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Planning Retail Distribution of Fuel Oils

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Abstract

In this paper, we study the Periodic Petrol Station Replenishment Problem (PPSRP), an important real problem relative to logistics in the fuel oil distribution. It consists, under suitable assumptions and subject to certain operational constraints, of determining the fuel oil procurement plans of a set of petrol stations and planning the delivering routes of petrol products to the stations along a certain planning horizon. The considered problem belongs to the class of Inventory Routing Problems (IRP), of which it is a particularization. In particular, it draws its concepts from two different classes of distribution problems, the Periodic Vehicle Routing Problem (PVRP) and the Petrol Station Replenishment Problem (PSRP). We provide a mathematical formulation of the problem, and due to the large size of the real instances which in general an oil company has to deal with we heuristically solve it. We propose different heuristic strategies based on a common partitioning-then-routing paradigm, and in order to assess their performances we test them on a set of scenarios coming from Italian fuel oil distribution real cases and compare the results with those obtained by using other known heuristic approaches.

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Keywords: Fuel Oil Distribution; Freight Transport;Transportation Planning; Vehicle Routing; Heuristics.

1. Introduction

We consider the problem of planning the distribution of petrol products to a set of petrol stations faced by an oil company. This is a very complex problem and in order to reduce its complexity, the decision process is typically

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subdivided by the oil company into three phases: 1) (strategic phase) petrol stations are preassigned to one or a few storage depots from which it will be refuelled during the next medium-large term planning horizon; 2) (tactical phase) given a few days planning horizon (e.g., a week) and the subset of petrol stations covered by the same few storage depots, planning the distribution of fuel oil from depots to the assigned petrol stations; 3) (operational phase) day by day final tank truck routes are established by considering also specific operational constraints.

In this work, we specifically consider the tactical phase when the weekly fuel oil replenishment plan for each station is defined by the oil company, by determining the days when each petrol station will be replenished, along with the delivery amount of petrol products. Simultaneously, the tank truck (vehicle) routes from depots to stations are determined for each day of the week, in order to deliver the planned fuel oil replenishment amounts to petrol stations. At this level, for simplicity, oil company defines replenishment weekly plans for each petrol station by assuming a single undifferentiated product, and determines petrol stations visiting sequences (vehicle routes) for each day of the week, assuming a fleet of homogeneous vehicles. The main aim at this phase is to minimize the total route length traveled by the tank trucks during the considered week.

Typical operational conditions and contract agreements with petrol stations requires for the oil company to refurnish each petrol station by covering its petrol demand typically for a couple of days, forcing the company to fulfill the estimated weekly demand of a petrol station with a number of replenishments during the week, with the chance to select one out of a set of replenishment plan (or pattern) established in accordance with the petrol station owner, where a replenishment pattern specifies the set of visiting days (visiting pattern) along with the (possibly distinct) fuel oil amounts (demand pattern) to be delivered in these days, respectively. We model this tactical problem as a Periodic Petrol Station Replenishment Problem (PPSRP) by modeling it as a generalization of the Periodic (capacitated) Vehicle Routing Problem (PVRP) and provide its mathematical formulation.

The problem is NP-hard and, due to the large size of the real instances which in general an oil company has to deal with, we heuristically solve the problem. Starting from the multi-stage heuristic approaches proposed by Triki (2013), we propose new heuristic strategies based on the group-first-route-second paradigm. In order to assess their performances, we test the heuristics on a set of scenarios coming from Italian fuel oil distribution real cases, comparing also the results with those of an hybrid genetic algorithm proposed by Carotenuto *et al.* (2015).

The paper is organized as follows. In Section 2 we recall the relevant literature, in Section 3 we formally define the problem addressed and provide a mathematical formulation of the same. Section 4 describes the proposed heuristic procedures. Section 5 is devoted to the experimental analysis, and finally Section 6 gives some conclusions.

2. Literature review

Our problem belongs to the class of multi-period petrol station replenishment problems (MPPSRP) (see, e.g., Cornillier *et al.*, 2008b), where the aim is to optimize the delivery of several petrol products to a set of petrol stations over a given planning horizon. In the more general version, the MPPSRP consists in finding for each period of the planning horizon the amount of petrol product to be shipped to each petrol station, the assignment and loading of petrol products into the compartments of the tank trucks, the delivery routes, and the assignment of the routes to tank trucks and their time schedule, with the aim of minimizing the (routing and service) total cost. It can be viewed as an Inventory Routing Problem (IRP) with specific additional constraints such as the use of heterogeneous vehicles with compartments, also known as IRP in fuel delivery (see, e.g., Vidović *et al.*, 2014). Ng *et al.* (2008) study two small petrol distribution networks in Hong Kong, proposing a model for simultaneously assigning trips to tank trucks and stations, assuming stations inventories being managed by the vendor. Cornillier *et al.* (2008b) propose a heuristic approach to solve the case where the number of stations on any given route is limited to two. Popović *et al.* (2012) propose a variable neighborhood search heuristic for solving a multi-product multi-period IRP in fuel delivery with multi-compartment homogeneous vehicles, given a distinct deterministic petrol consumption for each fuel type and for each petrol station; they consider routes with at most three stations. Vidović *et al.* (2014) extend this limit to four and propose a mixed integer formulation that can be solved at optimum by commercial solvers only for very small instances (with 10 petrol stations and 3 days); they also propose some heuristics for solving larger instances up to 50 petrol stations and a time horizon of 5 days.

The periodic version of the petrol station replenishment problems (i.e., the PPSRP) is a special case of the MPPSRP. In the PPSRP a periodic service requirements is specified for each petrol station or frequency of service,