A multi-compartment vehicle routing and loading problem arising in fuel distribution

Abdelaziz Benantar¹, Rachid Ouafi¹, Jaouad Boukachour²

¹ Department of Operational Research, USTHB University, P.O Box 32, 16111 Bab-Ezzouar, Algeria
a_benantar@yahoo.fr, rouafi@usthb.dz
² Institute of Technology, Le Havre University, 05 Rue Boris Vian, P.O Box 4006, F-76610, Le Havre, France
jaouad.boukachour@univ-lehavre.fr


1 Introduction

The specific problem which will be discussed in this paper is motivated by the daily replenishment-planning problem that the biggest Algerian petroleum company is facing. That company, is faced with the particular problem which consists of preparing the replenishment plan for their petrol stations every day. This plan requires a number of simultaneous and interrelated decisions to be made. To prepare such a plan, the company must determine the routes for the delivery of all the demanded products, assign these routes to vehicles, determine the time schedule for each vehicle, determine the quantities to be delivered by each route and assign these quantities to the compartments. On this point, it should be noted that in 2013 an Agreement was concluded between the company and the petrol station managers. According to this Agreement, the quantities loaded in the compartments can be adjusted up to a given threshold. This particular situation occurs quite frequently when the demands of petrol stations are high in winter. The replenishment-planning problem in this real-life application can be viewed as a combination of the loading problem and the vehicle routing problem with multiple compartments (MCVRP). Therefore, the resulting problem is called a multi-compartment vehicle routing and loading problem (MCVRLP). Combining these problems is therefore very challenging but leads to a better overall logistical solution. Many algorithms have been proposed for each problem variant in the literature. However, in system implementations, a real problem could be a generalization of various problems. Thus, it is difficult to evaluate the performance of algorithms for specific problem variants on real-life problems.

Viewpoint literature research, the integration of loading constraints in VRPs is a fairly recent domain of research. Since Iori and Martello’s review [1] up to 2010 of 31 papers concerning vehicle routing and loading constraints, contributions to this field have soared over the last couple of years. Pollaris et al. [2] extended these authors’ overview [1] by covering 76 papers. In the fuel distribution problem, which is the central application of our problem, researchers were more concerned with optimizing vehicles’ routes and less concerned with the truck loading problem. Therefore, most of them take a two-stage framework where the routing problem acts as the main problem and it iteratively calls for specific procedures to deal with the loading subproblem. Our paper attends to additional aspects which, according to the best of our knowledge, have not been considered in detail in the literature before. These aspects include (1) the integration of the loading aspect in the routing problem, (2) the restrictions imposed on the accessibility of vehicles and (3) the case in which the demands of customers are adjusted according to an agreement concluded between the parties. Especially the last aspect defines a new, unique problem structure for which we suggest a heuristic solution approach.

The MCVRP is NP-hard since it can be reduced to the VRP, which is known to be an NP-hard problem [3]. Furthermore, the MCVRLP is more complicated than the MCVRP, considering that it needs to tackle compartment loading and routing problems simultaneously. Because the practical
large-scale MCVRLP instances are difficult, if not impossible, to tackle efficiently within a reasonable amount of computing time even using the most powerful MIP solvers such as CPLEX, our aim is to propose an effective metaheuristic for MCVRLP. To make the implementation simpler, we employ the tabu search as an algorithm framework. Different structural neighborhood methods are used to broaden the exploration of the search space. Meanwhile, a Kolmogorov-Smirnov statistic (KSS) is introduced into the framework of the tabu search to manage the neighborhood size. The main idea of the KSS is to determine the neighborhood size according to a probability model that minimizes a given distance criterion and decides whether two customers are neighbors or not.

2 Contribution

The main contributions of this paper are fourfold:

- We introduce and model the MCVRLP, a kind of VRP model with multiple compartments and loading constraints.
- Unlike most of the relevant approaches which tend to use the classical moves, we introduce a neighbor reduction strategy that allows one to restrict the search process to a set of neighboring solutions. In fact, the criterion used to select such solutions is based on the Kolmogorov-Smirnov statistic.
- For the real-life application arising in fuel distribution, we develop an effective solution procedure which comprises two phases: (i) loading, (ii) routing. This is an advance on the existing work, where most researchers take a two-stage framework where the routing problem acts as the main problem and it iteratively calls for specific procedures to deal with the loading sub-problem.
- We conduct a series of numerical experiments on benchmark instances, as well as analysing a real case of fuel distribution to demonstrate the effectiveness of the proposed approach.

3 Experimental Results

The algorithm proposed in our solution procedure is coded in C++ and the mathematical model is solved by using IBM ILOG CPLEX 12.6 for 7200s CPU. All experiments are conducted on a laptop computer with an Intel Core i7 2.9 GHz processor with 8 GB RAM and Windows® 7 Professional edition. The algorithm is tested by using a well-known VRP instances which have been modified to fit the problem and a real data gathered from our industrial partner in the region of Algiers in Algeria. The obtained results are compared with those of El Fallahi et al. [4] and Reed et al. [5].

Références

Brown, G.G., & Graves, W.G.