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).

Figure 1: Problem inspired by Combi Terminal Twente (CTT), a Dutch LSP. Source figure: www.ctt-twente.nl

2. Problem Description

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

- Random freights $\mathcal{F}_t$ with different characteristics arrive.
- Trucks performing drayage operations are routed and terminals for pre-haulage freights are assigned in a drayage schedule x_t^{D} with costs $z_t^{\mathrm{D}}(x_t^{\mathrm{D}})$.
- 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 $z_t^{\mathrm{L}}(x_t^{\mathrm{L}})$.

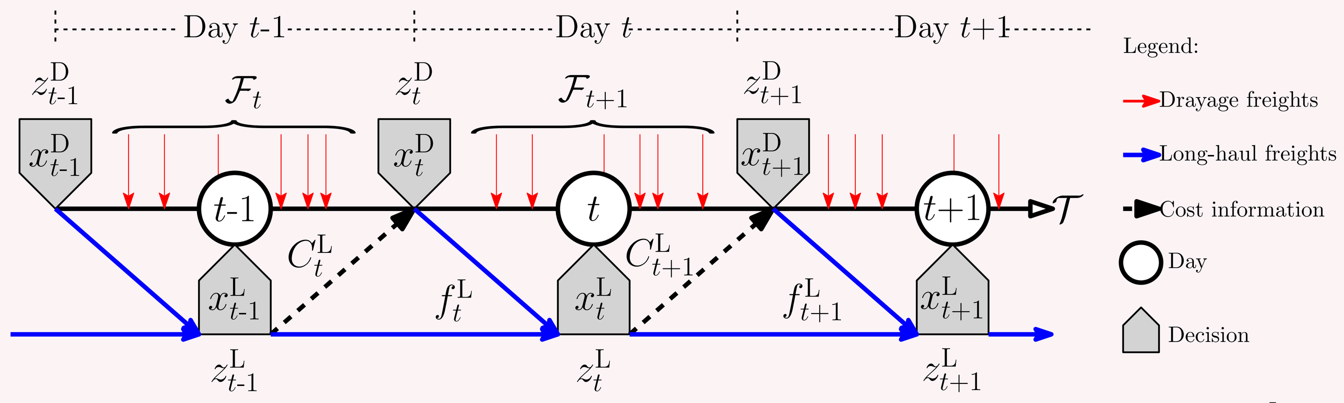

Figure 2: Timing of freight arrivals and decisions. The terminal assignment cost is denoted by C_t^{L} and depends on long-haul freights f_t^{L} present at the terminals.

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^{L} 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 $\mathcal{P}^{\mathrm{L}}$ of long-haul freight at the terminals (i.e., origins of the high-capacity modes) depend on drayage decisions.

The goal is to minimize the total expected costs in (1), where $x_{t,\pi}^{\mathrm{D}}$ is a drayage schedule dependent on a long-haul policy $\pi \in \Pi$, f_0^{L} represents the initial long-haul freights at terminals, $\mathcal{P}^{\mathrm{D}}$ describes the stochastic arrival process of freights for drayage (i.e., $\mathcal{P}^{\mathrm{D}} \to \mathcal{F}_t$), and Γ is a function that defines the long-haul probabilities $\mathcal{P}_\pi^{\mathrm{L}}$ from the drayage decisions.

$$\min_{\pi \in \Pi} \mathbb{E}\left[\sum_{t \in \mathcal{T}} \left(z_t^{\mathrm{D}}\left(x_{t,\pi}^{\mathrm{D}}\right) + z_t^{\mathrm{L}}\left(x_{t,\pi}^{\mathrm{L}}\right)\right) \middle| f_0^{\mathrm{L}}, \mathcal{P}^{\mathrm{D}}, \Gamma\right] \tag{1}$$

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^{L} resulting from the Value Function Approximation (VFA) of ADP.
- The *ADP* algorithm learns the VFA based on the observed distributions $\mathcal{P}_\pi^{\mathrm{L}}$ from a simulation of the problem using the integrated MH.

There are two challenges in our approach:

1. The overall probability distributions $\mathcal{P}^{\mathrm{D}}$ must be mapped to the long-haul probabilities $\mathcal{P}_\pi^{\mathrm{L}}$ 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.

