Multi-period capacitated profitable tour problem with electric vehicles

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1 Introduction

The growing number of publications related to electric vehicle routing problems (E-VRP) is an evidence of the research on electric vehicles (EVs) in transportation becomes more and more popular. This tendency can be attributed to the fact that electric vehicles (EVs) are good substitutes to ICVs[4]. However, according to [5], in France and UK the urban freight transport and service operators report some operational obstacles, after adopting EVs, that are related to the limited range and the risk of queueing at recharging stations (RSs).

To face this issues, in this paper, a multi-period variant of the electric capacitated profitable tour problem with mandatory stops (e-CPTPMS) is presented. The e-CPTPMS is introduced by [3]. This problem is a variant of a routing problem with profits where the fleet is composed of EVs and lunch breaks are mandatories. In addition, it is possible to recharge the EVs during the lunch break by having an agreement with restaurants. The aim is to benefit from idle time caused for both lunch time and recharging time. A multi-period variant is designed, mainly, due to the fact that the e-CPTPMS mixes operational (routing) and tactical decisions (agreements with restaurants). In literature, multi-period scenarios are considered to evaluate more fairly the influence of the tactical decisions on the operational decisions. In this variant, the agreements are made with clusters of restaurants and not with each restaurant individually. It represents scenarios where it is possible to negotiate with restaurant chains.

To solve the problem, we propose a Branch-and-Price algorithm and we test it on a set of instances adapted from instances proposed by [2]. Finally, computational tests to prove the efficiency of the algorithm are presented.

2 Problem statement and solution method

The problem is defined on a graph $G = (V', A)$ with a set of vertices $V' = \{V \cup F'\}$ and a set of arcs given by $A = \{(i, j, p) | i, j \in V'_{0,N+1}, i \neq j \ \wedge \ p \in P\}$. Let V be a set composed of customers and depot and P the periods. G_k is the set of restaurants that belongs to cluster $k\Gamma$. F' is the set of dummy vertices representing visits to restaurants. A homogeneous fleet of EV is available at the depot. For each visit to a restaurant, the lunch time is considered constant. Also, we assume that during that time the EV is charged to its maximum battery level. Energy consumption is described as a linear relation between distance and the consumption rate.

Each customer has associated a positive score that varies per period. Having an agreement with a cluster of restaurants has associated a fix cost. Likewise, each restaurant has a hard time window that represents the lunch time. Lastly, a maximum tour duration is represented by $Tmax$.

The problem seeks to find routes departing from the depot visiting a subset of customers per each period. Each route includes one stop to visit a restaurant during its lunch time. The objective function aims to maximize the total operational income computed as the sum of the profits minus the operational cost associated with the total distance and minus total agreement cost with the clusters of restaurants.

As a solution method we design a Branch-and-Price algorithm (BP). Thus the problem is formulated as a set-packing model. From the set-packing model, and the subproblem to be solved in the column generation phase is identified. In this case, it corresponds to an elementary longest path problem with resource constraints. A solution procedure based on a labeling algorithm is implemented to solve it. Finally, the branching strategies are adapted from those propose by [1], to be able to manage agreements with clusters of restaurants.

3 Computational results and conclusions

A set of instances of this problem is created based on the set of instances proposed by [2]. The BP is implemented in C++ and linear relaxations are solved by CPLEX 12.8. The execution time is limited up to 2 hours.

			B_{small}		B_{medium}		B_{large}	
Set	n	rs	$nbOp/nbInst$	CPU(s)	$nbOp/nbInst$	CPU(s)	$nbOp/nbInst$	CPU(s)
Set-1	30	4	**54**/54	0.13	**54**/54	1.22	**54**/54	1.07
Set-2	19	3	**33**/33	0.10	**33**/33	0.12	**33**/33	0.10
Set-3	31	4	**60**/60	0.89	**60**/60	3.60	**60**/60	1.03
Set-4	98	12	41/60	248.07	30/60	316.61	30/60	88.85
Set-5	64	8	68/78	509.59	60/78	103.43	58/78	173.28
Set-6	62	8	41/42	41.67	37/42	48.00	36/42	97.03
Set-7	100	13	48/60	222.05	39/60	17.39	38/60	21.18
Total			345/387		313/387		309/387	

TAB. 1 – Preliminary results with different B values

In Table 1, we present the resume of the preliminary results. n is the number of available customers, rs is the number of available restaurants, $nbOp/nbInst$ is number of optimal solutions reached by the algorithm over the set size, and CPU is the average computational time (in seconds) for those instances solved to optimality.

Preliminary results show that the proposed algorithm is capable to solve instances with 100 customers and 13 restaurants, in less than 3 minutes on average. Finally, it was observed that agreement with a cluster of restaurants decisions change between the mono and the multi-period scenarios, for some instances. It shows the pertinence of evaluating this type of decisions in a multi-period scenario.

Références

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