Combined Scheduling of Pre-haulage and Long-haul Freight Transportation

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1. Introduction

We study the combined scheduling of pre-haulage and long-haul transportation of freight in an intermodal/synchromodal network. The pre-haulage of freights is performed by trucks that also execute other drayage operations. The long-haul transportation of freights is performed by high-capacity modes that depart from different terminals.

Example trade-off: Consider a Logistics Service Provider (LSP) choosing a terminal to bring a freight for the start of the long-haul. A trade-off occurs when terminal which has the best consolidation for the long-haul (lowest long-haul costs) is not the closest terminal to the origin of the freight (not the lowest pre-haulage costs).

2. Problem Description

We consider a stochastic optimization problem over a finite time horizon $t \in T$ where:

- Random freights $F_t$ with different characteristics arrive.
- Trucks performing drayage operations are routed to terminals for pre-haulage freights are assigned in a drayage schedule $x_t^D$ with costs $c_t^D(x_t^D)$.
- Long-haul freights at each terminal are either consolidated in a high-capacity mode or postponed for future consolidation in a long-haul schedule $x_t^L$ with costs $c_t^L(x_t^L)$.

The goal is to minimize the total expected costs in (1), where $x_t^D$ is a drayage schedule dependent on a long-haul policy $\pi \in \Pi$. $f_t^D$ represents the initial long-haul freights at terminals, $P^D$ describes the stochastic arrival process of freights for drayage (i.e., $P^D \rightarrow F_t$), and $\Gamma$ is a function that defines the long-haul probabilities $P^L_t$ from the drayage decisions.

$$\min_{\pi \in \Pi, t \in T} \sum_{t \in T} \left[ c_t^D(x_t^D) + c_t^L(x_t^L) \right] f_t^D, P^D, \Gamma$$

3. Mathematical Model

- Drayage operations are modeled as a full-truckload pickup-and-delivery problem with time-windows (FTPDPTW).
- There is an assignment cost $C_t^D$ that depends on long-haul freights at each terminal and the assignment decision of freights picked-up.
- Long-haul transportation is modeled as a Markov Decision Process (MDP).
- Arrival probabilities $P_t^D$ of long-haul freight at the terminals (i.e., origins of the high-capacity modes) depend on drayage decisions.

4. Solution Approach

We use a Math-Heuristic (MH) for the FTPDPTW and Approximate Dynamic Programming (ADP) for the MDP.

- The MH algorithm uses various cuts based on the assignment cost $C_t^D$ resulting from the Value Function Approximation (VFA) of ADP.

There are two challenges in our approach:

1. The overall probability distributions $P_t^D$ must be mapped to the long-haul probabilities $P_t^L$ based on drayage scheduling observations.

2. The assessment of when the VFA is good enough involves the analysis of the total costs and the stability of drayage and long-haul scheduling decisions.

5. Preliminary Results

In numerical experiments, we calibrated our combined scheduling approach and compared it against a not-combined benchmark using various instances:

![Graph showing total costs savings compared to the benchmark](image)

<table>
<thead>
<tr>
<th>Instance legend: Location</th>
<th>Drayage freight: random (R) or clustered (C).</th>
<th>Majority of drayage freight: pre-haulage (P) or end-haulage (E).</th>
<th>Destinations of pre-haulage freight: balanced (B) or unbalanced (U).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instance</td>
<td>BC-P</td>
<td>RP-P</td>
<td>RC-P</td>
</tr>
<tr>
<td>Drayage Costs</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Pre-haulage/Costs</td>
<td>-25</td>
<td>-20</td>
<td>-15</td>
</tr>
</tbody>
</table>

6. Conclusions

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

- Preliminary results show that our approach performs up to 38% better than a separated scheduling benchmark in terms of total costs.

- Future research on the integration mechanisms of the MH and ADP, and their calibration, is necessary to achieve the most of our approach.

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