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

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1 Introduction

The prevalence of ride-sharing services presents a fundamental trade-off between the operational costs and the users' convenience. While ride-sharing operations reduce operational costs, users may experience certain inconveniences, such as longer ride times when sharing their rides with others. Along with the development of ride-sharing services, the emergence of new techniques, such as electric vehicles and autonomous techniques, has drawn academic interests 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 designing a set of minimum-cost routes for a fleet of electric autonomous vehicles (EAVs) by scheduling them to provide ride-sharing services for users specifying their origins and destinations. 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 of the BO-EADARP are the total travel time of all vehicles and the total excess user ride time of all users. We propose an exact algorithm to solve the problem. In the numerical study, we solve the BO-EADARP instances and the classical BO-DARP instances with our proposed method and methods in the literature (e.g., ϵ -constraint methods). Our proposed method has demonstrated efficiency in terms of solution quality and computational time. We also analyze the hybridization among different methods, which help to enhance the performance. Finally, we report the managerial insights that we observe from the obtained efficient solutions.

2 Problem statements and methodology

2.1 The BO-EADARP

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., $V = P \cup D \cup S \cup O \cup F$. P and D represent the set of all pickup and drop-off vertices, S is the set of recharging stations, and O and F denote the set of origin depots and destination depots, respectively. Each user request is a pair $(i, n + i)$ for $i \in P$ and has a maximum user ride time of m_i . The travel time on each arc $(i, j) \in A$ is denoted as $t_{i,j}$. Detailed MIP formulation of the E-ADARP can be found in [1]. The two objectives are :

$$\min \sum_{i,j \in V} t_{i,j} x_{i,j}^k \quad (1)$$

$$\min \sum_{i \in P} R_i \quad (2)$$

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 $n + i$.

2.2 Two-stage objective-space search algorithm

The proposed objective-space search algorithm is based on the notion of battery-restricted fragment, which was first introduced in [2] (so-called battery-restricted fragment) to solve the single-objective E-ADARP. Briefly speaking, each E-ADARP route can be regarded as the concatenation of several battery-restricted fragments, recharging stations (if required), an origin depot, and a destination depot. With the idea of battery-restricted fragment, we develop a two-stage objective space search algorithm to find non-dominated points in a given objective space. In the first step, we select the compatible fragments whose combination guarantees that each request is visited exactly once. In the second step, we use the selected fragments to construct a feasible solution using the B&P algorithm proposed in [3]. If we find a new efficient solution, then we use the corresponding non-dominated points to further partition the objective space. In each partitioned space, the two-stage algorithm is repeated to find new efficient solutions and further reduce the objective space. The whole procedure terminates when we finish checking the origin objective space and cannot find any new efficient solutions.

3 Numerical experiments and discussion

In this work, we solve the BO-EADARP, where the total travel time and the total excess user ride time are considered as separate objectives. To tackle the BO-EADARP, we introduce a fragment-based two-stage algorithm. In the computational experiments, the two-stage algorithm is shown to be more efficient and generate more efficient solutions in a less average computational time, compared with the classic ϵ -constraint method and generalized B&P algorithm. Then, we analyze the obtained efficient solutions, which offer the following managerial insights for different service providers : (1) for profitable service providers, it is possible to significantly improve service quality while keeping near-optimal operational costs ; (2) for non-profitable service providers, there exist efficient solutions of high service quality while at lower operational costs. These efficient solutions are very interesting for this kind of service provider. To sum up, the obtained efficient solutions can help decision-makers select Pareto-optimal transportation plans according to their priorities and preferences.

Références

- [1] Claudia BONGIOVANNI, Mor KASPI et Nikolas GEROLIMINIS. “The electric autonomous dial-a-ride problem”. In : *Transportation Research Part B : Methodological* 122 (2019), p. 436-456.
- [2] Yue SU, Nicolas DUPIN et Jakob PUCHINGER. “A deterministic annealing local search for the electric autonomous dial-a-ride problem”. In : *European Journal of Operational Research* 309.3 (2023), p. 1091-1111.
- [3] Yue SU et al. “A Branch-and-Price algorithm for the electric autonomous Dial-A-Ride Problem”. In : *Transportation Research Part B : Methodological* 186 (2024), p. 103011.