The two-echelon vehicle routing problem with backhauls and capacitated satellites

Dorian Dumez[1,2], Christian Tilk[3], Stefan Irnich[3],
Fabien Lehuédé[2], Katharina Olkis[3], Olivier Péton[2]

[1] HEC Montréal, CIRRELT, Montréal, Canada
`dorian.dumez@hec.ca`
[2] IMT Atlantique, Laboratoire des Sciences du Numérique de Nantes (LS2N, UMR CNRS 6004), Nantes, France
`{fabien.lehuede;olivier.peton}@imt-atlantique.fr`
[3] Chair of Logistics Management, Johannes Gutenberg University, Mainz, Germany
{tilk ;kaolkis ;irnich}@uni-mainz.de,}

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The present work aims to solve a 2-Echelon Multiple-Trip Vehicle Routing Problem jointly considering Capacitated Satellites and Reverse Flows (2E-MTVRP-CSRF). It fills two gaps in the two-echelon VRP literature : First, to the best of our knowledge, only inbound distributions activities were addressed in 2E-VRP. Second, the capacity at intermediate facilities (also called satellites) is generally considered either unbounded or null.

1 Problem description

We consider a distribution network consisting of a vehicle depot, a set of customers and a set of satellites. First-echelon routes are composed of multiple first-echelon trips. Each trip is a route starting from the depot, visiting one or several satellites and returning to the depot. Second-echelon routes are composed of multiple second-echelon trips. Each trip starts from a satellite, visits a (possibly empty) subset of customers and ends at a satellite. Deterministic customers demands may be pickup requests, delivery requests or a mixed requests. Customers must be visited exactly once, in their given time window. The fleet of vehicles at each echelon is assumed homogeneous, with limited size. Finally, we consider satellite capacity that restrict the number of items that can be simultaneously stored at satellites.

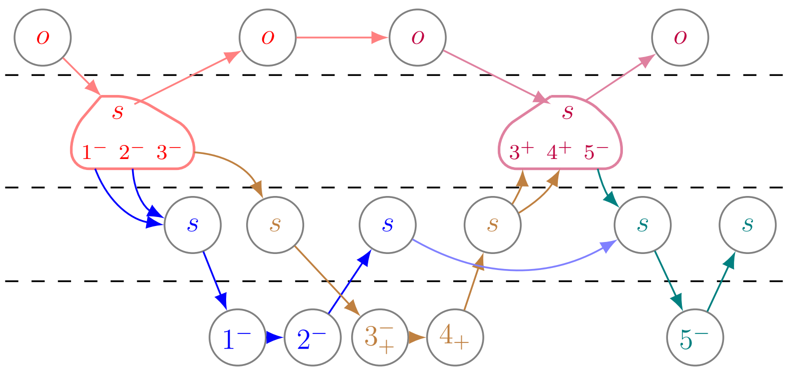

FIG. 1 – Representation of a 2E-MTVRP-CSRF on a time-expanded graph

This problem is represented on the time-expanded graph of Figure 1, depicting the routes and the precedence constraints induced by the transshipment at the satellites. This example shows one satellite of capacity 3, one first-echelon vehicle (in red), two second-echelon vehicles (in blue and brown), and five customers with unitary demand. The satellite is duplicated into 2 nodes corresponding to the visits of first-echelon vehicles and 6 nodes corresponding to the visits of second-echelon vehicles.

Customers 1, 2, and 5 are pure linehaul (represented by $^-$), customer 4 is pure backhaul (represented by $_+$), and customer 3 has mixed demand (denoted 3_+^-). The first-echelon vehicle performs two trip between the depot o and the satellite s. The first second-echelon vehicle performs two trips : $s, 1^-, 2^-, s$ and $s, 5-, s$. The second second-echelon vehicle performs one trip : $s, 3_+^-, 4_+, s$.

2 Methodology

To solve the 2E-MTVRP-CSRF we propose a decomposition-based matheuristic. It iteratively optimizes the first and the second echelon, by fixing the other echelon, and creates new complete solutions by solving a column-based MILP formulation with the set of generated trips.

Each iteration of our method is decomposed into three phases : (i) the second echelon is optimized while the first echelon is fixed in the sense that the sequences of visits to satellites and their date are fixed, but not the quantity handled. (ii) the first echelon is optimized while the second echelon is fixed, thus the customers are moved to the satellite according to the current states of the second echelon. (iii) a trip-based formulation of the 2E-MTVRP-CSRF is solved with Cplex, using the trips generated during the first two phases.

The optimization during these first two phases is performed with tailored Small and Large Neighborhood Search heuristics (SLNS, [2]). SLNS is a variant of the Large Neighborhood Search heuristic mainly relying on small destructions for fast iterations, in combination with periodic large destructions.

3 Experimental results

To evaluate the impact of satellite capacity on routing costs, we generated instances with up to 100 customers and 8 satellites. We considered a storage capacity at satellites varying from 20 units to infinity. Our numerical experiments highlighted that using medium-size satellites achieves a good trade-off between the routing cost and the cost of storage spaces in city-cores. In addition, we found that the integration of forward and backward flows in this type of setting reduces the routing costs by 34%.

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Références

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