A Large Neighborhood Search approach for the Daily Drayage Problem with Time Windows

Diana Abi-Nader[1,2], Nabil Absi[1], Dominique Feillet[1], Thierry Garaix[1], Cyriac Azefack[2], Taki Eddine Korabi[2]

[1] Mines Saint-Etienne, Univ Clermont Auvergne, INP Clermont Auvergne, CNRS, UMR 6158 LIMOS,
F - 42023 Saint-Etienne France
{diana.serhal,absi,feillet,garaix}@emse.fr

[2] DMS Logistics, 7 rue de la Republique, 13002 Marseille, France
{diana.abi.nader,cyriac.azefack,taki.korabi}@dms-logistics.io

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1 Introduction

As part of intermodal transportation, drayage operations are movements of empty and full containers in the hinterland area of an intermodal terminal. We consider a truck company owning a fleet of trucks and that receives a set of import and export missions from different clients to fulfill. The trucks start their journey from the truck company yard and execute the assigned missions by moving containers between different locations (depots where containers are stored, industrial customers and terminals) while respecting the associated time windows. This problem is known as the Daily Drayage Problem with Time Windows (DDPTW) [1].

The problem can be seen as a generalization of the Pickup and Delivery Problem with Time Windows (PDPTW). In addition to the traditional PDP constraints, composed requests introduce minimum time-lag constraints between pairs of pickup and delivery requests. Since solving the Mixed Integer Linear Programming (MIP) formulation of the DDPTW using a standard solver cannot scale on large instances, we propose a Large Neighborhood Search (LNS) heuristic.

2 Problem Description

We define the DDPTW as follows. A truck company owns an heterogeneous fleet $\mathcal{C}$ of trucks. The trucks carry the most common container sizes, that is, 20 ft or 40 ft containers. The standardized unit of measurement for container size is TEUs (Twenty-foot Equivalent Units). A 20 ft container is 1 TEU and a 40 ft container is 2 TEUs. Thus, a truck $c \in \mathcal{C}$ with a maximal capacity $Q_c = 2$ TEUs can carry either one 40 ft container or two 20 ft containers.

The company receives a set of missions $\mathcal{K}$ to serve, with well defined orders of pick-up and delivery. An import mission consists of moving a full container from a terminal to a customer, known as a full import request, then moving the empty container from the customer to a terminal or a depot, known as an empty repositioning request. An export mission consists of supplying an empty container from a depot or terminal to an industrial customer, known as an empty supply request, followed by moving a full container from the customer to a terminal, called full export. Other possible movements include the movements of empty containers between different depots or terminals upon request. Thus, a location can be at the same time a pickup and a delivery node. We define $\mathcal{N}$ the set of graph nodes with $\mathcal{N}^+$ as the set of pickup nodes, $\mathcal{N}^-$ the set of delivery nodes and $\mathcal{O}$ the truck yard node such that $\mathcal{N} = \{\mathcal{O}\} \cup \mathcal{N}^+ \cup \mathcal{N}^-$.

One of the main characteristics of our problem compared to the classical PDP are precedence constraints between some transport requests. These constraints are also called coupling constraints in the literature [2]. We introduce a set $\mathcal{S}$ of precedence constraints between requests to differentiate between a single request k and a composite request defined by two requests k and k' with a precedence constraint. For example, an import mission can be a composite request composed of two single requests : a full import request k followed by an empty repositioning request k', where k must be executed before k', with $(k, k') \in \mathcal{S}$. Note that these two requests can be done by different trucks. Note also that some temporal constraints are added in order to consider the customer treatment and service times.

In addition, each location has a defined time window $[w_i^-, w_i^+]$ where w_i^-, w_i^+ are respectively the opening and closing hours of node i. A truck c must arrive at a node i within the given time window and return to the yard before the end of the working day.

The planning horizon is set to one working business day, while the trucks operate on a local area of different multimodal terminals with a limited maximal shift-time T. All trucks start their day from the yard and must end their day at the yard. The objective of the planning is to maximize the number of satisfied transport requests while minimizing the total traveling time for the fleet of trucks.

3 Solution Method

In order to solve the studied problem efficiently, we propose a LNS heuristic. This heuristic depends mainly on removal and insertion operators. In our method, the main difficulty of the insertion operator comes from precedence constraints between requests that may imply several routes. So inserting a location within a given route can have an impact on the timing of linked routes. In order to reduce the complexity induced by insertion operations, we introduce some preprocessing procedures. The proposed LNS heuristic follows the classical scheme that uses destroy and repair operators, and completed with simulated annealing and local search.

4 Experimental Results

Experiments have been conducted on real data provided by a transport company in the region of Marseille-Fos, France, to demonstrate the effectiveness and efficiency of our approach.

In addition to the LNS heuristic, we proposed an MIP formulation and solved it using a commercial solver. The model was able to find an optimal solution in less than a minute on small instances (28 missions). However, on larger instances, the commercial solver was not able to find a good feasible solution in a reasonable time.

Références

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