Case Studies on Transport Policy 3 (2015) 287–294

Contents lists available at ScienceDirect

Case Studies on Transport Policy

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

An approach for identifying optimal service for rural bus routes

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ARTICLE INFO

Article history:
Available online 16 September 2014

Keywords:
Optimal bus service
Generalized cost (GC)
Model simulation
Willingness-to-pay (WTP)
Operational viability

ABSTRACT

An approach is demonstrated for identifying optimal bus service giving due considerations to both user costs and operational viability. The effects of demand level and route length on optimal service attributes are also investigated. A model is developed for simulating passenger movements and identifying the optimal service attributes for a demand level. The model is applied for different hypothetical scenarios in order to understand the variation of the optimal attributes with demand and route characteristics. The results indicate the influence of route characteristics, demand level, user costs, required cut-off revenue, etc. on the optimal bus service attributes. The findings from the present work related to fare model indicates that it is necessary to give due considerations to the demand and its distribution as well as length of different routes while recommending an optimal fare model for all the routes in a geographic region. The findings from the present work encourage further investigation on the effect of demand pattern on optimal bus service and selection of an optimal fare model for all routes in a geographic region.
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1. Introduction

In India, rural population constitutes about 69% (MHA, 2011) of the country's population. However, majority of the rural population is from economically weaker section with low vehicle ownership. As a result, rural populations are predominantly captive to public transportation system. It is, thus, necessary to improve public transport system in the rural areas in order to ensure inclusive economic growth of the country. Although India has a vast rail network spread across the country, the bus system is generally considered as the lifeline in rural areas. Unfortunately, rural bus service generally exhibits low journey speed, longer headway and relatively high discomfort level (due to crowding inside buses). Therefore, it is necessary to improve rural bus service for accelerating the economic growth of India.

Several studies have investigated the perception of trip makers toward bus system attributes. Phanikumar and Maitra (2004) modeled the disutility of travel to trip makers in the form of Generalized Cost (GC) using the stated choice data collected from trip makers along a rural bus route. Eboli and Mazzulla (2007) formulated a structural equation model to explore the relationship between passenger satisfaction and service quality attributes of bus service. Phanikumar and Maitra (2006) investigated the difference in the Willingness-to-pay (WTP) values between commuting and non-commuting trips. Apart from the behavioral aspects, several studies have been reported in the literature on network timetabling/scheduling (Bookbinder and Désilets, 1992; Chakroborty et al., 1995, 2001; Deb and Chakroborty, 1998; Bielli et al., 2010). Several studies have also been reported on network design problems (Chua, 1984; Ceder and Wilson, 1986; Chang and Schonfeld, 1991; Baaj and Mahmassani, 1995; Lee and Vuchic, 2005; Cipriani et al., 2012), most of which aimed to minimize operators' cost or maximize the profit. A few of them also considered social benefits during the design. Chen (2007) considered the problem of computing multiple headways for a single bus line to maximize the expected daily profit. Lampkin and Saalmans (1967) presented a case study with reference to design of routes, service frequencies, and schedules for a municipal bus undertaking in a small town in the north of England. Chakroborty et al. (1995) presented a GA based approach for determining optimal fleet size and schedule aiming to minimize waiting time and transfer time simultaneously for a given transit network. Vijayakumar and Jacobs (1990) studied the effect of time component on total system cost with the variation of vehicle size. But, practically no attempt has been made to relate user perceptions toward service attributes for the improvement planning of bus service in rural India. Traditionally, fare has been considered as the key issue in the context of rural bus system.

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http://dx.doi.org/10.1016/j.cstp.2014.09.003
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There is a need to improve rural bus service giving due consideration to the requirements of users and operators.

User benefit and operational viability are two key aspects in the context of improvement planning of rural bus service. User benefit may be perceived as a reduction in the disutility of travel. Disutility of travel is expressed using relevant quantitative (e.g., travel time, waiting time, bus fare) and qualitative (e.g., travel discomfort) attributes. These attributes generally have different measuring units, and therefore, need to be transformed to have a common unit for comparison or aggregation purpose. When monitory attribute is involved, the transformation is simple and the transformed value associated with each attribute is termed as Willingness-to-Pay (WTP) value. Aggregation of such WTP values, for the attributes describing an alternative or system is termed as Generalized Cost (GC). GC is a comprehensive measure of disutility associated with an alternative system or service. In the present work, the disutility associated with bus service is expressed in terms of GC and a reduction in GC is taken as a measure of user benefit. Bus service attributes such as headway of service and fare structure influence both user costs and operational viability. An attempt is made in the present work to minimize the GC (or maximize the benefit to bus users) through optimal selection of headway and fare model for the rural bus service. The operational viability is also duly considered in the process. Optimal service attributes and user benefit are also likely to vary with demand and route characteristics. The effects of demand level and route length on optimal service attributes and user cost are also investigated. Although the travel demand varies during different hours of the day, the service characteristics are determined on the basis of the peak hour demand only. The average revenue earned per hour during the span of operation is considered as 85% of the revenue earned during the peak hour to account for lower demand during the off-peak hours.

