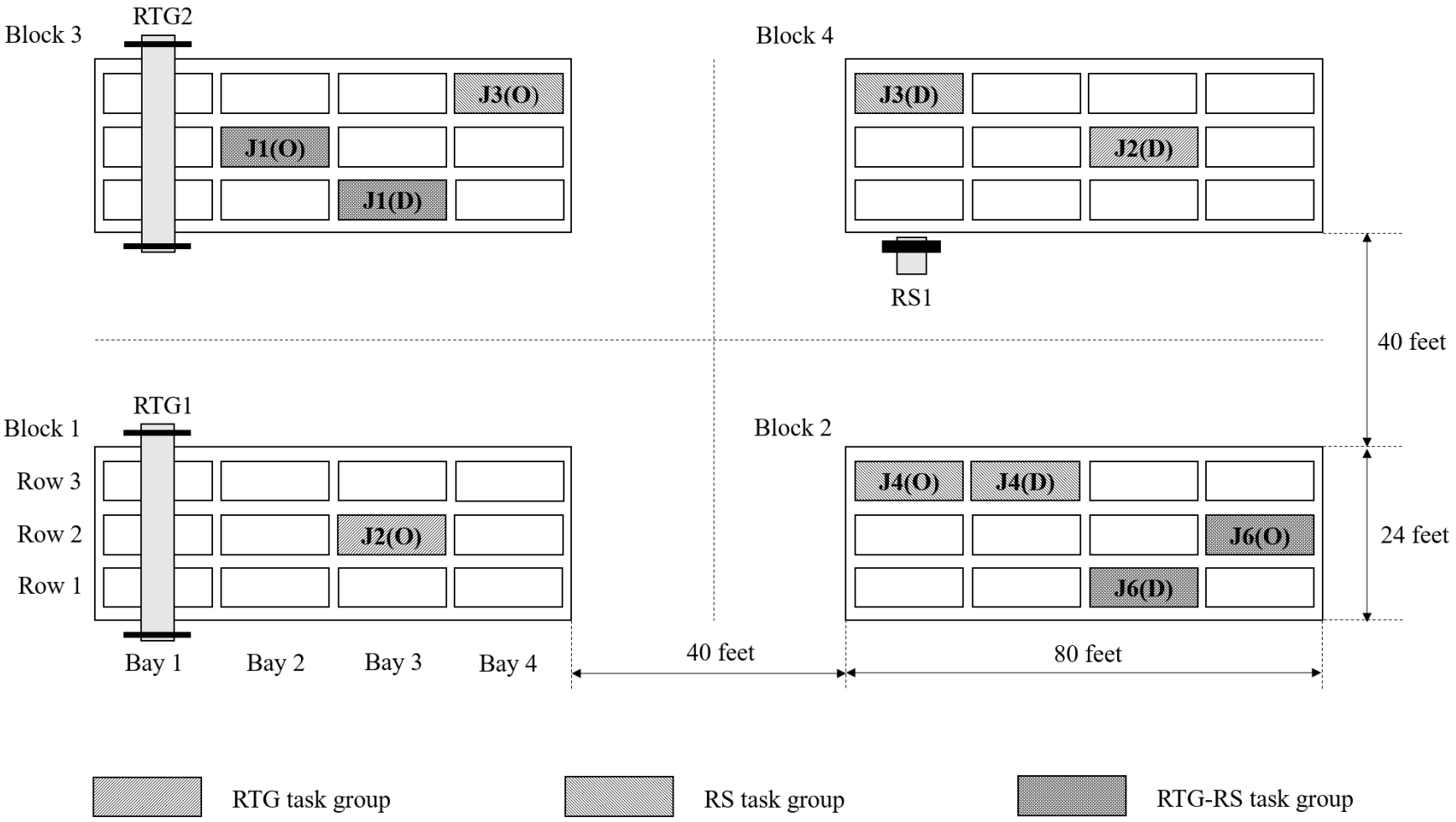


## Three task groups:

- RTG only tasks
- RS only tasks
- RTG-RS tasks

# Problem introduction

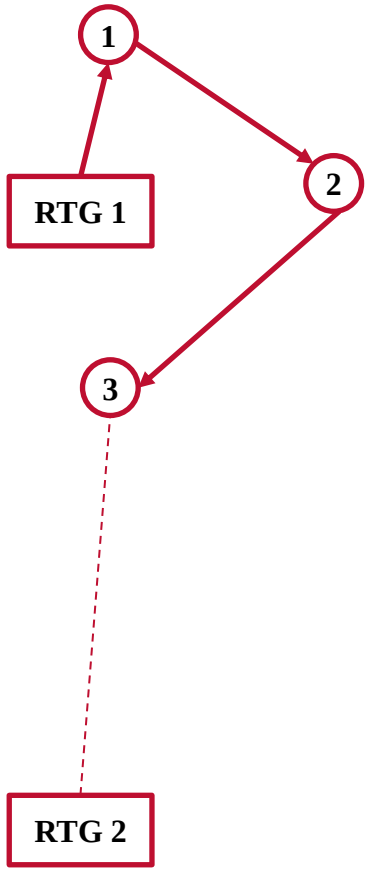




# YCSP Objectives



- Minimise the tardiness of container operations
- Minimise the energy consumption of yard cranes



# Literature review



He, J., Huang, Y., & Yan, W. (2015). Yard crane scheduling in a container terminal for the trade-off between efficiency and energy consumption. Advanced Engineering

Sha, M., Zhang, T., Lan, Y., Zhou, X., Qin, T., Yu, D., & Chen, K. (2017). Scheduling optimization of yard cranes with minimal energy consumption at container terminals. Computers & Industrial Engineering, 113, 704-713.

