The dial-a-ride problem: models and algorithms

Jean-François Cordeau · Gilbert Laporte

Published online: 5 May 2007
© Springer Science+Business Media, LLC 2007

Abstract The Dial-a-Ride Problem (DARP) consists of designing vehicle routes and schedules for \( n \) users who specify pickup and delivery requests between origins and destinations. The aim is to plan a set of \( m \) minimum cost vehicle routes capable of accommodating as many users as possible, under a set of constraints. The most common example arises in door-to-door transportation for elderly or disabled people. The purpose of this article is to review the scientific literature on the DARP. The main features of the problem are described and a summary of the most important models and algorithms is provided.

Keywords Dial-a-ride problem · Survey · Static and dynamic pickup and delivery problems

1 Introduction

The Dial-a-Ride Problem (DARP) consists of designing vehicle routes and schedules for \( n \) users who specify pickup and delivery requests between origins and destinations. Very often the same user will have two requests during the same day: an outbound request from home to a destination (e.g., a hospital), and an inbound request for the return trip. In the standard version, transport is supplied by a fleet of \( m \) identical vehicles based at the same depot. The aim is to plan a set of minimum cost vehicle routes capable of accommodating as many requests as possible, under a set of constraints. The most common example arises in
door-to-door transportation services for elderly or disabled people (see, e.g., Madsen et al. 1995; Toth and Vigo 1996, 1997; Borndörfer et al. 1997; Cololini and Righini 2001; Diana and Dessouky 2004; Rekiek et al. 2006; Melachrinoudis et al. 2007).

In western countries several local authorities are setting up dial-a-ride services or are overhauling existing systems in response to increasing demand. This phenomenon can be attributed in part to the aging of the population but also to a trend toward the development of ambulatory health care services. Some existing systems cannot adequately meet demand while others are faced with escalating operating costs. There is a genuine need for reliable cost effective systems, and operations research can help reach this goal.

From a modeling point of view, the DARP generalizes a number of vehicle routing problems such as the Pickup and Delivery Vehicle Routing Problem (PDVRP) and the Vehicle Routing Problem with Time Windows (VRPTW). For overviews on these problems, see Cordeau et al. (2007a, 2007b). What makes the DARP different from most such routing problems is the human perspective. When transporting passengers, reducing user inconvenience must be balanced against minimizing operating costs. In addition, vehicle capacity is normally constraining in the DARP whereas it is often redundant in PDVRP applications, particularly those related to the collection and delivery of letters and small parcels.

This paper updates and extends a previous survey published in 4OR (Cordeau and Laporte 2003b). It is organized as follows. The main features of the DARP are described in Sect. 2, followed by mathematical models in Sect. 3. The following two sections summarize the main algorithms for the single-vehicle DARP and for the multi-vehicle DARP, respectively. Conclusions follow in Sect. 6.

2 Main features of the DARP

Dial-a-ride services may operate according to a static or to a dynamic mode. In the first case, all transportation requests are known beforehand, while in the second case requests are gradually revealed throughout the day and vehicle routes are adjusted in real-time to meet demand. In practice pure dynamic DARPs rarely exist since a subset of requests is often known in advance.

Most studies on the DARP assume the availability of a fleet of $m$ homogeneous vehicles based at a single depot. While this hypothesis often reflects reality and can serve as a sound base for the design of models and algorithms, it is important to realize that different situations exist in practice. There may be several depots, especially in wide geographical areas, and the fleet is sometimes heterogeneous. Some vehicles are designed to carry wheelchairs only, others may only cater to ambulatory passengers and some are capable of accommodating both types of passenger. The main consideration in some problems is to first determine a fleet size and composition capable of satisfying all demand, while in other contexts, the aim is to maximize the number of requests that can be served with a fixed size fleet. Some systems routinely turn down several requests each day. A compromise consists of serving some of the demand with a core vehicle fleet and using extra vehicles (e.g., taxis) if necessary.

Given this, it makes sense to consider two possible problems: (1) minimize costs subject to full demand satisfaction and side constraints; (2) maximize satisfied demand subject to vehicle availability and side constraints. The most common cost elements relate to regular fleet size and operation, occasional use of extra vehicles, and drivers’ wages.

Quality of service criteria include route duration, route length, customer waiting time, customer ride time (i.e., total time spent in vehicles), and difference between actual and desired delivery times. Some of these criteria may be treated as constraints or as part of the