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Periodic capacitated vehicle routing for retail distribution of fuel oils

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Abstract

In this paper we consider the final distribution of fuel oil from a storage depot to a set of petrol stations faced by an oil company, which has to decide the weekly replenishment plan for each station, and determine petrol station visiting sequences (vehicle routes) for each day of the week, assuming a fleet of homogeneous vehicles (tankers). The aim is to minimize the total distance travelled by tankers during the week, while loading tankers possibly near to their capacity in order to maximize the resource utilization. The problem is modelled as a generalization of the Periodic Vehicle Routing Problem (PVRP). Due to the large size of the real instances which the company has to deal with, we solve the problem heuristically. We propose a hybrid genetic algorithm that successfully address the problem inspired to a known hybrid genetic algorithm from the literature for the PVRP. However, the proposed algorithm adopts some techniques and features tailored for the particular fuel oil distribution problem, and it is specifically designed to deal with real instances derived from the fuel oil distribution in the European context that are profoundly different from the PVRP instances available from literature. The proposed algorithm is evaluated on a set of real case studies and on a set of randomly generated instances that hold the same characteristics of the former.

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Keywords: Fuel Oil Distribution; Freight Transport;Transportation Planning; Vehicle Routing; Metaheuristics; Genetic Algorithm.

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1. Introduction

This paper deals with the problem of planning the final distribution of petrol products from storage depots to a set of petrol stations, addressed by the logistic department of a major European oil company. In such a context, many variables come into play: some of the most relevant are demand uncertainty and seasonality, agreements for exchange of products with other oil companies, contracts with carriers, etc.

In order to reduce the complexity of the problem, the whole decision process is subdivided by the oil company into three phases. In the first (strategic) phase each petrol station is assigned to a given depot from which it will be refuelled during the next medium-large term planning horizon. The second phase, the tactical-operational one, consists in defining the weekly delivery plan to refurnish the set of petrol stations assigned to a given depot, by determining the service days when each petrol station has to be served, along with the delivery amount of petrol products, and the routes for each specific day of the week that tankers have to perform in order to refurnish the petrol stations, considering some specific operational constraints.

As for the second phase, the real scenario faced by the oil company consists of a set of petrol stations that in general are not directly owned by the company. This implies that deciding how much and when to replenish the petrol stations are decisions that the oil company cannot make autonomously, but in accordance with the petrol stations' owners. Moreover, typically the budget available to a petrol station owner is very limited (specially for a very small petrol station), implying that the petrol order sent to the oil company by a petrol station often covers only its petrol demand for a couple of days. These operational conditions force the oil company to fulfill the estimated weekly petrol demand of a petrol station (typically for distinct product typologies) with a number of replenishments during the week (i.e., the weekly visit frequency), with the chance to select one out of a set of replenishment or visiting patterns established in accordance with the petrol station owner, where a visiting pattern specifies the visiting days along with the (possibly distinct) delivery petrol amounts for these days.

The oil company addresses this complex petrol distribution problem in two sub-phases. In the first one, let us say at tactical level, the oil company defines replenishment weekly plans for each petrol station by assuming for simplicity 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 vehicles during the considered week. In the second (operational) sub-phase, on a daily basis, the company plans in detail the routes minimizing the total route length, while considering all the operational issues and constraints, including those related to the vehicles characteristics (whose capacity is typically subdivided into compartments), to the distinct products to be delivered (e.g., gasoline and diesel fuel), and fulfilling the actual replenishment demands of petrol stations for the specific day.

In this paper, we address the above tactical problem faced by the oil company by modeling it as a generalization of the Periodic Vehicle Routing Problem (PVRP). Due to the large size of the real instances which the company has to deal with, we solve the problem heuristically. We propose a hybrid genetic algorithm that successfully addresses the problem. The proposed algorithm is evaluated on a set of problem instances derived from real case studies of a European oil distribution company, and on a set of randomly generated instances that hold the same characteristics of the former. Such a kind of optimization tool can be used not only in the optimization process of a given oil distribution network, but also for performing scenario analyses and economic assessments simulating variations of existing networks (acquisition or disposal of petrol stations).

The paper is organized as follows. In Section 2 we survey the relevant literature, in Section 3 we formally define the problem addressed. The proposed algorithm is detailed in Section 4. Section 5 is devoted to the experimental analysis, and finally Section 6 gives some conclusions.

2. Literature review

The problem we address belongs to the class of multi-period petrol station replenishment problems (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. They can be viewed as Inventory Routing Problems (IRP) with specific additional constraints such as the use of heterogeneous vehicle with compartments, also known as IRP in fuel delivery (see, e.g., Vidović *et al.*, 2014). Malépart *et al.* (2003) propose four heuristics for constructing