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Demi-flexible operating policies to promote the performance of public transit in low-demand areas

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ABSTRACT

The efforts of providing attractive transport service to residents in sparse communities have previously focused on operating flexible transit services. This paper identifies a new category of transit policies, called demi-flexible operating policies, to fill the gap between flexible transit services and conventional fixed-route systems. The passenger cost function is defined as the performance measure of transit systems and the analytic work is performed based on a real-world flag-stop transit service, in which we compare its system performance with another two comparable systems, the fixed-route and flex-route services, at expected and unexpected demand levels in order to be closer to reality. In addition, the dynamic-station policy is introduced to assist the flex-route service to better deal with unexpectedly high demand. Experiments demonstrate the unique advantages of demi-flexible operating policies in providing affordable, efficient, and reliable transport service in low-demand operating environments and this work is helpful to optimize the unifying framework for designing public transit in suburban and rural areas.

1. Introduction

Recent economic growth patterns and social changes have resulted in more sparse residential districts, which do not favor conventional fixed-route, fixed-schedule forms of transit services. Demand responsive transit might be an option in low-demand areas, which provides curb-to-curb services to all customers entirely based on the actual travel demand, without fixed stations or routes. However, due to the high operating cost, demand responsive transit is generally limited to special systems, such as paratransit, and it seems unpractical to provide this kind of costly personalized transport service to the general public.

In the past decades, planners have been trying to introduce flexible operating policies to the public transit market in suburban and rural areas, to encourage residents to leave their cars in the trips to nearby destinations. Similar to Koffman (2004), in this paper we use "flexible transit services" to name all types of hybrid services that are not pure demand responsive service or conventional fixed-route, fixed-schedule transit, but could offer some degree of complete curb-to-curb services to requests in designated service areas. In other words, flexible transit services provide curb-to-curb services on the basis of serving regular station-to-station passengers. In Koffman's survey, flexible operating policies mainly include six

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types: flex-route transit (also called route deviation transit), point deviation transit, demand-responsive connector, request stops, flexible-route segments and zone route.

The investigation by Potts et al. (2010) revealed that 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. The survey in Great Britain by Davison et al. (2014) also indicated that the future of these new services remains uncertain due to financial sustainability and operational issues. The development of flexible transit systems seems to be far behind prior expectation, especially considering the convenience of provided curb-to-curb services. Recently, researchers have begun to realize that applying flexible operating policies is more complex than it looks. Velaga et al. (2012a) summarized the challenges of operating flexible transit services, besides the lack of the support of public policies and appropriate planning and evaluation tools, another two primary bottlenecks are the uncertainties of travel demand in low-demand areas, and the short of sophisticated real-time communication systems between transit providers and customers.

In operation, flexible transit services are generally operated with predetermined slack time for curb-to-curb services, which is allotted based on the expected demand level, while the uncertain travel demand in low-demand areas makes it difficult for operators to forecast the actual passenger flow. In addition, the costs, staffing and training in the use of sophisticated support systems make transit divisions more hesitant to attempt at these emerging flexible operating policies. These challenges inevitably limit the popularity of flexible transit services, and explain why some transit agencies abandoned the efforts after several months or years.

In order to fill the gap between flexible transit services and conventional fixed-route systems, here we define another category of services named demi-flexible transit policies, which means that policies in this group do not provide complete curb-to-curb services, but still offer some kind of flexibility to transit customers. In reality, the concept of demi-flexible operating policies is not strange, and the most common form of services in this category is the flag-stop operating policy, which can be found in many transit systems operated in rural and suburban areas.

In this paper our analysis is performed by implementing comparable operating policies in a real-life transit service. Besides demi-flexible operating policies, appropriate flexible and fixed-route policies have also been examined in the same system. The system performance under different operating policies has been compared, considering the uncertainties of travel demand, to explore the advantages of demi-flexible operating policies in promoting public transit services in low-demand areas.

2. Literature review

Different from Koffman (2004) and our work, Errico et al. (2013) used "semi-flexible transit systems" to name all kinds of transit services combining on-demand service adjustment capabilities and schedule characteristics of conventional transit. In our framework, these services can be divided into two groups: flexible and demi-flexible operating policies. To our knowledge, demi-flexible operating policies have been seldom examined in existing studies. Almost all the efforts have been made on optimizing flexible transit systems and a limited number of related literatures have primarily focused on two common forms of flexible transit services: flex-route transit and demand-responsive connector.

Flex-route transit is regarded as an innovative combination of fixed-route transit and demand responsive service, and was by far the most popular form of flexible transit services (Potts et al., 2010). Daganzo (1984) proved that flex-route transit could possibly become cost-effective compared with demand responsive service. Fu (2002) revealed the fundamental relationships between system performance and design parameters in flex-route services. Quadrifoglio et al. (2006, 2008a) developed bounds on the maximum longitudinal velocity of service vehicles, and proposed a static scheduling formulation for a flex-route service called mobility allowance shuttle transit. Alshalalfah and Shalaby (2012) investigated the feasibility of applying flex-route policy as feeder transit in suburban areas. Nourbakhsh and Ouyang (2012) proposed a flex-route transit network that has a system advantage under low-to-moderate demand levels. Qiu et al. (2014a, 2014b) proposed a novel scheduling system for flex-route services and investigated the feasibility of utilizing accepted curb-to-curb stops to promote the operating reliability of flex-route services. Qiu et al. (2014c) developed a two-stage scheduling model for flex-route services. Furthermore, Qiu et al. (2015a,b) explored the choice modeling between fixed-route and flex-route operating policies in transit systems.

Demand-responsive connector is generally operated as feeder transit to collect passengers from their houses to the transfer terminal linked with the major transit network. Aldaihani et al. (2004) developed an analytical model to design a hybrid grid network that integrates demand-responsive connectors with a fixed-route major transit service. Li and Quadrifoglio (2009, 2010), and Quadrifoglio and Li (2009) investigated the zone design problem and service mode choice between demand-responsive connector and conventional fixed-route service. Chandra and Quadrifoglio (2013) estimated the optimal service cycle in operating demand-responsive connector.

In contrast, demand responsive transit has been extensively studied in the past decades. Most efforts were made on the efficient routing and scheduling of demand responsive service (Fu, 1999; Horn, 2002; Dessouky et al., 2003; Cremers et al., 2009). In addition, some other studies dealt with planning and operation problems in demand responsive service. Daganzo (1978) evaluated the system performance of many-to-many demand responsive service. A new high-coverage point-to-point transit system was proposed by Cortes and Jayakrishnan (2002). Palmer et al. (2004) and Quadrifoglio et al. (2008b) examined the effect of advanced technologies and specific operating practices on the productivity of demand responsive transit