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Enhancing the service quality of transit systems in rural areas by flexible transport services

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Abstract

Public transit services in rural areas need to be innovative to satisfy variable demand. In addition, travel demand is low and residents may have different destinations. Furthermore, rural communities vary widely within regions. Therefore, it is inadvisable to run a fixed schedule transit service. Government and local authorities have attempted to maintain public transit services in rural areas and improve accessibility to these services. Dial-a-Ride (DAR) systems are a form of flexible transportation for better service in rural areas by covering a relatively large area with respect to potential demand. The complexity of the problem makes the DAR problem an NP-hard problem, whose optimal solution is difficult to find in cases of medium- and large-sized problems. As a result, most paper handling solution methods for a DAR problem are based on heuristic methods. Here, we provide a solution for the DAR service problem based on a mixed-integer formulation. This study mainly discusses enhancing transit service in rural areas with complex road network topographies where fixed services are less available or are cost ineffective. In addition, we discuss improving service quality with respect to different user types. More attention is paid to considering the social side cost by minimizing not only operating costs but also the total travel times of all travelers. Computational experiments based on real-life data from a locality in Gifu Prefecture, Japan were carried out to test the effectiveness of the proposed algorithm. The results show decreased mean waiting time and excess ride time by considering user costs.

Keywords: Dial-A-Ride; Rural Areas; Social Costs

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1. Introduction

A common problem in rural areas is a lack of public transit systems, particularly for people with special needs which may lead to social exclusion. It is difficult to enjoy a transit service if the bus stop or station is distant from the traveler's origin and/or destination, particularly in adverse weather conditions. With increasing social awareness in recent years, we now understand that many people cannot use a traditional public transit system. As a result, flexible transit systems have replaced traditional transportation systems in some rural areas. ITS technologies and automated reservation and scheduling systems have enhanced the operational strategies of transit services. Use of GPS enhances dispatch operations, and mobile data terminals provide fast and accurate trip information. These enhancements have allowed more flexible and cost-effective transport services to be constructed, such as Demand-Responsive Transport (DRT) and Dial-a-Ride (DAR) services.

The Dial-a-Ride problem (DARP) is a generalization of the Pickup and Delivery Problem with Time Window (PDPTW), in which passengers are transported between specified origins and destinations. The DARP consists of designing vehicle routes and schedules for a number of users to be picked up and delivered to specified points within a given time window (TW). Due to the high level of service required for this type of service, additional operational constraints must be considered, which increase the complexity of the problem.

The area of this study is a rural mountainous area; therefore, the road network has complex topography, and communities are not well connected (Fig. 2a). The communities varied widely across the area (e.g., the distance between the two furthest served points was 18.6 km, which requires travelling 40 min). In addition, traffic demand is low and more than 40% of the population are elderly people. Therefore, it is inadvisable and cost ineffective to run a fixed-route bus service. Instead, local authorities have provided a dial-a-ride service and improved the availability and accessibility of these services at a low cost. The aim of this study was to use a DAR service as a public transit system in places where regular fixed services are less available or cost ineffective due to low demand, low population density, or areas with complex road network topographies. The objective was to minimize the total operational costs of the service and total travel times while satisfying a set of passenger service constraints. In addition, the quality of the service provided was to be enhanced with respect to different user types. More attention was paid to the design of the service, considering user and operating costs.

The remainder of the study is organized as follows: Section 2 reviews DARP-related studies, and Section 3 describes the details of formulating a DARP model. Section 4 reports some computational results, and the conclusions and comments are discussed in Section 5.

2. Literature review

The DARP is a generalization of the PDPTW. However, people are transported in a DARP, instead of goods, which focuses the problem on controlling user inconvenience. The reader is referred to Parragh et al. (2008a, b) for PDPTW and Cordeau and Laporte (2003a–2007a) for PDPTW and DARP surveys.

According to Psarafits (1980) DAR systems can be operated in static and dynamic modes, based on demand characteristics. In the static case, all travelers' requests are known in advance, whereas in dynamic mode requests are received during the day, and the vehicles' routes and schedules are updated in real time. However, Cordeau and Laporte (2003a) reported that a pure dynamic DAR rarely exists, as a subset of the requests is known in advance.

Kurauchi et al. (2005) reported that a variety of request assignment methods exist. The "First-Request-First-Serve" protocol, in which service is provided based on the sequence of requests, is simple but inefficient for handling many requests. An earlier request always has priority in the "First-Request-First-Assign" system but the results may not be globally optimal, as demand is assigned sequentially. Those authors stated that gathering all requests in advance and assigning them simultaneously is necessary to obtain an optimal global solution.

The DAR problem is complex, which makes it an NP-hard problem, whose optimal solution is difficult to find. Therefore, most studies that have described DARP solutions were based on heuristic and metaheuristics methods. Diana and Dessouky (2004) presented a parallel regret insertion heuristic to solve the DARP with a TW. The proposed algorithm was tested on datasets of 500 and 1,000 requests in Los Angeles County (CA, USA). The results showed that the quality of the solution was improved consistently when compared with the classical insertion heuristic.