2. Methodology

In the present work, a model is developed, using MATLAB, for simulating passenger movements and identifying the optimal service attributes for a demand level. The model is then applied for different hypothetical scenarios in order to understand the variation of the optimal attributes with demand and route characteristics. The steps followed in the process are summarized in Fig. 1 and explained subsequently.

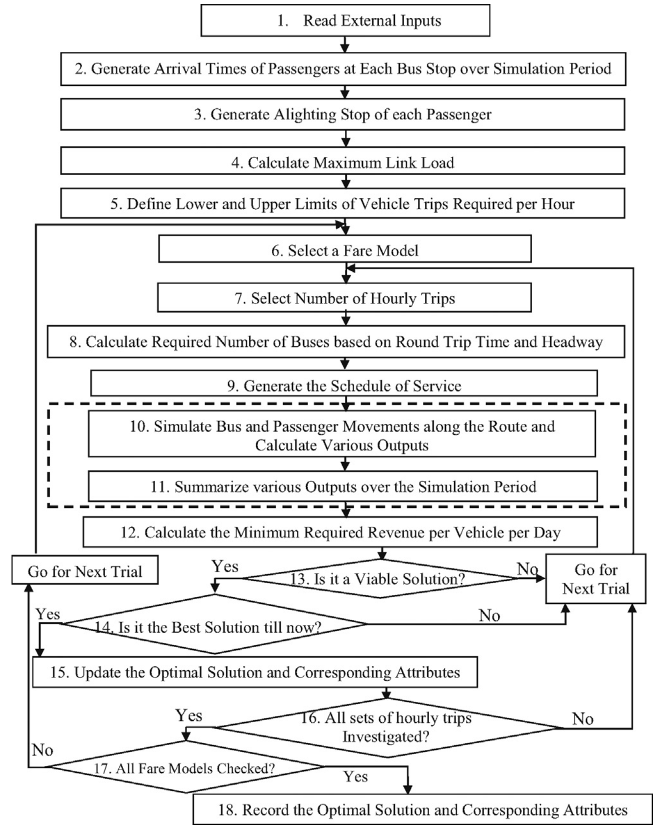

Fig. 1. Methodology for identifying optimal bus service attributes.

2.1. Step-1: Read external inputs

All the external inputs are read at the beginning. The external inputs include route characteristics, demand characteristics, bus characteristics, ranges for fare model components, user cost coefficients, operating hour, simulation period, layover time and vehicle operating cost. All these inputs are summarized in Fig. 2.

The route characteristic includes route length, number of stops along the route, and distance between successive stops (i.e., link length). The demand characteristic includes travel demand at different stops, and Origin–Destination (O–D) matrix. The bus system is supposed to serve the travel demands at different stops efficiently. O–D matrix gives the passenger distribution from each stop to the successive stops. Travel demand influences service characteristics and operational viability. The bus characteristics include seating capacity, crush capacity and average journey speed. Bus capacity influence the user cost associated with discomfort (due to crowding inside buses), whereas, the journey speed, route length and layover time influence the round trip time, and hence influence the number of buses required to serve the observed demand. The bus characteristics may also influence the operating cost. Fare model influence the direct cost to passengers, and hence, the user cost. A practical range of fare model components are considered during the investigation. The fare model includes upper and lower limits of minimum fare, maximum distance for minimum fare, and fare increment beyond the distance of minimum fare. The fare model also influences the revenue. User cost coefficients indicates WTPs of users with respect to various attributes of bus system. In the present works, WTP values are considered with respect to in-vehicle travel time, waiting time, and discomfort during travel. Three levels of discomfort are considered: seating, comfortable standing and congested standing. The WTP values are taken considering seating as the best level and congested standing as the worst one. Operating hour influences the average number of trips made per bus per day, revenue earned per bus per day and also the cutoff revenue requirement per bus per day. Simulation period indicated the number of peak hours simulated during model runs. The vehicle operating costs includes fixed costs and variable costs. The fixed costs consist of Equated Monthly Installment (EMI), maintenance cost, salary of driver and conductor and profit, if any. Variable costs include fuel charge, overtime charges for driver and conductor, etc. Variable costs also depend on the fuel efficiency of the vehicle, travel distance, operating hour, etc. For the operation beyond normal working hour, overtime charge is to be paid to the crew.

2.2. Step-2: Generate arrival times of passengers at each bus stop over simulation period

In general, passengers arrival at bus stops may be assumed to follow uniform distribution when the frequency of bus is high (say, headway <11 min) (Fan and Machemehl, 2009). However, in almost all the rural regions bus schedules are not displayed at bus stops, commuters (expect daily or frequent travelers) are generally not aware of the bus schedule (except for the first and the last

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