Improving Sharing Rates of a Dial-a-Ride Problem implemented for an Austrian Mobility Provider

Philipp Hungerländer\textsuperscript{a}, Kerstin Maier\textsuperscript{b,∗}, Veronika Pachatz\textsuperscript{c}, Christian Truden\textsuperscript{a}

\textsuperscript{a}Department of Mathematics, Alpen-Adria-Universität Klagenfurt, Klagenfurt, Austria
\textsuperscript{b}MANSIO Karl Popper Kolleg, Alpen-Adria-Universität Klagenfurt, Klagenfurt, Austria
\textsuperscript{c}Hex GmbH, Klagenfurt, Austria

Abstract

The Dial-a-Ride Problem (DARP) aims to find a set of minimal cost tours for passenger vehicles in order to satisfy a set of transport requests. Each request requires to pick-up one or more passengers at a defined pick-up point and then drop-off the passengers at the desired destination. In this work, we consider a DARP that has been implemented by an Austrian mobility provider. The company focuses on rural regions that suffer from insufficient public transportation and offers a sustainable form of mobility. Moreover, the provider is especially interested in improving the sharing rates of the mobility service. Therefore, we propose a Large Neighborhood Search for solving the respective DARP. In a computational study, we compare different configurations of the service and identify the most promising configurations regarding sharing rates, passenger convenience and, hence, overall efficiency of the service.

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Keywords: Dial-a-Ride Problem, Large Neighborhood Search, Vehicle Routing

1. Introduction

In this work, we present a Dial-a-Ride Problem (DARP) that was implemented for an Austrian mobility provider. The DARP constitutes a variant of the Vehicle Routing Problem with Pick-up and Delivery Time Windows (VRPPDTW) that is concerned with the specific characteristics of passenger transportation. It describes the problem of finding a set of minimal cost tours for passenger vehicles in order to satisfy a set of transportation requests. Each request requires to pick-up one or more passengers at a defined pick-up point and then drop-off the passengers at the desired destination. A typical feature of the DARP, ensuring its efficiency, is that passengers share the vehicles on their trips.

In the literature, there is a vast number of variants and approaches for the VRPPDTW and the DARP. Concerning the DARP, we refer to [Ho et al. 2018] for an up-to-date review of recent developments and solution approaches.

In particular, we investigate a dynamic-deterministic version of the DARP. Hence, new transportation requests may be integrated at any time, but stochastic requests are not considered.

∗ Corresponding author.

E-mail address: kerstin.maier@aau.at

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The considered mobility provider focuses on rural regions that suffer from insufficient public transportation and offers a sustainable substitute. In order to improve efficiency of the service, the mobility provider is interested in improving the sharing rates among its service. Hence, we are interested in two different definitions of the sharing rate: (a) driven kilometers: a driven distance is considered as being shared if passengers associated with more than one transport request ride in the same vehicle at the same time, and (b) shared requests: a request is shared if the pick-up is not immediately followed by the drop-off, i.e., other passengers are picked up or dropped of meanwhile.

Common reasons for using the mobility service are: commuter trips to the nearest train station, school transports, transports to doctor’s appointments, or transportation of citizens who are not able to use public transportation.

The heterogeneous fleet of vehicles consists of cars, minibuses, and especially equipped vehicles that allow transportation of persons with disabilities. Clearly, for each transportation request, the appropriate vehicle must be selected.

2. Problem Definition

In the static case, a DARP instance is defined by a set of transport requests \( i \in I, |I| = n \), that must be fulfilled. A request \( i \) consists of a pick-up \( p_i \), a drop-off \( d_i \), and a number of passengers \( c_i \). Pick-up and drop-off must take place at locations \( \ell_{p_i} \) and \( \ell_{d_i} \), respectively. Pick-up must occur within time window \( w_{p_i} = [s_{p_i}, e_{p_i}] \) and drop-off must occur within time window \( w_{d_i} = [s_{d_i}, e_{d_i}] \). Moreover, a heterogeneous fleet of vehicles \( k \in \mathcal{K}, |\mathcal{K}| = m \), is given. Each vehicle has a passenger capacity \( C_k \) that defines how many passengers can be transported. Further, each vehicle \( k \) has assigned vehicle operation times \( S_k \) and \( E_k \). Therefore, the vehicle is not available earlier than \( S_k \) and later than \( E_k \). Each vehicle starts and ends its tour at a defined location \( \ell_k \), e.g., a vehicle depot or the driver’s home address. Accordingly, \( \mathcal{L}, |\mathcal{L}| \leq 2(n + m) \), defines the set of all occurring locations.

As input we consider the travel times \( t_{ij} \), \( i, j \in \mathcal{L} \), and the (road) distances \( r_{ij} \), \( i, j \in \mathcal{L} \), that are implied by the road network. Further, for each request there is an estimated (un)boarding time \( b_i \), i.e., the required time for the passengers to enter/exit the vehicle. Additionally, special requirements, e.g., availability of child seats or accessibility for persons with impaired mobility, can be modeled by introducing compatibility indicators \( m_{ik} \), \( i \in I, k \in \mathcal{K} \), which are \( \text{true} \) if request \( i \) is executable by vehicle \( k \) and \( \text{false} \) otherwise.

The tour of each vehicle is defined as a sequence of pick-ups and drop-offs. Passenger transportation implies that for each request \( i \in I \), pick-up \( p_i \) and drop-off \( d_i \) must be executed by the same vehicle, that \( p_i \) must occur prior to \( d_i \), and that the maximal tolerable detour time \( u_i \), i.e., the maximal time a passenger spends in a vehicle additional to the travel time \( t_{p_i,d_i} \), is not exceeded. Moreover, the capacity \( C_k \) of the vehicle must not be exceeded at any time. Now, the DARP asks for the set of tours satisfying all transport requests \( i \in I \), while minimizing the total driven distance.

In the dynamic environment, the schedule is build iteratively as new transportation requests come in. The requests are booked through an app or arranged by a call-center agent. Clearly, requests that have already been executed, being executed at the moment, or close to being executed can not be rescheduled.

3. Approach & Benchmarking

First, we provide a Mixed-Integer Linear Program (MILP) in order to give a clear description of the considered variant of the static DARP problem. In practice, as the MILP does not scale sufficiently well, we use a Large Neighborhood Search (LNS). Hence, we propose a LNS, based on [Ropke and Pisinger 2006], that we adapted to our problem description and allows to dynamically add new transportation requests.

In a computational study, we aim to find favorable configurations of the mobility service in order to improve its sharing rates. Such configurations are characterized by a well-chosen compromise between passenger (in)convenience and cost-efficient operations.

References
