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A dynamic station strategy to improve the performance of flex-route transit services

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ABSTRACT

As an innovative combination of conventional fixed-route transit and demand responsive service, flex-route transit is currently the most popular type of flexible transit services. This paper proposes a dynamic station strategy to improve the performance of flex-route transit in operating environments with uncertain travel demand. In this strategy, accepted curb-to-curb stops are labeled as temporary stations, which can be utilized by rejected requests for their pick-up and drop-off. The user cost function is defined as the performance measure of transit systems. Analytical models and simulations are constructed to test the feasibility of implementing the dynamic station strategy in flex-route transit services. The study over a real-life flex-route service indicates that the proposed dynamic station strategy could reduce the user cost by up to 30% without any additional operating cost, when an unexpectedly high travel demand surpasses the designed service capacity of deviation services.

1. Introduction

In recent decades, transit planners have focused on providing fixed-route, fixed-schedule transit services in relatively dense city areas. However, recent social development has resulted in more sparse suburban and rural communities, which requires transit services to be more flexible. Based on an investigation of transit agencies in North America by Potts et al. (2010) flex-route transit is by far the most popular form of flexible transit services. This new type of flexible transit service is generally considered a combination of conventional fixed-route transit and demand-responsive service (see Fig. 1). It is regarded as a fixed-route service because it includes a base route through the service area, with predetermined schedules and mandatory checkpoints located at high-density demand locations. Conversely, it is considered demand responsive because vehicles are allowed to deviate from the base route to serve curb-to-curb requests.

Flex-route transit is generally recognized as a cost-efficient alternative to provide curb-to-curb service. Pure demand responsive transit could provide the desired flexibility, but the high operating cost limits this type of operation mode to special services, such as paratransit. The reactions of customers to flex-route transit appear to be generally positive, and nearly 70% of respondents confirmed that flex-route services are more convenient than regular bus routes, in an investigation towards flex-route transit customers (Higgins and Cherrington, 2005).

As an emerging type of flexible transit, there are only a few studies examining flex-route systems. Daganzo (1984) presented a preliminary study of the feasibility of checkpoint dial-a-ride systems, which are similar to flex-route services.

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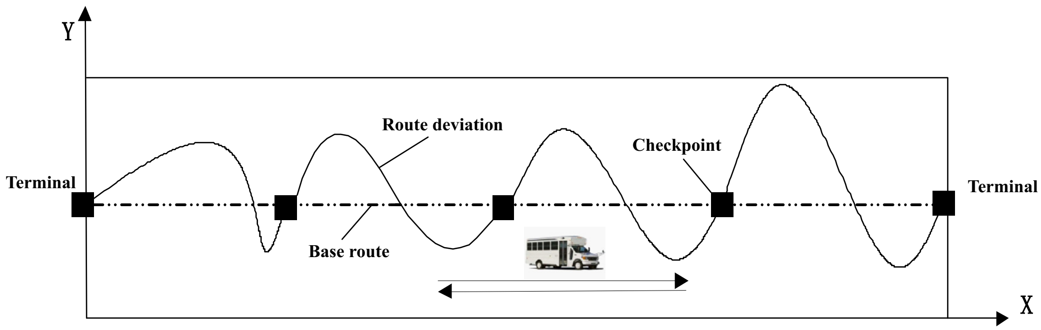

Fig. 1. The flex-route transit service.

Fu (2002) revealed the fundamental relationships between system performance and design parameters. Quadrifoglio et al. (2007, 2008a) constructed scheduling algorithms for dynamic and static operating scenarios of flex-route transit. Nourbakhsh and Ouyang (2012) developed a new structured flexible-route transit system that works well at low-to-moderate demand levels. Alshalalfah and Shalaby (2012) explored the feasibility of flex-route as a feeder transit service to rail stations.

In contrast, transit systems that operate in a demand-responsive fashion, have been extensively studied. Daganzo (1977, 1978) estimated the system performance in many-to-one and many-to-many demand responsive service. Lots of performance measure models (Horn, 2002a; Aldaihani et al., 2004; Quadrifoglio and Li, 2009; Diana et al., 2009; Li and Quadrifoglio, 2010) were subsequently presented to study the settings for operating demand responsive systems. Palmer et al. (2004) explored the impacts of advanced technologies and management practices on demand-responsive transit operation. The more diffuse and less predictable travel behaviors to-day were considered in designing flexible transit systems (Nelson et al., 2010), and developing integrated flexible transit platforms (Velaga et al., 2012a). Errico et al. (2013) proposed a unifying modeling framework for planning flexible transit systems. In addition, many scheduling systems and software (Fu, 1999; Horn, 2002b; Dessouky et al., 2003; Tsubouchi et al., 2010; Qiu et al., 2014) have been developed for operating flexible transit services.

Although the concept of flexible transit services has been proposed for over 40 years, these innovative operating policies have been applied only by a small percentage of transit agencies (Potts et al., 2010). The research by Velaga et al. (2012b) revealed that one of the challenges of providing flexible transit services is that the uncertain travel demand in low-demand areas is difficult to forecast. In flex-route systems, the slack time for deviation services is generally designed based on the expected curb-to-curb demand level. This is considered to be fragile in operating environments with uncertain travel demand, because some of requests might be rejected as actual demand exceeds the service capacity of deviation services, which is defined as the maximum feasible number of stops under predetermined slack time.

Previous studies have tended to idealize the treatment of rejected requests. Fu (2002) considered that deviation services are only offered to disabled people in his operating environment, and rejected demand can be accommodated by a specialized paratransit service. However, due to the high operating cost, providing this type of specialized service for general public seems unaffordable in operation. Quadrifoglio et al. (2007) assumed that a no-rejection policy is applied in their flex-route services, and rejected requests would be attempted to be inserted in the following rides. Our investigation over more than 110 real-life flex-route services in North America implied that flex-route policy is seldom applied to support frequent transit services, and most flex-route services have service headways of at least 1 h. Thus the no-rejection assumption might not be realistic because waiting for the next available vehicle makes it difficult for passengers to adhere to their daily schedules.

With the help of the ITS technique, customers can easily reserve deviation services through the client sides on cell phones and websites. Curb-to-curb customers immediately receive the decision from the schedule system whether they are accepted or not, and accepted customers could directly obtain the operating schedule. Here, we propose a dynamic station strategy in which pick-up or drop-off locations of accepted stops are regarded as temporary stations, and rejected customers, if any, could utilize temporary stations for their pick-up or drop-off, instead of walking to/from checkpoints or waiting for the follow rides. This strategy is easily implemented by sending the schedule information of suggested temporary stations to rejected customers from the scheduling system.

In this paper, we intended to study the feasibility of applying the dynamic station strategy to flex-route services, and test the ability of this strategy to improve the performance of flex-route services when the varying demand exceeds the designed service capacity of deviation services. This new technique is not complex but it is still regarded as an indispensable improvement in operating flex-route transit services.

2. Model description

2.1. Service area and demand

For illustration purposes, the model in our analysis was constructed based on a hypothetical flex-route transit service. The system includes a single service vehicle and a rectangular service area of width $2M$ and length L, delimited by two terminal