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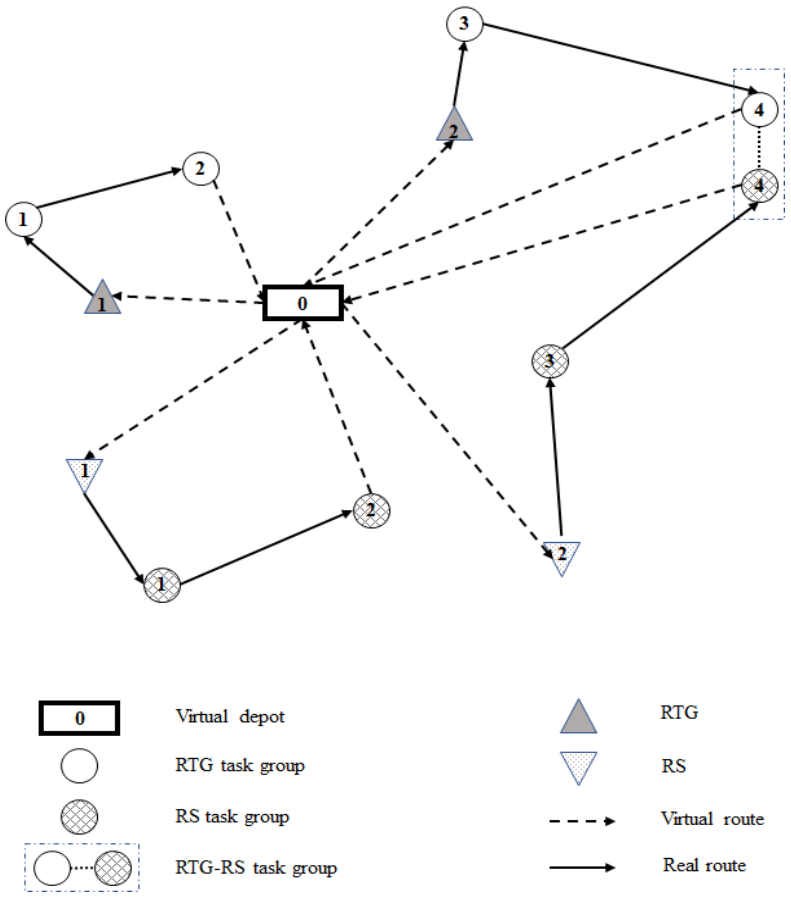
# Model formulation



**YCSP** is formulated as a **vehicle routing problem** with **time windows.**

- Each crane RTG/RS is considered as a vehicle
- Each container movement task is considered as a job/customer
- Each job has a independent time window



# Model formulation



## Decision variables

- $U_{kij}$ 1 if arc $(i,j)$ is traversed by RTG or RS $k$, and 0 otherwise
- $V_i$ Service starting time of RTG or RS for customer $i$

