DIGITAL SUSTAINABLE LOGISTICS NEXUS

Computational Modelling of a Carrier Assignment Problem under the ROAR-NET API

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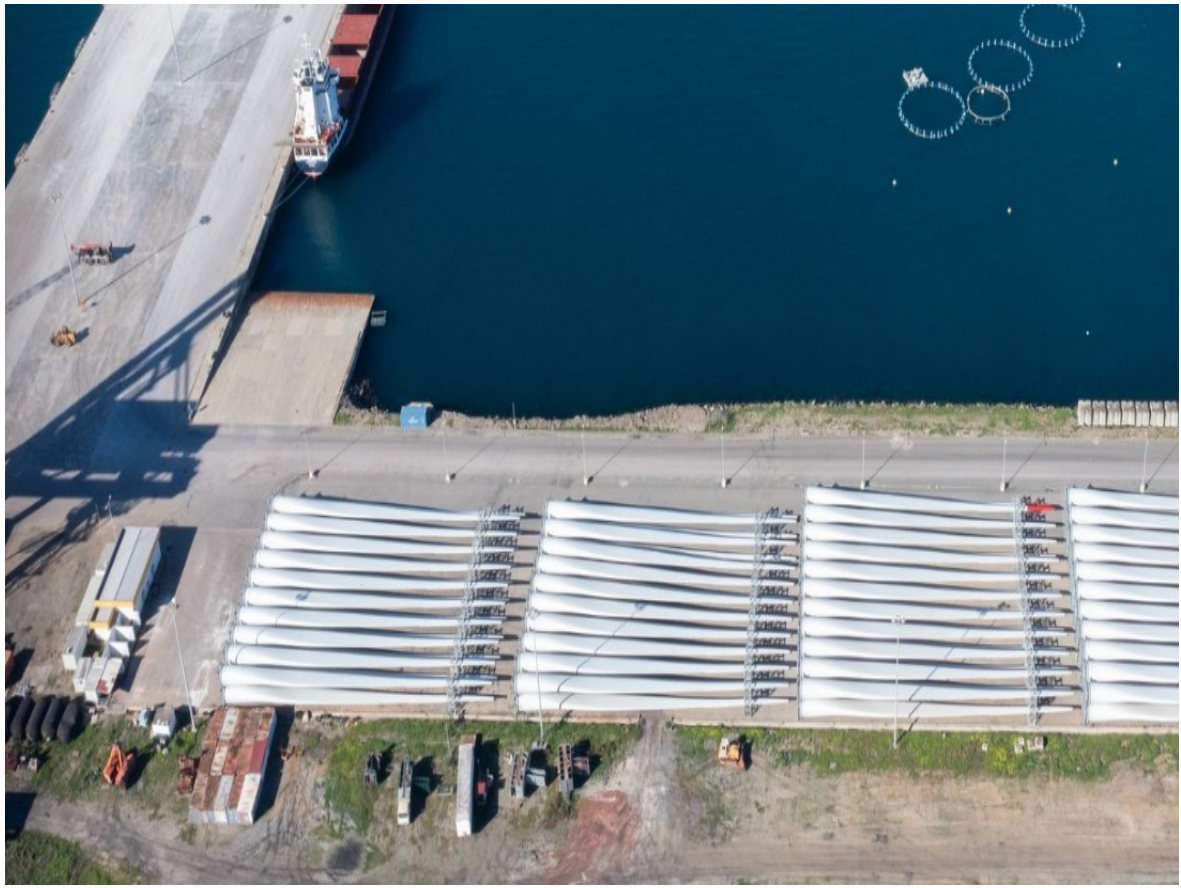
The NEXUS Agenda Consortium

- Led by the Port of Sines
- 35 Partners
  - Port authorities, maritime and terminal operators
  - Railway operators, carriers, dry ports, logistics operators
  - Technology suppliers, importers, exporters
  - Universities and research institutes
- Shipperform
  - Service procurement platform under development by Devlop
  - Spot quotes, tender and contract support



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Tenders in Shipperform

- The Shipper discloses the lanes: **origin**, **destination**, **load volume**
- Carriers submit their bids: **lane**, **carrier**, **load volume**, **price**
  - Bidding on **partial lane load volumes** allowed
- The Shipper determines the winning bids
  - A set of lane-carrier assignments (many to many)

  considering
  - Price vs. unassigned load volume
  - Maximum numbers of carriers (total, for each lane, for each location)
  - Maximum volume for each carrier
- Unassigned load volume is dealt with in a new tender round

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Approach

Problem statement

Solver-independent local-search model based on the ROAR-NET API

Multiple objectives and constraints handled via a preference model

Preference-aware Pareto Local Search

Other local-search solvers available off the shelf (SA, ILS, ...)

