Assessment of a Shared-Taxi Routing Service for Disabled People: Barcelona Case Study

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Abstract

Nowadays, multiple passenger ridesharing and its variants look one of the more promising emerging mobility concepts. However, the real implementation of these systems accounting specifically requirements for user’s should raise certain challenges, even further for disabled people, which inherits requirements that need special consideration: short ride times, specific vehicle characteristics depending on the mobility handicaps, narrow time windows constraints, etc. This paper presents the real case study of the public transport service that Barcelona city offers to people with reduced mobility, which could program weekly taxi trips within the city at specific time. The proposed routing algorithm integrated in this service management system is based on a Tabu search heuristic approach used to minimize the dimension of the heterogeneous fleet and the total travelled time. Furthermore, this work exhaustively analyses the operational factors of this mobility service and how affect to the service performance and to the sharing vehicle factors. The obtained results show that certain operational decisions could make better use of the resources allocated to the sharing services.

Keywords: ride-sharing; routing; tabu search; disabled people.

1. Introduction and Related Work

In the analysis of the Future of Mobility and New Mobility Business Models, Sullivant and Frost (2015) identify the growing trend of “Ride Sharing” models as one of the consequences of the paradigmatic shift from “car ownership” to “vehicle usage”. Furthermore, according to the definition of the European Commission, Demand Responsive Transport (DRT), Dial-a-Ride Transit or Flexible Transport Services are emerging user-oriented forms of public transport characterized by flexible routing and scheduling of small/medium vehicles operating in shared-ride mode between pickup and drop-off locations according to passenger needs.

Our research specifically addresses Dial-a-Ride Problem, whose common application is the door-to-door transportation of elderly and disabled people, which often cannot make use of standard public transportation services because these are not adapted to their needs.

A state of the art survey on the variants of ridesharing systems, their alternatives and likely future evolution can be found in Furuhata et al. (2013). More recent, Mourad et al. (2019) present an exhaustive survey of models and algorithms for optimizing shared mobility. According to their classification, the variant solved in this paper correspond to what is known as Multidepot Heterogeneous Dial-a-Ride Problem (MD-H-DARP) with heterogeneous users. Although this problem has hardly been studied, Braekers et al. (2014), is highly relevant since these problem characteristics often jointly arise in practice.

Our research presents the real case study of the public transport service that Barcelona city council offers to people with reduced mobility (elderly and disabled), which daily programs shared-taxi trips at specific time windows. The developed heuristic based on the Tabu search approach is used to exhaustively analyse the different operational factors and how they affect to the KPI of this real shared service.

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2. Developed Heuristic

Solving the MD-H-DARP with exact solutions is computationally impracticable with real instances of the problem, hence, an implementation of a heuristic algorithm is needed for solving daily scenarios (like the proposed service in Barcelona) in a reasonable time. The developed algorithm constructs an initial greedy solution assigning user trips to the minimum number of vehicles possible on a single iteration over the user requests. This kind of insertion heuristics can be found in the literature of the MD-H-DARP and its variants (Toth and Vigo (1996) and Lau and Liang (2002)), and are very helpful for obtaining a good initial solutions and speeding up the optimization process.

This initial solution is then improved with a Tabu search by exploring the solution space with the traditionally used search operators: Within Route Insertion (WRI), Single Pair Insertion (SPI) and Double Pair Insertion (DPI). Also, a Tabu list is used to avoid undoing operator movements that improved the cost function during several iterations.

In order to validate the heuristic algorithm performance and the obtained results, we have formulated the integer linear optimization model inspired in the proposal by Toth and Vigo (2002). To customize the model to the proposed service, some adaptations have also been included: sharing constraints depending on the user, artificial multi depot to emulate the participation of a vehicle in the service and a minimum ride time defined for each user. Then, the results from the heuristic algorithm can be compared with the exact optimum solutions obtained through CPLEX.

In the next section an experiment design is detailed to study how these parameters affect to the results.

3. Computational Experiments, Preliminary Results and Discussion

The developed heuristic has been validated using a set of artificial instances with similar characteristics of the proposed case study. The results obtained from the heuristic are close to the optimal solutions computed by CPLEX (from 0%-9%). Furthermore, the execution times and resources required with CPLEX grow exponentially with the size of the instances, justifying the need of a heuristic approach for real scenarios with more than 100 users.

To evaluate the operational parameters impact, a factorial experimental design is proposed including as factors: time-windows (5min, 10min and 20min), service time (2min, 4min) and temporal horizon (1h, 2h). The performance of the heuristic is measured with the following KPIs: number of used vehicles, % of car-shared distance, mean of occupation by distance unit and % of empty car distance.

Time-window parameter (TW) has a significant role in minimizing the cost (minimizing the fleet). Using a 20min TW reduces the required fleet in a 30% vs. using 5min TW. With 5min TW, sharing KPIs are very low, having around 0% of car-shared travelled distance, while with 20min TW, we obtain a 20-30% of car-shared travelled distance. We noted that with 10min TW the achieved fleet reduction is 10-15% with respect to the 5min TW, however, the car-sharing improvement is not proportional to the TW size and KPIs are still a bit low (<5% of car-sharing travelled distance). We also observed a tendency to faster algorithm convergence when the time-windows are wider.

References