## Mixed integer nonlinear model for bi-objective

- Tardiness of all jobs $Minimise\ Z_1 = \Sigma_{i \in J} \max(V_i + s_i - b_i, 0)$,
- Energy consumption: moving energy and working energy of RTGs, moving energy and working energy of RSs

$$Minimise\ Z_2$$

$$= \sum_{k \in R_{RTG}} \sum_{i \in W} \sum_{j \in W, j \neq i} (t_{ij}^{RTG} \gamma^{RTG} + d_{ij} \delta^{RTG}) U_{kij} + \sum_{i \in J_{RTG}} (s_i \ \gamma^{RTG} + h_i \ \beta^{RTG})$$

$$+ \sum_{k \in R_{RS}} \sum_{i \in W} \sum_{j \in W, j \neq i} d_{ij} \delta^{RS} U_{kij} + \sum_{i \in J_{RS}} h_i \ \beta^{RS}$$

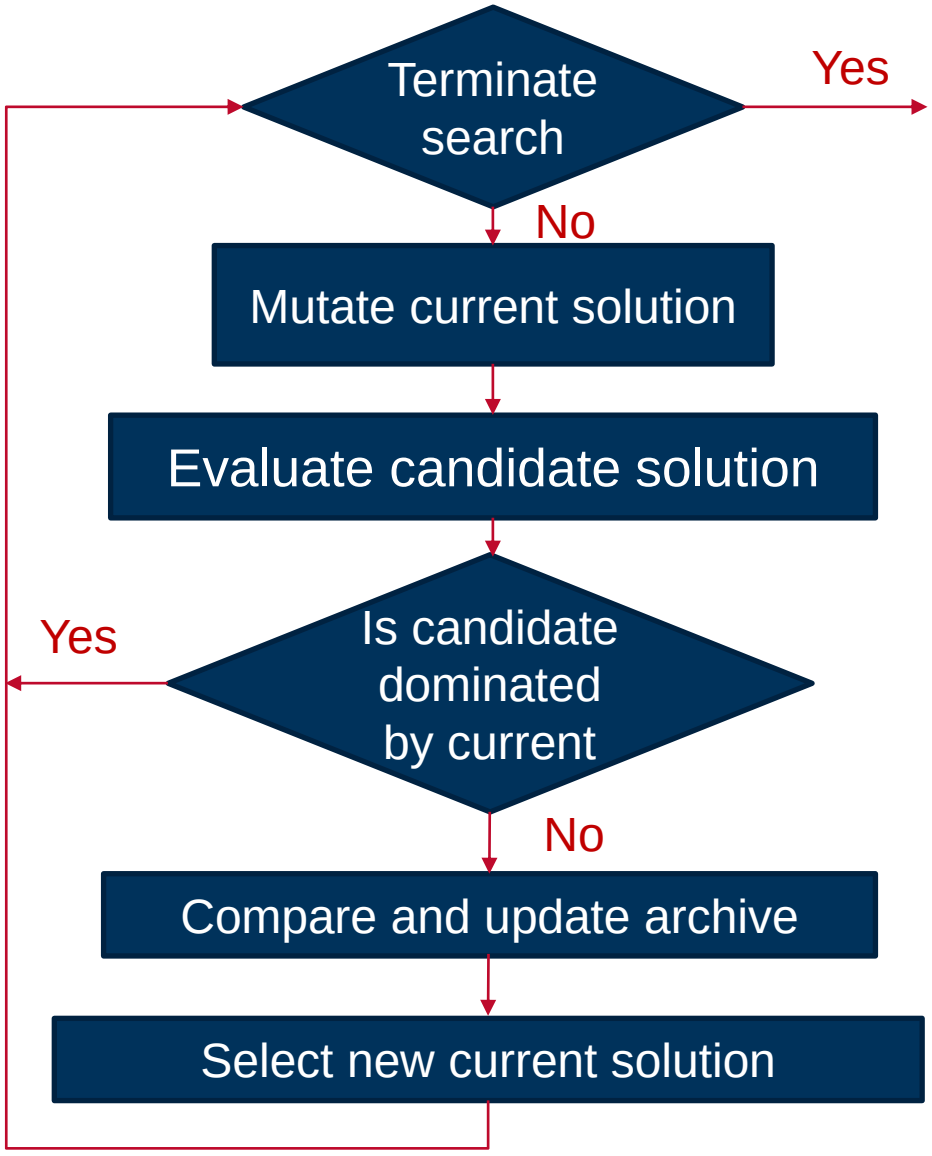
# A hybrid metaheuristic for YCSP



- A Pareto Archived Evolution Strategy (PAES)
- Simulated Annealing as local search
- Completing a job includes set-up time and processing time. The set-up time is sequence dependent. (Akpinar et al., 2012; Ruiz et al., 2004; Abreu et al., 2020)

