INTEGRATED SCHEDULING OF DRAYAGE AND LONG-HAUL TRANSPORTATION IN SYNCHROMODALITY

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- Problem and model description
- Heuristic approach
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“In an intermodal transportation chain, the initial and final trips represent 40% of total transport costs.”

SYNCHROMODALITY
WHAT IS SYNCHROMODAL TRANSPORTATION?

*Source of video: Dutch Institute for Advanced Logistics (DINALOG) www.dinalog.nl

UNIVERSITY OF TWENTE.
EXAMPLE TRADE-OFF
TRANSPORTATION OF CONTAINERS FROM TWENTE TO ROTTERDAM

*Source of artwork: Combi Terminal Twente (CTT) www.ctt-twente.nl
UNIVERSITY OF TWENTE.
PROBLEM DESCRIPTION

- **Schedule when (and where) to transport each freight** to achieve minimum costs over the network and over time.
PROBLEM DESCRIPTION

A stochastic optimization problem over a finite horizon where:

- Random freights arrive
- Sequential schedules are made
SCHEDULING DRAYAGE TRANSPORTATION

Full-Truckload Pickup-and-Delivery Problem with Time-Windows (FTPDPTW) to route trucks and assign terminals:

- Assignment of initial terminal for the long-haul of freights

SCHEDULING LONG-HAUL TRANSPORTATION

Markov Decision Process (MDP) to consolidate freights in daily barges or postpone their transport:

- **Arrival of freight is stochastic and dependent on drayage decisions**
INTERMEZZO – SOME PUBLICITY
WWW.TRUCKSANDBARGES.NL
The goal is to minimize the total expected network-wide costs, where the drayage schedule depends on the long-haul policy, and where the long-haul policy depends on the arrivals from the drayage schedule.

$$\min_{\pi \in \Pi} \mathbb{E} \left[ \sum_{t \in T} \left( z_t^D(x_{t,\pi}^D) + z_t^L(x_{t,\pi}^D) \right) \right]$$

where

$$x_{t,\pi}^D = \arg\min_{x_t^D \in \mathcal{X}_t^D} \mathbb{Z}_t(x_t^D)$$

and

$$\Gamma\left( \mathcal{P}_t^D, \mathcal{X}_t^D \right) = \mathcal{P}_t^L$$
HEURISTIC APPROACH
HEURISTICS FOR THE DRAYAGE SCHEDULE AND LONG-HAUL POLICY

- We use a Matheuristic (MH) for scheduling drayage transportation, which uses various cuts based on the ‘terminal assignment cost’ resulting from the long-haul policy.

- We use an Approximate Dynamic Programming (ADP) algorithm for learning a long-haul policy, i.e., Value Function Approximation (VFA), based on the observed distributions from a simulation of the MH.
HEURISTIC APPROACH
INTEGRATION OF THE TWO HEURISTICS

Sequential Integration

Overall drayage probabilities $P^D$

(A) Define long-haul probabilities $P^L_{\pi}$ using $\Gamma$

(B) Run ADP using $P^L_{\pi}$

Convert VFA into $C^L_t, \forall t \in T$, to use in the MH

Iterative Integration

VFA for drayage and long-haul scheduling

No

Yes

(D) Stop?

Observed drayage decisions and arrival distribution

(C) Simulate drayage $(x^D_{t,\pi})$ + long-haul $(x^L_{t,\pi})$ scheduling.
NUMERICAL EXPERIMENTS
INSTANCES SETUP

Freight demand: 20 freights per day (≈Poisson dist.)

Drayage location: Random (R) or Clustered (C).

Drayage type: Pre-haulage (P) or End-haulage (E).

Long-haul Destinations: Balanced (B) or Unbalanced (U).
We divide the experiments in two phases:

1. **Calibration phase:**
   - Settings for heuristic parameters.
   - Influence in drayage and long-haul schedules.

2. **Evaluation phase:**
   - Savings with respect to a benchmark approach commonly found in practice.
   - Sensitivity to different cost setups.
NUMERICAL EXPERIMENTS
CALIBRATION PHASE – PARAMETERS FOCUS ON DRAYAGE OR LONG-HAUL

**Figure 6.10:** Total Costs C-P-U

**Figure 6.11:** Individual Costs C-P-U
### NUMERICAL EXPERIMENTS

**EVALUATION PHASE – NORMAL COST SETUP**

![Bar chart showing percentage savings in total costs for different instances.]

**Table 1:** Percentage difference with the benchmark in normal drayage-cost setup

<table>
<thead>
<tr>
<th>Instance</th>
<th>R-P-U</th>
<th>R-P-B</th>
<th>R-E-U</th>
<th>R-E-B</th>
<th>C-P-U</th>
<th>C-P-B</th>
<th>C-E-U</th>
<th>C-E-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-haul Costs</td>
<td>-10%</td>
<td>-14%</td>
<td>-63%</td>
<td>-65%</td>
<td>-14%</td>
<td>-13%</td>
<td>-63%</td>
<td>-65%</td>
</tr>
<tr>
<td>Drayage Costs</td>
<td>17%</td>
<td>18%</td>
<td>33%</td>
<td>32%</td>
<td>16%</td>
<td>12%</td>
<td>21%</td>
<td>22%</td>
</tr>
<tr>
<td>Long-haul Utilization</td>
<td>4%</td>
<td>1%</td>
<td>-55%</td>
<td>-55%</td>
<td>5%</td>
<td>0%</td>
<td>-56%</td>
<td>-55%</td>
</tr>
<tr>
<td>Pre-haulage Closest</td>
<td>-21%</td>
<td>-27%</td>
<td>-82%</td>
<td>-81%</td>
<td>-37%</td>
<td>-35%</td>
<td>-81%</td>
<td>-82%</td>
</tr>
</tbody>
</table>
### Table 6.5: Percentage difference with the benchmark in high drayage-cost setup

<table>
<thead>
<tr>
<th>Instance</th>
<th>Costs</th>
<th>Long-haul Utilization</th>
<th>Pre-haulage to closest terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Long-haul</td>
<td>Drayage</td>
</tr>
<tr>
<td>R-P-U</td>
<td>3%</td>
<td>-12%</td>
<td>6%</td>
</tr>
<tr>
<td>R-P-B</td>
<td>5%</td>
<td>-5%</td>
<td>7%</td>
</tr>
<tr>
<td>R-E-U</td>
<td>13%</td>
<td>-62%</td>
<td>29%</td>
</tr>
<tr>
<td>R-E-B</td>
<td>12%</td>
<td>63%</td>
<td>30%</td>
</tr>
<tr>
<td>C-P-U</td>
<td>-9%</td>
<td>50%</td>
<td>-20%</td>
</tr>
<tr>
<td>C-P-B</td>
<td>-12%</td>
<td>38%</td>
<td>-23%</td>
</tr>
<tr>
<td>C-E-U</td>
<td>4%</td>
<td>-64%</td>
<td>19%</td>
</tr>
<tr>
<td>C-E-B</td>
<td>3%</td>
<td>-64%</td>
<td>18%</td>
</tr>
</tbody>
</table>
CONCLUSIONS

We proposed the integration of a MH for drayage scheduling and an ADP for long-haul scheduling through (i) the inclusion of long-haul assignment costs in drayage decisions, and (ii) an improved VFA in the long-haul decisions.

- Numerical experiments show that our integrated scheduling approach performs up to 38% better than separated scheduling in terms of total network costs, with larger drayage costs.

- Further research on the integration mechanisms of the MH and ADP, and their calibration, is necessary to achieve the most of integrated scheduling in synchromodal transport.
THANKS FOR YOUR ATTENTION!

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