Transportation Research Part B 000 (2018) 1–27

Contents lists available at ScienceDirect

Transportation Research Part B

journal homepage: www.elsevier.com/locate/trb

Review

A survey of dial-a-ride problems: Literature review and recent developments

Sin C. Ho[a], W.Y. Szeto[b,*], Yong-Hong Kuo[c,d], Janny M.Y. Leung[e], Matthew Petering[f], Terence W.H. Tou[g]

[a] Department of Systems Engineering and Engineering Management, The Chinese University of Hong Kong, Hong Kong, China
[b] Department of Civil Engineering, The University of Hong Kong, Hong Kong, China
[c] Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Hong Kong, China
[d] Stanley Ho Big Data Decision Analytics Research Centre, The Chinese University of Hong Kong, Hong Kong, China
[e] School of Science and Engineering, The Chinese University of Hong Kong (Shenzhen), Shenzhen 518172, China
[f] Department of Industrial and Manufacturing Engineering, University of Wisconsin-Milwaukee, Milwaukee, USA
[g] MTR Corporation Limited, Kowloon Bay, Hong Kong, China

ARTICLE INFO

Article history:
Received 21 May 2017
Revised 29 December 2017
Accepted 1 February 2018
Available online xxx

Keywords:
Dial-a-ride
Heuristics
Exact methods
Survey
Share-a-ride
Pickup
Delivery

ABSTRACT

There has been a resurgence of interest in demand-responsive shared-ride systems, motivated by concerns for the environment and also new developments in technologies which enable new modes of operations. This paper surveys the research developments on the Dial-A-Ride Problem (DARP) since 2007. We provide a classification of the problem variants and the solution methodologies, and references to benchmark instances. We also present some application areas for the DARP, discuss some future trends and challenges, and indicate some possible directions for future research.

1. Introduction

1.1. History of the problem

Public transit systems always face the conflicting objectives of cost-efficient operations and high quality service – in delivering customers from/to their desired origin/destination at the desired time. Scheduled bus or train services can carry a large number of passengers (and thus are cost efficient), but travel on fixed routes at scheduled times to which passengers must adjust their travel plans accordingly. Scheduled bus services are often not provided (or very infrequent) for rural communities because the cost of running the service cannot be justified by the low demand. Taxi services offer door-to-door services on request, but the cost of this service is high, both in monetary terms and in impact to the environment. Thus, there has been much interest in on-demand public transit services that combine cost-efficiency and customizable

* Corresponding author.
E-mail addresses: sinho@hku.hk (S.C. Ho), ceszeto@hku.hk (W.Y. Szeto), yhkuo@hku.hk (Y.-H. Kuo), jannyleung@cuhk.edu.cn (J.M.Y. Leung), mattpete@uwm.edu (M. Petering), whtou@mtr.com.hk (T.W.H. Tou).

https://doi.org/10.1016/j.trb.2018.02.001
0191-2615/

Table 1
A comparison between three public transportation services.

	Bus	On-demand transit	Taxi
Route	fixed	flexible	customized
Schedule	fixed	by request	by request
Speed	slow	medium	fast
Cost	low	medium	high
Mode	shared	shared	non-shared
Capacity	high	medium	low
Reservation	not needed	often needed	not needed

service. On-demand transit vehicles do not have fixed routes or schedules but are dispatched based on the transport requests received; unlike taxi services, passengers may share the use of the vehicles and thus may not be taken along the most direct route from their origin to destination. A comparison of these three types of public transportation services is given in Table 1.

The first trial of an on-demand public transit service, called Dial-A-Ride (since customers phone in their transport requests) was offered in Mansfield, Ohio, USA in 1970. The first demand-responsive service in the United Kingdom was offered in Abingdon in 1972 by the City of Oxford Motor Services. The feasibility of such Dial-a-Ride (DAR) services was demonstrated and similar schemes sprang up elsewhere (see Oxley, 1980). DAR services are particularly valuable to disabled persons and the elderly who may have difficulties using standard public transit services. The Americans with Disabilities Act (ADA), signed into law in 1990, requires all public transport agencies to provide specialized transportation comparable to public transit bus services (sometimes called paratransit) for individuals with disabilities. As a consequence, many demand-responsive systems have evolved from general public service to focused paratransit services. The complexities of operating DAR services (e.g., tight time-windows, last-in-first-out due to vehicle layout) mean that computerized planning and scheduling is necessary for systems of realistic size.

Early solution approaches for the planning and scheduling of DAR systems were heuristic methods, e.g., those developed at MIT for the DAR systems in Rochester, New York, USA (see Wilson et al., 1971). Stein (1978) presented the first models for the planning and scheduling problem of DAR systems, i.e., the Dial-a-Ride Problem (DARP), and obtained bounds for both the static and dynamic versions. Psaraftis (1980) developed a dynamic-programming exact algorithm for both the static and dynamic versions of the DARP with a single vehicle. In the past 40 years, research into the DARP has been growing steadily. For a survey of the models and algorithms developed up to 2007, the reader is referred to Cordeau and Laporte (2007).

1.2. Applications

DARPs are always motivated by real-life applications. Each addresses various realistic features that lead to specific constraints or objectives and yields further insights. Below, we highlight several major application areas since 2007.

A traditional application is non-profit DAR services for the elderly and disabled, which often have cost minimization as the objective. Operational constraints include ride and waiting time, pickup/delivery time-windows, vehicle capacity, and equipment layout within the vehicle (e.g., Karabuk, 2009; Qu and Bard, 2013; Qu and Bard, 2015). Some DAR systems use heterogeneous fleets (e.g., Häll and Peterson, 2013; Häll et al., 2015). Others may allow transfers from one vehicle to another, e.g., for mentally disabled but ambulant passengers (Masson et al., 2014). With different stakeholders, DAR systems often have multiple (and sometimes conflicting) goals, necessitating multi-criteria models (e.g., Paquette et al., 2013; Lehuédé et al., 2014).

Many airports offer dedicated transportation for injured, elderly, weak, and disabled passengers with reduced mobility (PRMs). There are very tight time-windows for pick-ups (exactly when alighting upon arrival) and drop-offs (seated in aircraft well before departure when boarding), and the PRMs may not be left unsupervised. These constraints often originate from a service contract among the service provider, the airport, and the airlines (Reinhardt et al., 2013).

Another major application area is in health care. In this application, time urgency and equipment/staff compatibilities are important. Staff and maintenance scheduling concerns also add considerable complexity. For intra-hospital transportation, which involves the movement of patients, supplies, and equipment for diagnostic or therapeutic reasons, additional constraints may include non-sharing of ambulances of isolation patients, accompanying staff/equipment, specific pickup and delivery sequence of doctors and patients, and prioritization (urgent vs. normal) of requests (Hanne et al., 2009; Beaudry et al., 2010). For non-urgent patient transportation to/from hospitals, the vehicle may be re-configured to provide for staff seats, patient seats, stretchers, and wheelchairs. Constraints include mode-dependent capacities, driver-vehicle assignments, maximum shift lengths, and mandatory driver breaks. Parragh (2011), Parragh et al. (2012), and Schilde et al. (2011, 2014) studied the Austrian Red Cross in Graz. For the Hong Kong Hospital Authority (HKHA), each ambulance interior must be disinfected between consecutive trips to avoid the spread of disease. The choice not to serve some clients is allowed (Zhang et al., 2015; Liu et al., 2015; Lim et al., 2017). In Molenbruch et al. (2017c), restrictions on particular user–user and user–driver combinations are considered. In the application in Tuscany studied by Detti et al. (2017), a patient can choose the transport provider among different non-profitable organizations.