# A hybrid metaheuristic for YCSP





# A hybrid metaheuristic for YCSP



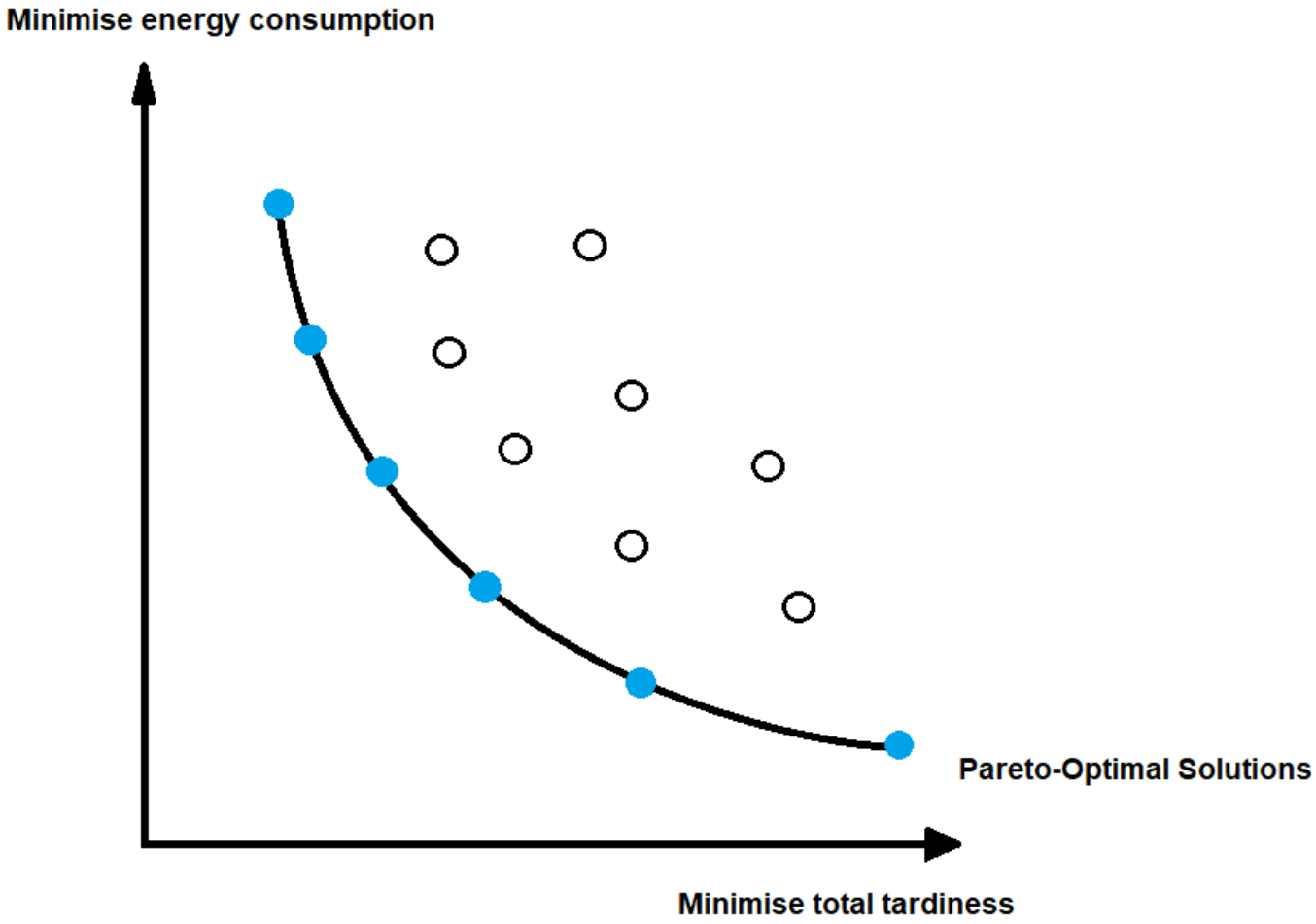
- Chromosome example

| | | | | | | |
|---|---|---|---|---|---|---|
| Crane 1 | 2 | 1 | 5 | 7 | 10 | 4 |
| Crane 2 | 9 | 3 | 6 | | | |
| Crane 3 | 8 | 11 | 12 | | | |