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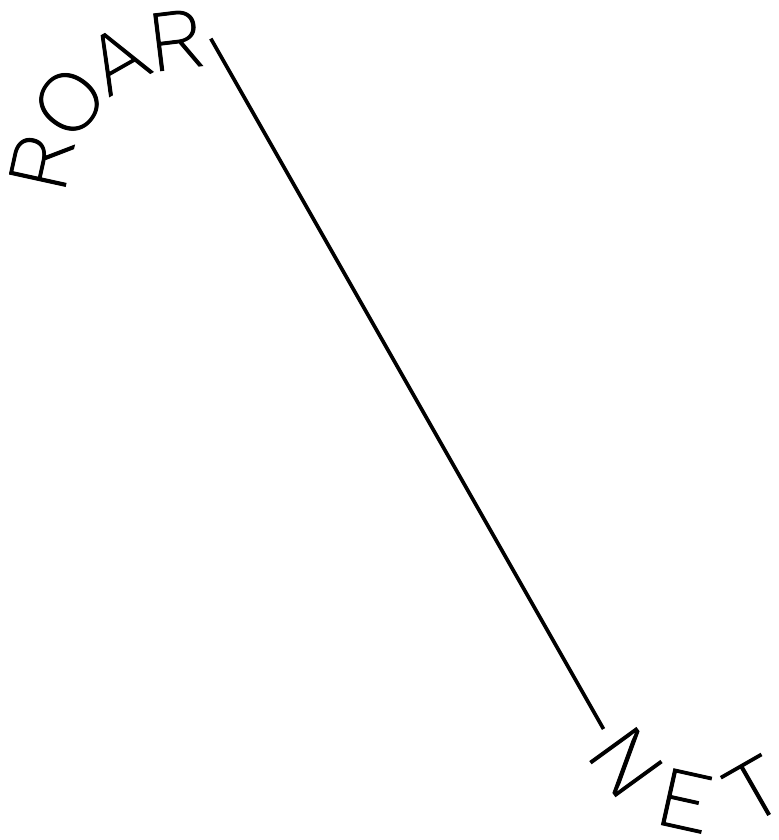
The ROAR-NET API Specification*



- Types
  - **Problem, Solution**
  - **Neighbourhood, Move** (construction, destruction, **local search**)
- Operations
  - Solution generation: **empty_solution**, random_solution, **heuristic_solution**
  - Solution evaluation: **objective_value**, lower_bound
  - Neighbourhood exploration: **moves**, random_move, random_moves_without_replacement
  - Solution modification: **apply_move**, revert_move
  - Move evaluation: **objective_value_increment**, lower_bound_increment

* https://github.com/roar-net/roar-net-api-spec

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Model Development

Under the ROAR-NET API Python implementation*

- Problem representation
  - Lists of lanes and bids
  - Constraints on carriers and locations
- Solution representation
  - Carriers assigned to each lane (list of sets)
  - Lanes assigned to each carrier (list of sets, auxiliary)
  - Objective values (list of integers)
  - Additional data structures to support incremental evaluation

