Omega 51 (2015) 1–10

Contents lists available at ScienceDirect

Omega

journal homepage: www.elsevier.com/locate/omega

Applications

A multi-compartment vehicle routing problem arising in the collection of olive oil in Tunisia ☆

Rahma Lahyani [a,b], Leandro C. Coelho [c,*], Mahdi Khemakhem [b], Gilbert Laporte [d], Frédéric Semet [a]

[a] LAGIS, École Centrale de Lille, Cité Scientifique – BP 48, 59651 Villeneuve d'Ascq, France
[b] LOGIQ, University of Sfax, Tunisia
[c] CIRRELT, Faculté des sciences de l'administration, Université Laval, Quebec City, Canada G1V 0A6
[d] CIRRELT, HEC Montréal, 3000 chemin de la Côte-Sainte-Catherine, Montreal, Canada H3T 2A7

ARTICLE INFO

Article history:
Received 13 March 2014
Accepted 29 August 2014
This manuscript was processed by Associate Editor Bish
Available online 6 September 2014

Keywords:
Vehicle routing with compartments
Incompatible products
Valid inequalities
Branch-and-cut

ABSTRACT

We introduce, model and solve to optimality a rich multi-product, multi-period and multi-compartment vehicle routing problem with a required compartment cleaning activity. This real-life application arises in the olive oil collection process in Tunisia, where regional collection offices dispose of a fleet of vehicles to collect one or several grades of olive oil from a set of producers. For each grade, the quantity offered by a producer changes dynamically over the planning horizon. We first provide a mathematical formulation of the problem, along with a set of known and new valid inequalities. We then propose an exact branch-and-cut algorithm to solve the problem. We evaluate the performance of the algorithm on real data sets under different transportation scenarios to demonstrate to our industrial partner the advantages of using multi-compartment vehicles.

1. Introduction

In this paper, we introduce, model and solve a real-world application of a multi-product, multi-period and multi-compartment vehicle routing problem (MPPC-VRP) arising in the collection of olive oil in Tunisia. In 2012, that country was the fourth largest exporter of olive oil worldwide, with an export production of 163,000 tons. This amount was expected to increase in 2013 according to the General Directorate for Research at the Ministry of Agriculture. For climatic and geographical reasons, olive groves are rather widespread in the central part of the country, as shown in Fig. 1. Collecting olive oil is particularly important during the four-month production season. It mobilizes considerable human and material resources, and timeliness is crucial in this operation. The producers work non-stop 24 h a day in order not to damage the harvest. On any given day, olive oil collection is carried out over six periods lasting almost 24 h in total. This activity is performed by a fleet of capacitated heterogeneous vehicles, with compartments of equal or different sizes, all equipped with a debit meter, enabling the decision maker to have full knowledge of the load contained in each compartment at all times. The oil must be collected before the producer runs out of storage space. A good forecast is available for the production rate of each product by each producer.

Olive oil comes in three different grades known as *extra*, *virgin*, and *lampante*. The top two grades with superior tastes are extra and virgin, which are suitable for consumption, whereas lampante oil is mostly destined for industrial uses. The transportation is regulated by law to protect the natural flavors of the oils. In particular, at each producer site, a quality controller is in charge of checking the oil grade proposed. Once the quality control process has been completed with success, the quality controller seals the tank containing this offer. Thereafter, once the vehicle loading starts, it cannot be stopped until the tank is empty. In addition, the different grades must be kept separate during transportation, hence the need to have multi-compartment vehicles. It is forbidden to load superior grades immediately after lampante oil in the same compartment, unless it has been cleaned before the changeover. The cleaning activity incurs a cost and takes time.

Routing problems with a cleaning activity have not been widely studied from a scientific perspective, but similar constraints appear in other contexts. Oppen et al. [33] consider the problem of transporting different types of live animals from farms to slaughterhouses by means of multi-compartment vehicles. They add time between consecutive tours to allow for unloading and disinfection of the vehicles. Hvattum et al. [24] deal with a tank

☆This manuscript was processed by Associate Editor Bish.

* Corresponding author.
E-mail addresses: rahma.lahyani@ec-lille.fr (R. Lahyani), leandro.coelho@cirrelt.ca (L.C. Coelho), mahdi.khemakhem@isecs.rnu.tn (M. Khemakhem), gilbert.laporte@cirrelt.ca (G. Laporte), frederic.semet@ec-lille.fr (F. Semet).

http://dx.doi.org/10.1016/j.omega.2014.08.007
0305-0483/

Fig. 1. Map of Tunisia pinpointing producers and regional offices locations.
Source: Google Maps, accessed March 2014.

allocation problem arising in the shipping of bulk oil and chemical products by tanker ships. They consider that a cleaning activity is required if two incompatible products are assigned to the same compartment within less than three trips.

The use of fleet with several compartments is common in fuel and oil distribution [2,8,10,11,15,38,42] and in some maritime applications [5,22,24,40]. Transporting oil and fuel with multi-compartment vehicles is more challenging and interesting from a scientific point of view than transporting food, where dry, refrigerated and frozen commodities can be pre-assigned to suitable compartments. In this case, the loading problem reduces to a simple capacity checking procedure [13,14,30,31]. In contrast, in