- Mutations
  - Insert a random job to another position
  - Swap a number of jobs between two cranes
  - Reverse a number of jobs in a random crane

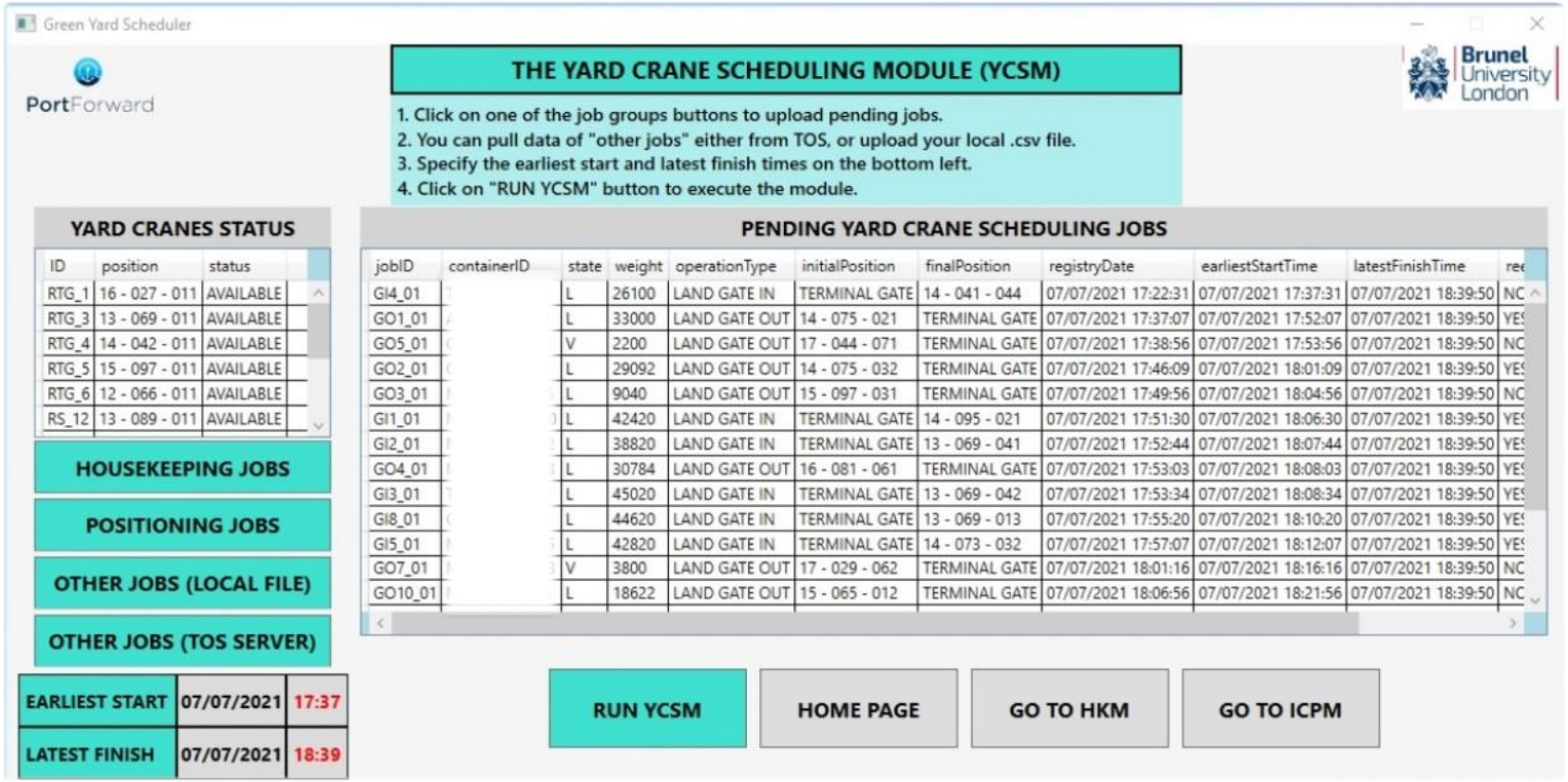
# Pareto frontier example





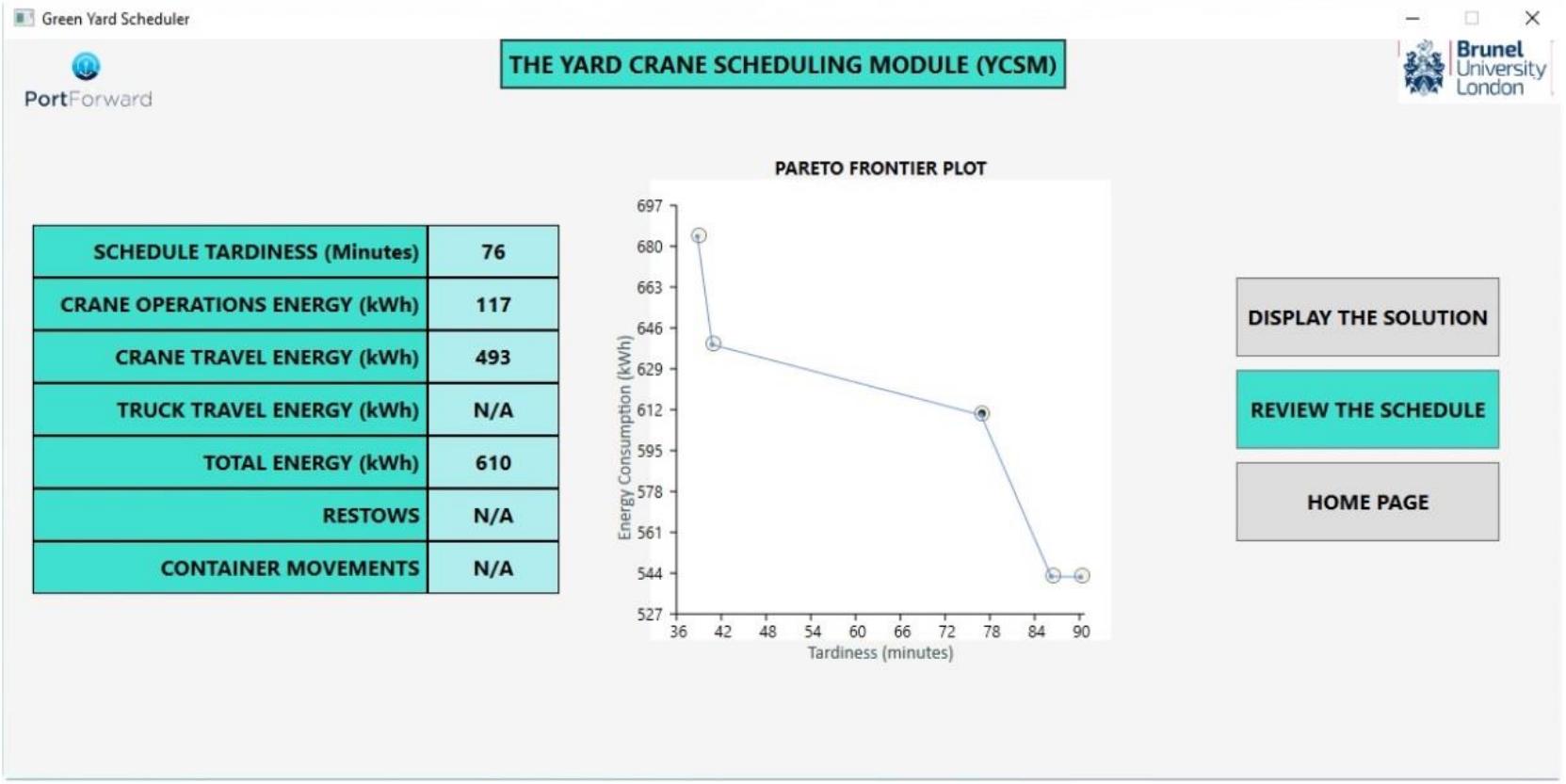
# Case study




Green Yard Scheduler
PortForward
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.
Brunel University London
YARD CRANES STATUS
ID position status
RTG_1 16 - 027 - 011 AVAILABLE
RTG_3 13 - 069 - 011 AVAILABLE
RTG_4 14 - 042 - 011 AVAILABLE
RTG_5 15 - 097 - 011 AVAILABLE
RTG_6 12 - 066 - 011 AVAILABLE
RS_12 13 - 089 - 011 AVAILABLE
HOUSEKEEPING JOBS
POSITIONING JOBS
OTHER JOBS (LOCAL FILE)
OTHER JOBS (TOS SERVER)
EARLIEST START 07/07/2021 17:37
LATEST FINISH 07/07/2021 18:39
PENDING YARD CRANE SCHEDULING JOBS
jobID containerID state weight operationType initialPosition finalPosition registryDate earliestStartTime latestFinishTime
GI4_01 L 26100 LAND GATE IN TERMINAL GATE 14 - 041 - 044 07/07/2021 17:22:31 07/07/2021 17:37:31 07/07/2021 18:39:50
GO1_01 L 33000 LAND GATE OUT 14 - 075 - 021 TERMINAL GATE 07/07/2021 17:37:07 07/07/2021 17:52:07 07/07/2021 18:39:50
