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Willingness to board: A novel concept for modeling queuing up passengers

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ABSTRACT

This paper addresses an innovative concept, termed as queuing passengers' willingness to board (WTB) the transit vehicles. In the peak hours, some queuing passengers cannot board a crowded bus/train, but when the same vehicle arrives at the next stop, some other passengers could still get on. This phenomenon reflects that passengers at different queuing locations have heterogeneous level of ambitions to board. A methodological framework is proposed for the quantitative investigation of WTB. First, a general model is proposed, together with a new least square method (LSM) for the calibration. Then, a parametric model is developed, which is also calibrated by the LSM. To refine the calibration method and deal with the biasness of survey data, a weighted least square method is further developed. Based on real survey data, the calibration results clearly support the existence of WTB, which can be used to estimate the capacity of transit vehicles. This paper also sheds some lights on the practical applications of the quantitative WTB.

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1. Introduction

Urban transportation network is a huge and complex system, involving millions of travelers. The network operation condition is an outcome of the travelers' decision making, interaction and decision adjustments. To improve the network efficiency and to make wise/balanced use of network resources, accurate predictions are usually needed for the network flows (Liu and Wang, 2015). For decades, the transport scholars have endeavored to develop more accurate tools for flow predictions; for instance, the well-known user equilibrium theory is a widely used means for flow prediction.

Improvements of such sort of models usually drive from better understanding of the travelers' behaviors; for instance, stochastic user equilibrium is an extension of UE, which was developed by addressing the travelers' perception errors on travel time. To this end, this paper focuses on an interesting psychological factor of the travelers, which is termed as willingness to board (WTB). This idea comes from the observations in practice on an interesting phenomenon: a crowded bus or train comes to a stop, and only a proportion of the queuing passengers can get on board; however, when this bus or train arrives at the next stop and no one alights, some passengers still can get on! Such a phenomenon is very common at the metro stations in the dense mega cities in the peak hours. This phenomenon gives us the impression that different queuing passengers have different levels of ambitions to get on board. Hence, this paper aims to holistically define this concept, and then quantitatively calibrate this value based on real survey data.

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Section 2 gives an in-depth discussion of the WTB, which is followed by two mathematical models in Sections 3 and 4, respectively. The basic concept for the calibration is developed from the least square method (LSM). However, in view of the unique features of WTB, the existing LSMs are not suitable to be directly adopted. Hence, as another major contribution of this paper, two new LSMs are developed to calibrate the WTB. These two new LSMs also contribute to the state-of-the-art statistical regression methods.

1.1. Literature review

Based on real survey data, LSM aims to calibrate the parameters of assumed function types that best fit the data (May, 1990). The least square method (LSM) and weighted least square method (WLSM) that was proposed by Aitken (1935) have been widely applied in economics, aerospace design, urban studies, political studies, etc. They of course also play a significant role in transportation analysis problems.

Lewandowski and Protzel (2001) established a local linear model with adaptive kernel functions to obtain a well fitted function with consideration of computing costs. Local linear regression model applied to short-term traffic prediction was proposed by Sun et al. (2003). Then the parameters of bandwidth and covariate vector dimension were chosen by optimizing an overall average square error between computed values by the cross validation method and observed values. Time-varying coefficient linear regression model was also applied to traffic prediction (Rice and Van, 2004), where the difference of departure time is used to get the weighting function.

The relationship between dwell times and number of alighting and boarding passengers at bus bays was established by using linear regression approaches through a survey study, however, the relevant low coefficient of determination and high root mean square error were acquired by least square method. Then a probabilistic approach was developed that could consider the interactions among buses, arriving passengers and traffic in estimation of bus dwell time, which were not estimated by the linear regression approaches (Meng and Qu, 2013).

The raw traffic data is usually not well distributed among each section; for instance, the traffic counting data of a suburban road with light traffic are mainly small values. In such case, if LSM is directly employed, then the small values will be dominated by these small values, thus giving rise to inaccurate results. To cope with this issue, Qu et al. (2015) proposed a weighted least square method (WLSM) to fit the empirical data for six well-known single-regime models. Based on large sample tests, the WLSM performs excellently both in light-traffic conditions and congested conditions.

The concept of WTB proposed in this paper is similar to the economics term, willingness to pay (WTP). Willingness to pay (WTP) is the maximum amount of money that an individual would pay to obtain a desired good or service. Consumer preference/welfare theory was further developed quantitatively by Rosen (1974) with the calculation of willingness to pay. Shin (2015) carried out a detailed analysis of consumer preference for alternative fuel types and technology options. Jou and Chen (2015) determined the compensation caused by traffic accidents of different types based on willingness to pay of parties to traffic accidents for loss of productivity and consolation. Schniederjans (2014) suggested consumer attitude and peer pressure were positively associated with intention which was positively relevant with willingness to pay for green transportation. Moreover, Lera-López (2014) indicated that younger, better educated and more environmentally-aware citizens are more willing to pay to reduce noise and air pollution. Lanzini et al. (2016) investigated key-determinants of drivers' willingness to pay for biofuels in Northern Italy. Gupta (2016) showed that the analysis of Indian willingness to pay for effective implementation of carbon tax in road passenger transport from three metropolitan cities. However, these studies have not provided any clear methodology to address the heterogeneity of the travelers' willingness to pay on a particular transport system, which is addressed in this paper.

To sum up, the contribution of this paper is to (a) provide an in-depth discussion of WTB with a clear conceptual framework, and (b) to propose a methodology for the quantitative measurement of WTB using real survey data. It should be pointed out that although this paper focuses on the queuing phenomenon of transit passengers, the proposed concept and methodology have much wider applications to other queue related topics in transport and traffic engineering studies. Most of the existing studies on the queuing problems/systems treat each individual as homogeneous, while WTB considers the heterogeneity of the queuing ones in terms of their location. For example, at a non-signalized intersection, the gap acceptance of queuing/waiting vehicles on the minor roads are heterogeneous; the first vehicle uses longer critical gaps but the queuing vehicles frequently take the risk to accept shorter critical gaps. The proposed methodology is suitable for and can easily be adjusted to address the heterogeneity of these queue-related problems.

2. Problem descriptions

The following notations are adopted in this paper:

B	Total number of new boarding passengers. It is used to represent a general B^i.
$\hat{B}$	The maximum number of boarding passengers, i.e., the largest B^i.
B^i	Total number of new boarding passengers of the data record i.
$C(k)$	Willingness to board of the kth passenger in the queue.
i	ID of a collected data record.
k	The passenger in the kth position in the queue.
K	Total number of waiting passengers. It is used to represent a general K^i.

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