* https://github.com/roar-net/roar-net-api-py

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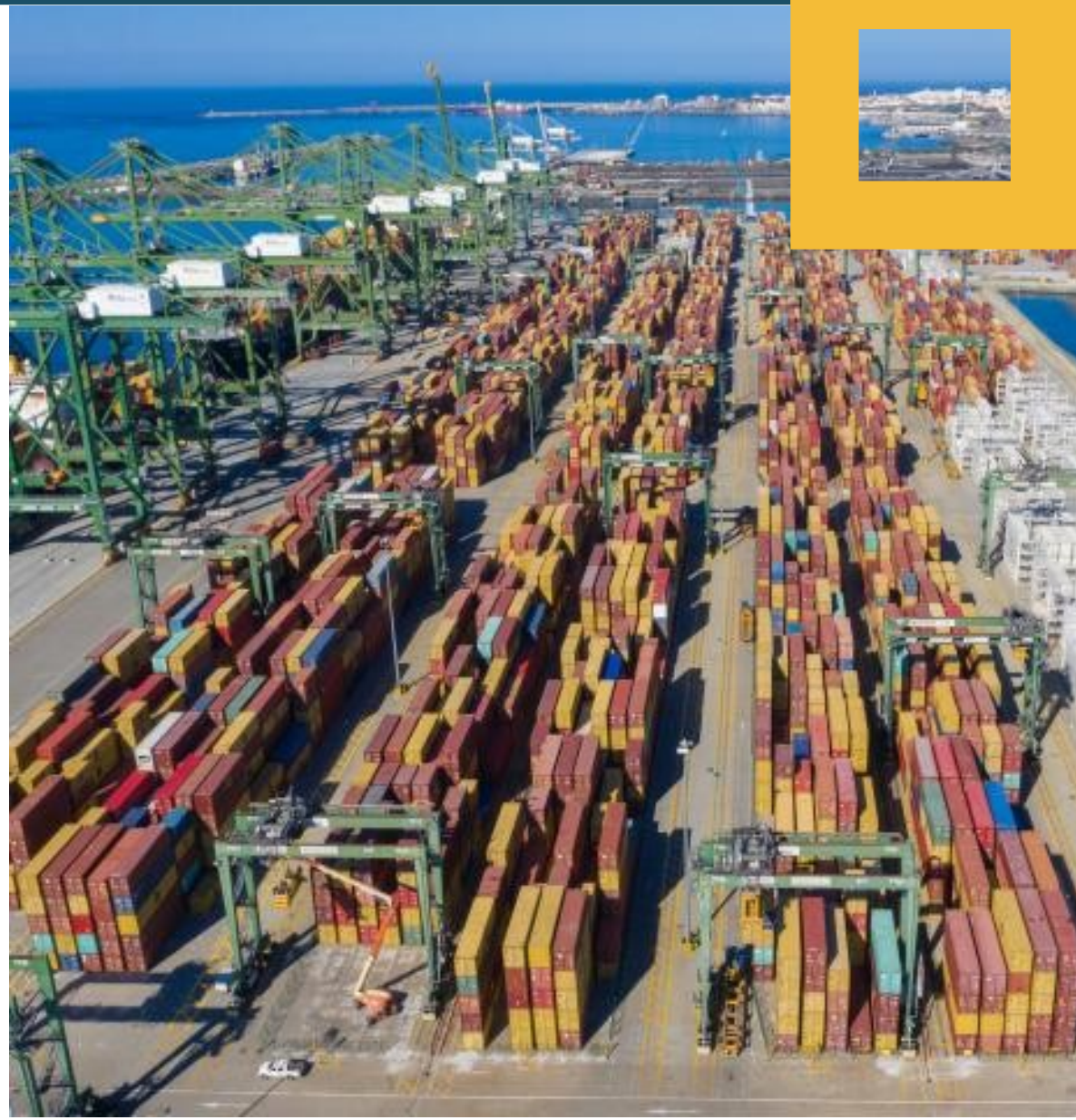
Model Development

- Solution evaluation
  - Main objectives (to be minimised)
    - Cost
    - Unassigned load volume
  - Constraints:
    - Sum of excess load volume per carrier
    - Sum of excess carriers per lane
    - Sum of excess carriers per location
    - Total number of carriers

NOTE: Lane load volume is always respected by the search operators (structural constraint)



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Model Development

- Solution evaluation
  - Limits on numbers of carriers and load volumes may vary with lane, location and carrier
  - Handling each such constraint as a separate function would lead to significant overhead when comparing solutions
  - Aggregating related constraints
    - Maximum violation would lead to bottleneck constraints
    - Sum of violations more efficient and effective
  - Objective and constraint function values are updated incrementally for efficiency

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Model Development

- Neighbourhood structures
  - Ensure connectivity of the whole decision space
    1) Add bid to lane
    2) Remove bid from lane
  - Knapsack-like constraints
    3) Remove a bid from a lane and Add another bid to the same lane
    4) Remove a bid by a carrier and Add another bid by the same carrier
  - Bottleneck constraints (in progress…)
    5) Remove all bids by a carrier that involve a given location
    6) Remove all bids by a carrier

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Model Development

- Neighbourhood structures
  - Exposed to the solver individually or as a single, combined neighbourhood
  - Move enumeration in constant time per move
  - Move evaluation
    - In constant time for neighbourhood structures 1) to 4)
    - In time linear on the number of relevant lanes for neighbourhood structures 5) and 6)
  - Cost of evaluating all 6) moves similar to the cost of evaluation all 2) moves
  - Cost of evaluating all 5) moves up to twice the cost of evaluation all 2) moves
  - Modifying a solution has the same complexity as move evaluation (in **this** model)

