Heuristics for multi-commodity capacitated profitable tour problem

Christophe Rapine[1], Sara Martins[2], Ayse Akbalik[1]

[1] Université de Lorraine, LCOMS, Metz, France
{christophe.rapine}/{ayse.akbalik}@univ-lorraine.fr
[2] INESC TEC and Faculty of Engineering, University of Porto, Portugal
sara.martins@fe.up.pt

Keywords : *Multi-compartment vehicles, Grocery distribution, Prize collecting problem, VRP, Route-first Cluster-second heuristics.*

1 Context of grocery retail distribution

We study the multi-commodity fleet sizing problem of a grocery retailing company, using single and multi-compartment vehicles for the distribution to the stores from a central depot. The commodities correspond to the different product segments (ambient, chilled and frozen) ordered by the stores. These product segments require distinct temperature conditions during their transportation.

On one hand, single-compartment vehicles (SCV) can be configured to transport a product segment by switching on/off the refrigeration system and setting the right temperature. Therefore, an SCV can only carry one commodity at a time. If a store requests different commodities, it has to be visited by several SCVs, one per commodity ordered. Since the capacity of a vehicle is often larger than the volume ordered of a commodity, SCVs allow to consolidate the deliveries of the same commodity to different stores. On the other hand, multi-compartment vehicles (MCV) allow to deliver all the commodities ordered by a store on a single trip, by dividing their total volume in different compartments, dedicated to each commodity. There are different types of MCVs according to their internal layout, lateral or frontal compartment door positions, flexible or fixed positioned partitions. In this study, we assume that the compartment size of MCVs are flexible, which means that their respective volume can be adjusted according to the commodity-based request, and only one customer-visit is authorized due to practical loading/unloading constraints. Hence, MCVs allow to consolidate the deliveries of different commodities to the same store. Nevertheless, MCVs are a bit more expensive than SCVs.

We address the key problem of defining the mix of vehicles to use, between SCV and MCV, to deliver different commodities to the stores. We assume that the delivery of a specific commodity to a store cannot be split: due to some practical considerations, it has to be delivered by the same vehicle. The objective is to minimize the distribution cost, which comprises a fixed cost per vehicle used and a routing cost depending on the travelled distance.

2 Problem formalisation

Determining the mixed of SCVs and MCVs to deliver several commodities to a set of stores is a generalization of the problem combining fleet sizing and routing, known as the "fleet size and mix vehicle routing problem" (FSM-VRP) in the literature, see Koç *et al.* (2016) for a recent survey on heterogeneous VRP. In the literature, the works from Ostermeier and Hübner (2018) and Archetti *et al.* (2016) are the closest to our study, considering single and multi-compartment vehicles, and temperature-specific product distribution.

In our study, we consider that each SCV has the same finite capacity Q and can only carry one commodity at a time. We have M different commodities to deliver. We assume, justified by real practices, that the capacity of an SCV is always sufficient to deliver the demand for any commodity ordered by a store, and that the capacity of an MCV is always sufficient to deliver the overall demand ordered by a store. Recall that an MCV can only serve one store in a tour, delivering all the commodities it requires. Therefore, visiting a store i by an MCV can be modelled as a penalty cost π_i, representing the go/back trip from the depot of the MCV, of not visiting it with SCVs. We model our problem as a Capacitated Profitable Tour Problem (CPTP) considering only SCVs, see Feillet *et al.* (2005). One particularity of our problem is that either a store is visited by a vehicle type SCV for *each* commodity it requests, or it is not visited for *any* of the commodities. Hence, deciding the customers to be visited is a linking constraint between the commodities. Indeed, given the set of discarded stores, the problem for SCVs boils down to M independent VRP problems, one per commodity.

3 Route-first Cluster-second heuristics

We investigate route-first cluster-second heuristics to solve the multi-commodity CPTP for SCVs. In a route-first cluster-second heuristic for CVRP, a giant tour is first built by relaxing the capacity constraint of the vehicles, resulting into a TSP problem to be solved either exactly or heuristically. The second step consists in splitting this giant tour into feasible tours respecting the capacity of the SCVs. For CPTP, during this splitting step, some stores can be discarded based on their distance or the volume of their demand. Recall that a store who is discarded from the SCVs solution is in fact served by an MCV, with a penalty cost.

We propose a *Discard & Split* procedure for the multi-commodity CPTP. For a given order of the stores, the procedure determines the subset of stores to discard and a capacitated tour for each commodity. This procedure outputs the optimal solution relatively to the given order of the stores, assuming that shortcuts are not allowed. That is, a vehicle may decide not to visit the next store in the giant tour only if it is currently located at the depot. We show that this procedure can be solved as a shortest path problem in time $O(Mn^3)$, with M the number of commodities and n the number of stores.

We also propose a *Discard & Split* procedure for the multi-commodity PTP, relaxing the capacity of the vehicles. We show that it can be optimally solved in time $O(n^2)$ as a shortest path problem. Notice that, since the capacity of the vehicles is relaxed, this procedure discards the stores only based on their distance. Since our *Discard & Split* procedure for CPTP is restricted to no-shortcut solutions, which adds a restriction on how stores are discarded, we apply this *Discard & Split* PTP procedure as a pre-computation step to possibly discard a larger set of stores. Numerical results will be reported during the conference.

References

[1] C. Archetti, A.M. Campbell, M.G. Speranza. Multicommodity vs. single-commodity routing. *Transportation Science*, 50(2), 461-472, 2016.

[2] D. Feillet, P. Dejax, M. Gendreau. Traveling salesman problems with profits. *Transportation Science*, 39(2), 188-205, 2005.

[3] Ç. Koç, T. Bektaş, O. Jabali, G. Laporte. Thirty years of heterogeneous vehicle routing. *European Journal of Operational Research*, 249, 1-21, 2016.

[4] M. Ostermeier, A. Hübner. Vehicle selection for a multi-compartment vehicle routing problem. *European Journal of Operational Research*, 269(2), 682-694, 2018.