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Original Research Paper

Timetable optimization for single bus line based on hybrid vehicle size model

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ABSTRACT

This study proposes a flexible timetable optimization method based on hybrid vehicle size model to tackle the bus demand fluctuations in transit operation. Three different models for hybrid vehicle, large vehicle and small vehicle are built in this study, respectively. With the operation data of Shanghai Transit Route 55 at peak and off-peak hours, a heuristic algorithm was proposed to solve the problem. The results indicate that the hybrid vehicle size model excels the other two modes both in the total time and total cost. The study verifies the rationality of the strategy of hybrid vehicle size model and highlights the importance of the adaptive vehicle size in dealing with the bus demand fluctuation. The main innovation of the study is that unlike traditional timetables, the arrangement of the scheduling interval and the corresponding bus type or size are both involved in the timetable of hybrid vehicle size bus mode, which will be more effective to solve the problem of passenger demand fluctuation. Findings from this research would provide a new perspective to improve the level of regular bus service.

1. Introduction

As one of the most troublesome problems in urban transit operation research, bus demand fluctuation at different periods is widespread, seriously challenging the bus operating efficiency (Ahmed, 2014; Doust, 2014). Bus resource waste at off-peak time is a common phenomenon, which generally leads doubts to the rationality of the bus timetable (Sun et al., 2011; Xue et al., 2015). Consequently, timetable optimization is an important task for transportation researchers to tackle the problem.

Determining an appropriate schedule interval for a bus line is the main method to adjust to the demand fluctuation. In the previous works of bus operation optimization, microeconomic model was proposed, considering passenger waiting time, in-vehicle time and access time, and the total cost was a function

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of bus schedule frequency, where the fittest frequency could be easily calculated (Mohring, 1972). Hurdle (1973) devised a schedule to minimize the total cost, including passenger waiting time, and vehicle operation cost using fluid flow model and found the optimal solutions for a number of hypothetical frequency. Since the demand for high quality bus service increased, Marques et al. (1996) introduced a notion of flexible and dynamic public transport schedule, and the system comprehensively analyzed service supply, demand and network data to reschedule the so-called SUPERBUS. Feasibility evaluation of the technology, user-acceptance and socioeconomics for SUPERBUS was also included in the study. Mekkaoui et al. (2000) used an explicit traveler choice model, which assumed bus riders select the solution to minimize the cost incurred by traveling earlier or later than their ideal schedule time, to obtain the desirable solution. Ceder (2005, 2007) introduced four different methods in determining a timetable based on a range of data collection techniques. Bai et al. (2013) analyzed bus scheduling method including big interval departure, time in coordination, adopted three synchronization methods and obtained inhomogeneous departure intervals.

As presented, the majority of previous literature focused on the optimization of schedule interval, while the importance of the adaptive bus size for each bus trip is ignored, although some researchers tried to find the optimal bus size for a single bus line and some literature focused on the estimation of fleet size (Ceder, 2005; Oldfield and Bly, 1988). As referred, vehicle waste is common and the existence of low-loading bus will seriously lower the operation efficiency. In fact, some scholars indicated that in this condition, the merits of public transport were significantly reduced (Potter, 2003). Hybrid-vehicle-type bus was considered in some vehicle scheduling research, while the types of bus in these studies were arbitrary, which influenced its application (Kliewer et al., 2006; Site and Filippi, 1998). Unlike the former literature, Ceder et al. (2013a, 2013b) dealt with the creation of bus timetables using several fixed types bus to improve urban public transport service, concluded that the implementation of the mixed vehicle size bus fleet was promising. Unfortunately, their study is mainly limited to traditional timetabling strategies, with the deficiency of reasonable modes to reveal the systematic relationship between passenger time cost and operational cost with the changing of vehicle size for the bus trip.

Based on the achievements of literature, three different models for hybrid vehicle size bus, large vehicle size bus and small vehicle size bus are built, respectively in the study. The operation mode is defined by the vehicle type. In the study, vehicle bus is used in hybrid vehicle sizes model, only large vehicle bus is used in large vehicle size model and only small vehicle bus is used in small vehicle size model. The bus type is determined by the number of seats in the vehicle. As to be mentioned in Section 4.2, the seats numbers in large vehicle bus and small vehicle bus are 29 and 19 respectively. The result comparisons are conducted to verify whether the hybrid vehicle size model is suitable to real world bus operation. In additional to the description of background and literature review, problem formulation is presented in Section 2. Three different models are introduced in Section 3 and Section 4, schedule schemes for the three models were obtained and compared. Conclusions and future research are summarized in Section 5.

2. Problem formulation

For a single vehicle size model (large vehicle size model or small vehicle size model), the operation arrangement is to determine the schedule interval, while it needs to determine both the schedule interval and the type of bus for the hybrid vehicle size model. The schedule interval and the type of vehicle affect both the level of service, represented by the total time cost of passengers and the operational cost (Xue et al., 2014). The object of the study is a bus line with several bus tops in which the passenger's OD matrices can be calculated from the data of IC card and GPS (Zhao et al., 2007; Sun et al., 2014). The task of the study is to determine the operation arrangement for each bus trip at the condition of travel demand fluctuation. To determine the main factors in the study, assumptions were proposed to simplify the process as follows:

(1) The travel time between two stops will be calculated by the average speed of the bus;
(2) The operation parameters (i.e., speed, acceleration, etc.) are assumed to be equal for all vehicle size buses in the study;
(3) No capacity constraint, meaning all passengers arriving at the stop can be loaded by the next vehicle;
(4) No quantity restrictions in the use of any vehicle size buses.

Based on the assumptions, the main factors are determined as time periods and vehicle size. The application of

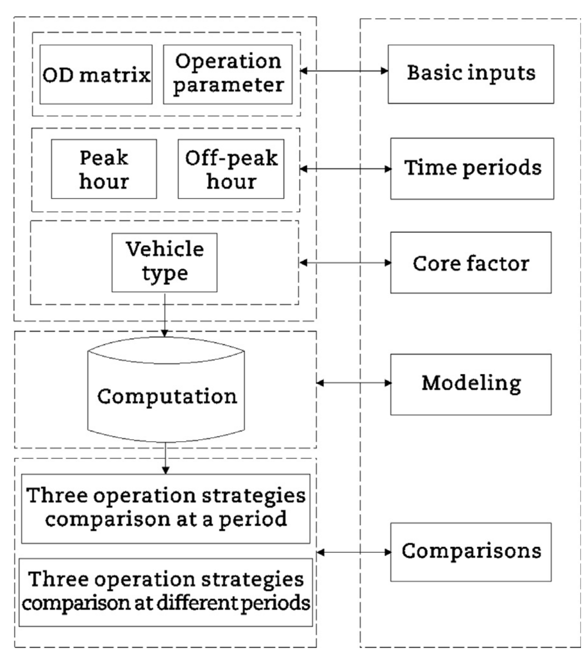

Fig. 1 – Framework of problem formulation.