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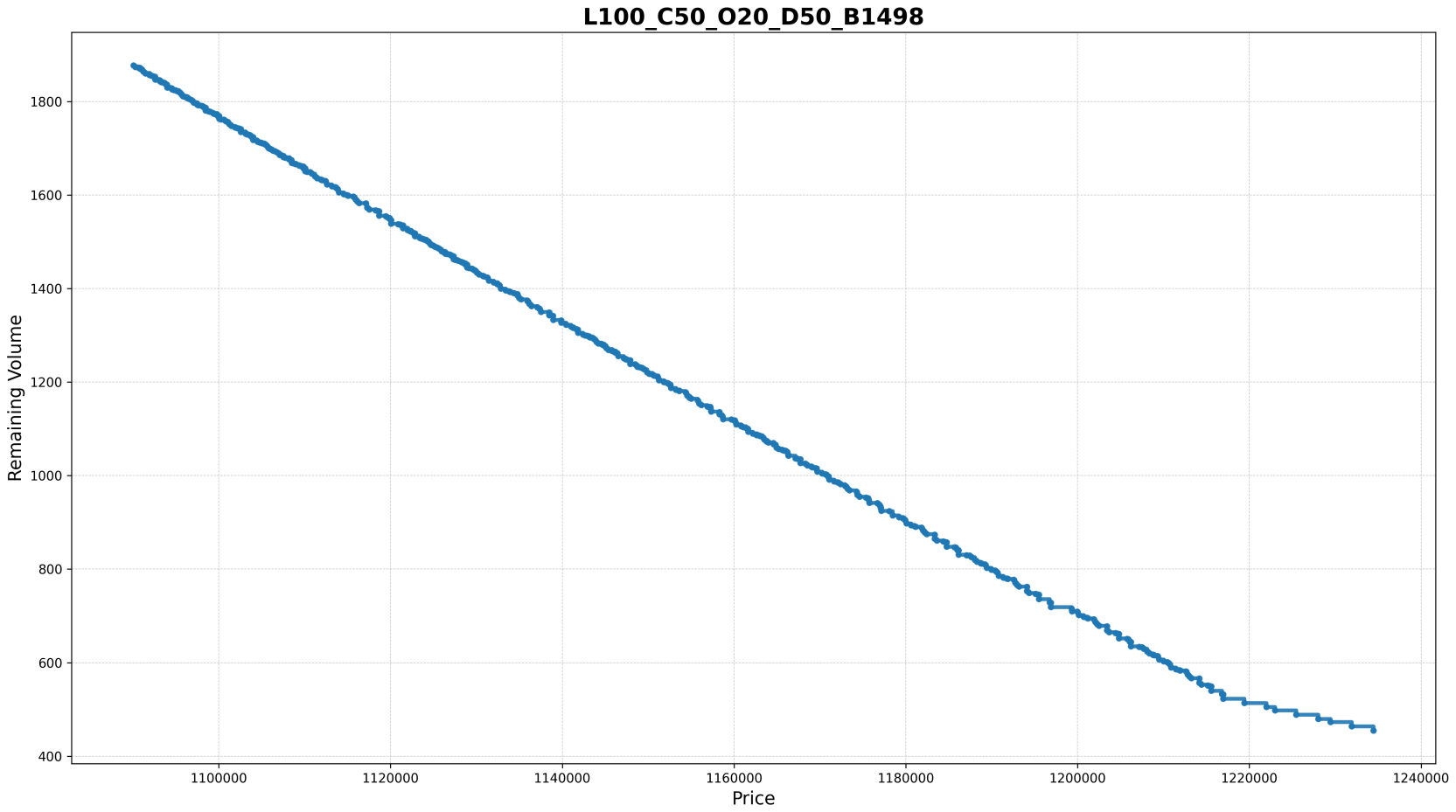
Preference model

- ROAR-NET API preference models
  - Specification under development
  - Support for scalarisations and partial pre-orders
- Preferability relation (Fonseca and Fleming, 1998)
  - Refinement of Pareto dominance given goals and priorities
  - Unified handling of hard and soft constraints
- Model configuration
  - Cost and unassigned load volume assigned priority 0 (soft objectives)
  - Goal values for each objective set to simple upper bounds
  - Constraints assigned priority 1, goals set to the applicable limits (zero or max. no. carriers)

