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A column generation based heuristic for the multicommodity-ring vehicle routing problem

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Abstract

We study a new routing problem arising in City Logistics. Given a ring connecting a set of urban distribution centers (UDCs) in the outskirts of a city, the problem consists in delivering goods from virtual gates located outside the city to the customers inside of it. Goods are transported from a gate to a UDC, then either go to another UDC before being delivered to customers or are directly shipped from the first UDC. The reverse process occurs for pick-up. Routes are performed by electric vans and may be open. The objective is to find a set of routes that visit each customer and to determine ring and gates-UDC flows so that the total transportation and routing cost is minimized. We solve this problem using a column generation-based heuristic, which is tested over a set of benchmark instances issued from a more strategic location-routing problem.

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1. Introduction

The Multi-commodity Ring Vehicle Routing Problem (MRVRP) studied in this paper can be considered as belonging to the family of the Multi-level VRPs. Differently from canonical VRPs where the vehicles that visit the final customers start from a central depot, in Multi-level VRPs goods are dispatched to intermediate depots before

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reaching their final destination. The motivation to study such complex distribution systems comes mainly from real-world traffic restrictions that prevent big trucks to enter the city center. This imposes transshipment or cross-docking operations outside the urban area, in order to load smaller vehicles to perform shipments to retailers.

The MRVRP is derived of the so-called Multi-commodity Ring Location Routing Problem (MRLRP) studied in the framework of a research project called MODUM (see recent publication Gianessi et al. (2015)). The MRLRP is a strategic planning problem with a high degree of difficulty, due to several decision levels. It consists in locating Urban Distribution Centers (UDCs) around the city and connect them through a ring over which massive transportation flows circulate. These massive flows, that may use shuttles for example, are supposed to make it less costly to use the ring to go to the other side of the city. To estimate the cost of this system, not only the construction cost of UDCs and ring are considered, but also the transportation cost and the routing cost (both pick-up and delivery are considered).

In the MRVRP, we skip the strategic location issue and consider only the transportation and routing aspects, i.e. the ring and distribution centers are already installed. All other aspects of the problem remain the same in every respect. We briefly describe them here; more details are given in the next section. Goods to be delivered arrive to a first UDC from gates, are possibly transported along the ring, and finally shipped using electric vans that can get into the city center; the reverse process occurs for pick-up. No time dependence is considered. Each delivery or pick-up demand is characterized by a quantity of goods, a customer and a gate. The attribute *multicommodity* in the problem name refers solely to the different gates. The retail shipments performed by electric vans have both maximum route length and maximum load limits. The fleet of vehicles is shared among UDCs and Self-service Parking Lots (SPLs) that are located inside the city. Service routes can be open, i.e. the start node of a route is not necessarily the end node. Hence a rebalancing policy is imposed to simplify repositioning. The objective is to ship every demand (delivery or pick-up) from its source to its destination, in such a way as to minimize the overall routing and flow transportation costs, while respecting UDC and ring arc capacities and the rebalancing constraints. Here, the term *flow transportation* refers to the circulation of goods from the gates to the ring (using trucks) and along the ring (possibly using larger trucks or railway shuttles), whereas *routing* refers to the delivery of goods from UDCs to customers, or to pick-up from customers to UDCs, using electric vans.

This problem is not far from another Multi-level VRP, the *Two-Echelon Vehicle Routing Problem (2E-VRP)*, in which goods are initially stored at a central warehouse, from where they are delivered to secondary-level logistic platforms or satellites which correspond to our UDCs. After being consolidated in second-level vehicles, products can finally be shipped to customers. Split delivery are forbidden at the second level, but allowed at the first level, therefore a UDC can receive the merchandise it has to deliver from many first-level vehicles. UDCs have a capacity that bounds the first-level deliveries. Second-level vehicles can only perform one service route and must return at the depot from where they started. In more general versions, other features can be taken into account, like multiple warehouses, possibility to deliver customers via first-level vehicles, possibility that second level vehicles perform more than one service trip, time dependent travel times, customer time windows, synchronization between first- and second-level. No ring structure has been studied so far for VRP, to our knowledge. The paper Crainic et al. (2009) studies a widely generalized version of a two-tier distribution structure in which many of these aspects are considered. Several heuristic approaches to the 2E-VRP can be found in the literature. In Crainic et al. (2008), a set of two-phase heuristics are proposed. The second-level subproblem is solved as a *Multi-Depot VRP (MDVRP)*, or alternatively as a set of small VRPs after a clustering of the customers in order to assign them to UDCs. Then, the first level subproblem is solved as a common Capacitated VRP. In the second phase, a series of heuristics are used to improve the solution. In Crainic et al. (2011b), the problem is approached in a similar way. A greedy initial clustering heuristic is used to decompose the problem in as many Capacitated VRPs as the number of UDCs plus one, i.e. the first-level problem. Then, a *local search (LS)* step changes the customer-UDC assignment so as to improve the solution. Finally, a multi-start phase is applied for a given number of iterations: the current best solution is perturbed according to *savings*-inspired criteria, yielding either an infeasible solution, which is then repaired, or a feasible one. In the latter case, if the quality is promising, the solution in further improved by means of the customer-UDC assignment improvement LS tool. To mention other heuristic algorithms, we refer the reader for instance to the *Greedy Randomized Adaptive Search Procedure (GRASP)* with path-relinking of Crainic et al. (2011a) or the *Adaptive Large Neighborhood Search (ALNS)* proposed in Cordeau et al. (2011).