GO5_01 V 2200 LAND GATE OUT 17 - 044 - 071 TERMINAL GATE 07/07/2021 17:38:56 07/07/2021 17:53:56 07/07/2021 18:39:50
GO2_01 L 29092 LAND GATE OUT 14 - 075 - 032 TERMINAL GATE 07/07/2021 17:46:09 07/07/2021 18:01:09 07/07/2021 18:39:50
GO3_01 L 9040 LAND GATE OUT 15 - 097 - 031 TERMINAL GATE 07/07/2021 17:49:56 07/07/2021 18:04:56 07/07/2021 18:39:50
GI1_01 L 42420 LAND GATE IN TERMINAL GATE 14 - 095 - 021 07/07/2021 17:51:30 07/07/2021 18:06:30 07/07/2021 18:39:50
GI2_01 L 38820 LAND GATE IN TERMINAL GATE 13 - 069 - 041 07/07/2021 17:52:44 07/07/2021 18:07:44 07/07/2021 18:39:50
GO4_01 L 30784 LAND GATE OUT 16 - 081 - 061 TERMINAL GATE 07/07/2021 17:53:03 07/07/2021 18:08:03 07/07/2021 18:39:50
GI3_01 L 45020 LAND GATE IN TERMINAL GATE 13 - 069 - 042 07/07/2021 17:53:34 07/07/2021 18:08:34 07/07/2021 18:39:50
GI8_01 L 44620 LAND GATE IN TERMINAL GATE 13 - 069 - 013 07/07/2021 17:55:20 07/07/2021 18:10:20 07/07/2021 18:39:50
GI5_01 L 42820 LAND GATE IN TERMINAL GATE 14 - 073 - 032 07/07/2021 17:57:07 07/07/2021 18:12:07 07/07/2021 18:39:50
GO7_01 V 3800 LAND GATE OUT 17 - 029 - 062 TERMINAL GATE 07/07/2021 18:01:16 07/07/2021 18:16:16 07/07/2021 18:39:50