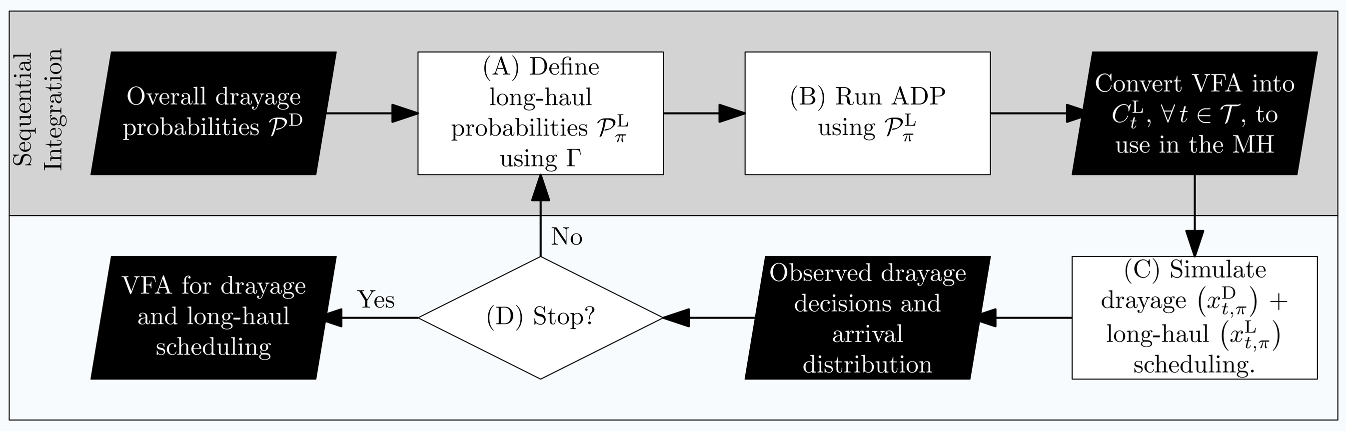

Figure 3: Proposed solution approach to the combined scheduling problem

5. Preliminary Results

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

Instance legend: *Location drayage freight:* random (R) or clustered (C). *Majority of drayage freight:* pre-haulage (P) or end-haulage (E). *Destinations of pre-haulage freight:* balanced (B) or unbalanced (U).

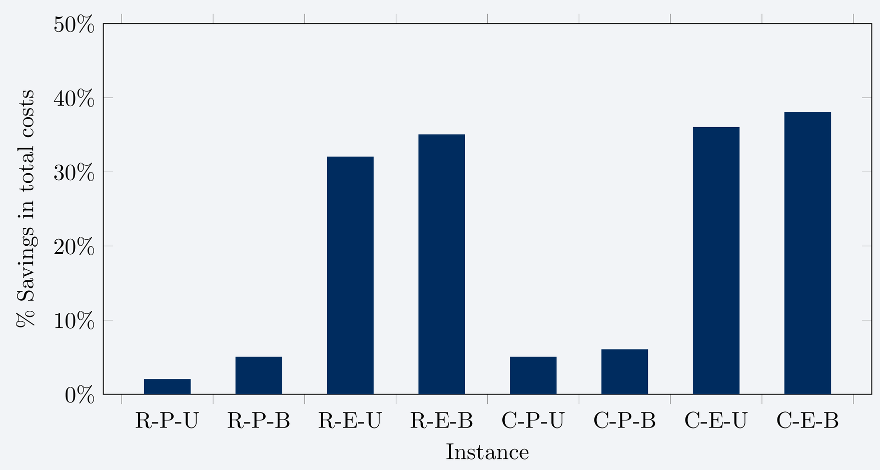

Figure 4: Total costs savings compared to the benchmark

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

Instance	R-P-U	R-P-B	R-E-U	R-E-B	C-P-U	C-P-B	C-E-U	C-E-B
Long-haulCosts	-10%	-14%	-63%	-65%	-14%	-13%	-63%	-65%
DrayageCosts	17%	18%	33%	32%	16%	12%	21%	22%
Long-haulUtilization	4%	1%	-55%	-55%	5%	0%	-56%	-55%
Pre-haulageClosest	-21%	-27%	-82%	-81%	-37%	-35%	-81%	-82%

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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