The Bi-objective Electric Autonomous Dial-A-Ride Problem

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1 Introduction

The Dial-A-Ride problem (DARP) consists in designing a set of minimum-cost routes for a fleet of vehicles that provides ride-sharing services for users specifying their origins and destinations [2]. In the transportation of users, there is a fundamental trade-off between service quality and operational efficiency : users may not be transported directly to their destinations in the optimal operational plan. Many works consider quality-oriented objectives in the objective function (e.g., [3]) to find a good balance between human and economic perspectives. As well as the development of sharing economy, the popularisation of using electric vehicles, and the development of autonomous techniques have drawn the academic interest of scholars in operations research to apply a more eco-friendly and comfortable mode of transport. The Electric Autonomous Dial-A-Ride Problem (the E-ADARP) was first introduced by [1], which consists in scheduling a fleet of Electric Autonomous Vehicles (EAVs) to accommodate customer requests. In this work, we emphasize the conflicting interests of service providers and users in the objective function of the E-ADARP and investigate the Bi-objective E-ADARP (hereafter BO-EADARP). The two objectives in the BO-EADARP are total travel time of all vehicles and total excess user ride time of all users.

2 The BO-EADARP Description

The problem is defined on a complete directed graph $G = (V, A)$, where V represents the set of vertices and $A = \{(i, j) : i, j \in V, i \neq j\}$ the set of arcs. V can be further partitioned into several subsets, i.e., $V = N \cup S \cup O \cup F$, where N represents the set of all customers, S is the set of recharging stations, O and F denote the set of origin depots and destination depots, respectively. The set of all pickup vertices is denoted as $P = \{1, \cdots, i, \cdots, n\}$ and the set of all drop-off vertices is denoted as $D = \{n+1, \cdots, n+i, \cdots, 2n\}$. The union of P and D is N, i.e., $N = P \cup D$. The travel time on each arc $(i, j) \in A$ is denoted as $t_{i,j}$, and the battery consumption is denoted as $b_{i,j}$. Detailed MIP formulation of the E-ADARP can be found in [1]. We replace the weighted-sum objective function iin [1] to separate objective functions, shown in Equation (1) and (2)

$$\min \sum_{i,j \in V} t_{i,j} x^k_{i,j} \tag{1}$$

$$\min \sum_{i \in P} R_i \tag{2}$$

where $x_{i,j}^k$ is a binary decision variable which denotes whether vehicle k travels from node i to j. R_i denotes the excess user ride time of request $i \in P$ and is formulated as the difference between the actual ride time and direct travel time from i to $n+i$.

3 Numerical Experiments and Discussion

In numerical studies, we focus on finding all Pareto optimal solutions, including supported and non-supported solutions, for existing benchmark instances in [1]. We take instance a2-16, which contains 2 vehicles to serve 16 customer requests, as an example.

We first embed the column generation in [4] into the Dichotomic method to calculate all extreme supported solutions, which are located on the convex hull of the Pareto Front. Then, we use an ϵ-constraint based approach to obtain non-supported solutions. In Figure 1, we present Pareto optimal solutions for a2-16 by applying the ϵ-constraint method. From these results, we have a clear view of how these two conflicting objectives interact. It can be observed that the total excess user ride time can be reduced significantly with only a slight increase in total travel time. This finding offers practical interest for service providers to largely improve the service quality at a slight operational cost increase. In the next step, we will focus on obtaining all Pareto optimal solutions to give decision-makers the full picture of all possible Pareto optimal solutions.

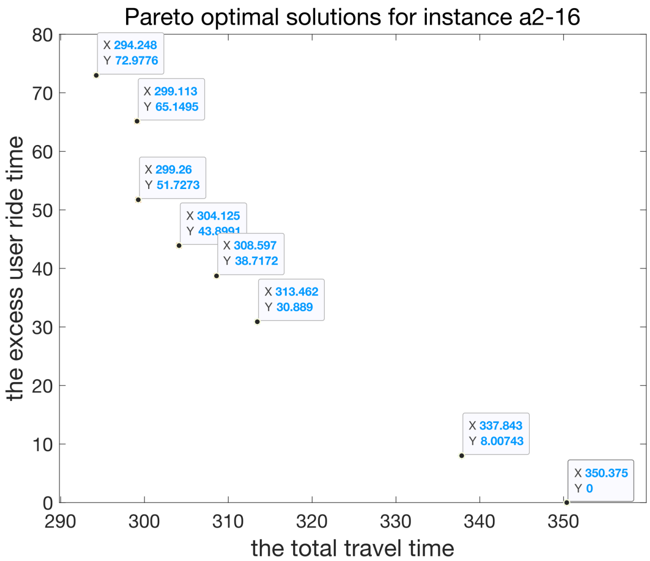

FIG. 1 – Pareto-optimal results for instance a2-16

Références

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