GO10_01 L 18622 LAND GATE OUT 15 - 065 - 012 TERMINAL GATE 07/07/2021 18:06:56 07/07/2021 18:21:56 07/07/2021 18:39:50
RUN YCSM
HOME PAGE
GO TO HKM
GO TO ICPM

# Case study




Green Yard Scheduler
PortForward
THE YARD CRANE SCHEDULING MODULE (YCSM)
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PARETO FRONTIER PLOT
Energy Consumption (kWh)
697
680
663
646
629
612
595
578
561
544
527
36
42
48
54
60
66
72
78
84
90
Tardiness (minutes)
SCHEDULE TARDINESS (Minutes) 76
CRANE OPERATIONS ENERGY (kWh) 117
CRANE TRAVEL ENERGY (kWh) 493
TRUCK TRAVEL ENERGY (kWh) N/A
TOTAL ENERGY (kWh) 610
RESTOWS N/A
CONTAINER MOVEMENTS N/A
DISPLAY THE SOLUTION
REVIEW THE SCHEDULE
HOME PAGE

# Conclusions



- Future work

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

# Thank you for your attention! Questions, comments?

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# References



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Levi R. Abreu, Jesus O. Cunha, Bruno A. Prata, Jose M. Framinan, A genetic algorithm for scheduling open shops with sequence-dependent setup times, Computers & Operations Research, Volume 113, 2020.