A Time Dependent Two-echelon Vehicle Routing Problem

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1 Introduction

The fast rates at which urban population is growing coupled with increasing demands expressed within cities has given rise to challenging freight transportation problems. The Two-echelon Vehicle Routing Problem (2E-VRP) has been proposed as a possible scheme in city logistics to reduce traffic congestion, pollution, costs, and improve the quality of service [2]. Nevertheless, to fully understand its characteristics, challenges, and pertinence in city logistics, different attributes of these contexts need to be addressed. One of the most important peculiarities for this kind of applications is the dependent travel times from, to, and within cities. These last change across the day as a consequence of the inherent changing traffic flows and congestion patterns, and have important effects on both the feasibility and objectives of VRPs.

The 2E-VRPs has attracted much attention as shown in the review of [3]. While this statement also remains true for the VRPs with dependent travel times, the cross-path of these two problems is nearly unexplored in particular in a urban context. In [1] a 2E-VRP is addressed considering dependent travel times only at the first echelon, since bicycles are used at the second echelon. Using a GRASP and Path Relinking heuristic, the authors solve a real instance based on Vienna data. Meanwhile, in [4] a MILP is proposed to deal with a 2E-VRP in which second echelon vehicles are subject to traffic congestion. However, in a case study presented by the authors the amount of travels with dependent travel times is very restricted. In this work we address a 2E-VRP with dependent travel times (2E-TDVRP) at both echelons, in which spatial and temporal synchronization are required.

2 Problem description

The proposed 2E-TDVRP can be described as follows. Let $G = (V, A)$ be a direct graph where $V = V_d \cup V_s \cup V_c$ where V_d is the subset of depots, V_s a subset of satellites, and V_c a subset of customers. The set A is further composed by $A^1 \cup A^2$. The subsets $A^1 = \{(i,j) \mid \{i \in V_d, j \in V_s\} \cup \{(i,j) \mid i,j \in V_s\}\}$ and $A^2 = \{(i,j) \mid \{i \in V_s, j \in V_c\} \cup \{(i,j) \in V_c\}\}$ represent the arcs at the first and second echelons respectively. Each customer $v_i \in V_c$ is characterized by a demand q_{v_i} an a mixed hard soft time window $[e_{v_i}, l_{v_i}, l'_{v_i}]$. Early services are forbidden, therefore, a vehicle has to wait until e_{v_i} to start it. Meanwhile, late services are allowed by paying a penalization defined by a function $P_{v_i}(t)$, where $t > l_{v_i}$ is the time when the service starts, nevertheless, it is limited up to a time l'_{v_i}. The time to serve a customer depends on its demand and is modelled as a function $st(q_{v_i})$. Customers are served only by second echelon vehicles, while first echelon vehicles visit satellites to transfer charge to the second echelon ones. Satellites have no storage capacity ; therefore synchronization is required between vehicles, *i.e.* both vehicles need to be present at the same time and satellite to transfer the charge. Besides, the transfer times depend on the quantities transferred. The time to traverse an arc is defined as a function $tt_a(t)$ $\forall a \in A$. In this work $tt_a(t)$ is modelled as a piecewise linear function for every arc on A.

Concerning vehicles, it is assumed that an unlimited fleet of vehicles K^1 and K^2 are available to start their routes at any depot or satellite for first and second echelon routes. Vehicles are homogeneous within each echelon and have a capacity Q^1 and Q^2 respectively. First echelon vehicles must return to their depot, while second ones can start at any satellite and finish at any customer. Furthermore, the two types of vehicles have a duration limit per route defined by T_k^1 and T_k^2 for first and second echelon vehicles respectively. The purpose is to design a set of routes for the first and second echelons (multi-trips), such that each customer is visited by only one vehicle, and vehicles capacities and total times per route are respected. We consider a hierarchical objective function composed by the fixed cost of vehicles at both echelons and the total travel times, waiting times and the time windows penalizations.

3 Instances and preliminary results

To fully address the characteristics of a real 2E-VRP a new set of instances based on real data is created. For the city of Bogota, different instances sizes are used $|V_c| = \{200, 500, 1000\}$. Travel times are modelled by interpolating points between hours guaranteeing that the average for each hour slot equal those of open information retrieved from Uber Movement Data. Customers are selected among a data base of restaurants in the city, while satellites are derived from locations of gas stations. Figure 1 presents an example of an instance with 1000 customers. Preliminary results show that decomposing the echelons in a two-phase approach and using a classical savings heuristic can give results for instances with 1000 customers in around a second. Moreover, the fact of introducing the dependent travel times nature into the heuristic decreases the number of second echelon vehicles by 20% and first echelon ones by 8% when compared with an static approach.

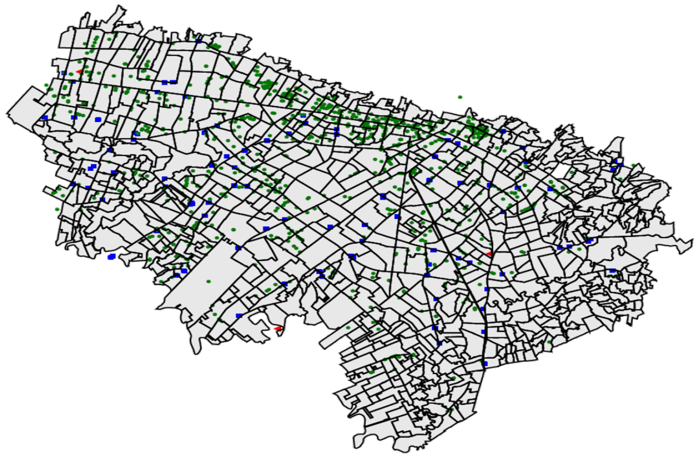

FIG. 1 – Instance example. Red : depots, Blue : satellites, Green : customers.

References

[1] Anderluh, Alexandra and Larsen, Rune and Hemmelmayr, Vera C and Nolz, Pamela C *Impact of travel time uncertainties on the solution cost of a two-echelon vehicle routing problem with synchronization.* Flexible Services and Manufacturing Journal, 2019.

[2] Cattaruzza, Diego and Absi, Nabil and Feillet, Dominique and González-Feliu, Jesús. *Vehicle routing problems for city logistics.* EURO J Transp Logist, 6–51, 2017.

[3] Cuda, Rosario and Guastaroba, Gianfranco and Speranza, Maria Grazia. *A survey on two-echelon routing problems.* Computers & Operations Research, 55, 185–199, 2015.

[4] Soysal, Mehmet and Bloemhof-Ruwaard, Jacqueline M and Bektaş, Tolga *The time-dependent two-echelon capacitated vehicle routing problem with environmental considerations.* International Journal of Production Economics, 164, 366–378, 2015.