Preference-Aware Pareto Local Search

- Pareto Local Search (Paquete *et al.*, 2004) with dominance replaced by preferability
- Very simple multiobjective extension of local search
- Goal values define region of interest
- Results sensitive to initial solution(s)



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Concluding Remarks

A **problem model** rather than a dedicated algorithm

Structural vs. functional constraints

Multiple objectives

Preferences

Solver development handled separately

Integration in Shipperform due soon

Real-world use case of the ROAR-NET API

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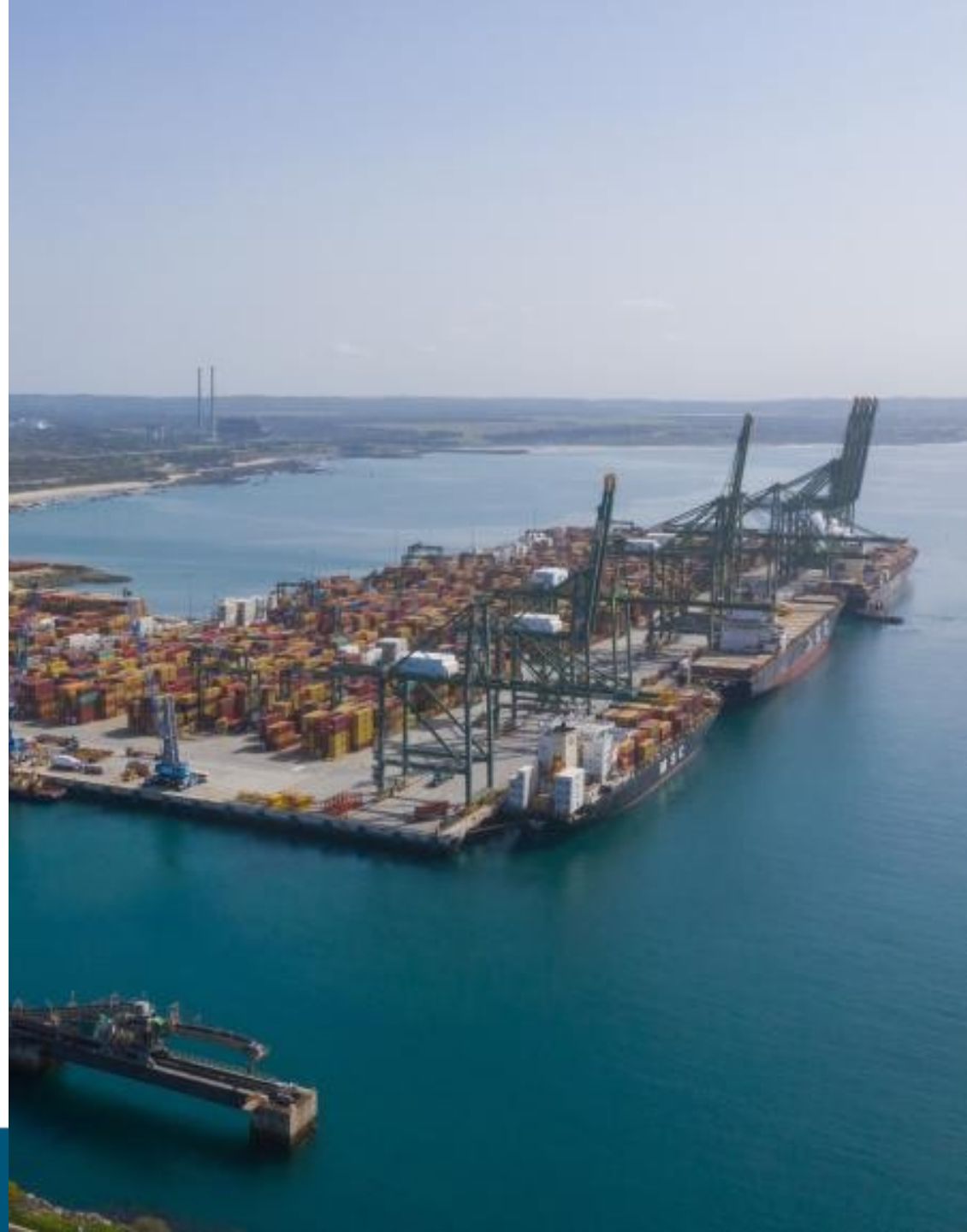

Thank You!

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