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Variations in mode-specific valuations of travel time reliability and in-vehicle crowding: Implications for demand estimation

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ABSTRACT

This paper presents a two-stage Stated Preference survey to investigate the impacts of travel time reliability and in-vehicle crowding on the mode choice decisions across four different transport modes, i.e. car, metro, park and ride (P&R) and bus. The decisive attributes considered are average travel time, travel time reliability, cost and in-vehicle crowding. Five model specifications are defined for the parameter estimations. Significant interaction effects between in-vehicle crowding and travel time are found. Time multipliers are defined to represent the effects of in-vehicle crowding. In contrast, no evidence could be established for the interaction between in-vehicle crowding and travel time reliability. Results of the mode-specific valuations of travel time reliability and in-vehicle crowding, vary remarkably across the four different transport modes. In the mode-specific models, the range of time multipliers is estimated to be [1.44, 2.00]. Besides, demand estimates would be biased when the mode-specific willingness to pay (WTP) is ignored. For instance, the mode share of metro will be underestimated when its reliability level is high, and vice versa. This suggests that mode-specific WTP of travel time reliability and in-vehicle crowding should be considered in the demand estimations and in the earlier stage of public transport project appraisal.

1. Introduction

Traffic congestion is increasingly a serious problem in most of the cities and car remains to be the most attractive mode in the cities like Shanghai. To alleviate the problems including congestion, parking, emission, safety and noise of saturated urban roads, the use of more sustainable transport modes should be promoted (dell'Olio et al., 2010). One possible approach to reduce the car usage is to improve the service quality of public transits and to develop an efficient multi-modal transport system (Nesheli and Ceder, 2015). Unfortunately, actual public transport mode shares are often substantially lower than that of prior target and demand predictions. In Shanghai, of the six Park and Ride (P&R) facilities introduced in recent year, three were underused, with the average occupancy rate below 20% in 2014 (Li et al., 2016a). On the other hand, car mode share has been increasing, while the bus mode share has been decreasing during the period between 2012 and 2014 (Shanghai Urban-Rural Construction and Transportation Development Research Institute, 2015). The possible reason of the inaccurate estimation for public transport demand might be the deficiency in the model specifications and in the estimation of travelers' WTP. This requires a better understanding on the effects of contributory decisive factors on travelers' mode choices.

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Service quality of public transport could be measured by attributes including in-vehicle travel time, waiting time, travel time reliability, fare, in-vehicle crowding, transfers, etc. Travel time reliability has long been recognized as a significant contributory factor to travel behavior (Carrion and Levinson, 2012). Also, in-vehicle crowding is another crucial factor (Tirachini and Hensher, 2011). Many researchers have attempted to quantify the effects of in-vehicle crowding on travel behavior using Stated Preferences (SP) (Haywood and Koning, 2015) and Revealed Preferences (RP) surveys (Tirachini et al., 2016). Cantwell et al. (2009) suggested that travelers' satisfaction levels decreased with the increased level of in-vehicle crowding and service unreliability. Human perception and behavior in response to a dense in-vehicle environment seems to be unpredictable. In particular, the deterministic factors to travelers' discomfort and non-satisfaction go far beyond the physical environment, standing capacity and passenger density (Tirachini and Hensher, 2011). Yet, it was rare that travel time reliability and in-vehicle crowding were considered simultaneously in the mode choice models, except that waiting time variability and in-vehicle crowding was considered simultaneously in a mode choice model among bus and metro (Batarce et al., 2016). Most studies on mode choices either focused on the attributes within a trip (travel time, finely defined crowding levels, etc.) or across repeated trips (mean travel time, reliability, etc.) only. However, both travel time reliability and in-vehicle crowding affect travelers' decisions.

Therefore, this study attempts to incorporate the effects of these two important attributes in the mode choice model. In this study, a Stated Preference survey for mode choice was conducted in Shanghai (with population of 24.26 million and private car ownership of 3.04 million in Year 2014, (Shanghai Urban-Rural Construction and Transportation Development Research Institute, 2015)). The interaction terms for the joint effects of in-vehicle crowding and average travel time and/or travel time reliability are incorporated into the model specifications. In addition, time multipliers are established to denote the effect of in-vehicle crowding. Also, variations in the valuations of travel time reliability and in-vehicle crowding across the four different modes are estimated. The impacts of ignoring mode-specific taste variations on the demand estimation will be addressed. This study is an extension of the previous work of the same research group (Li et al., 2016a), with substantial contribution from the perspectives of (1) Expanded sample size, from 204 respondents (1224 observations) to 386 respondents (2316 observations); (2) five model specifications set out to examine the effects of travel time reliability and in-vehicle crowding; (3) time multipliers defined to measure the effects of in-vehicle crowding; (4) mode-specific WTP and its impacts on the demand estimation. Results of this study are expected to foster the advance in the techniques for public transport demand estimation and project appraisals.

The rest of this paper is structured as follows: we will first give an overview of existing literatures on the in-vehicle crowding and travel time reliability using Stated Preference survey approach in Section 2. Then, the experimental design of proposed Stated Preference survey and model specifications will be described in Section 3. In Section 4, results of the model estimations will be presented. Last but not the least, concluding remarks and recommendations for future research would be given in Section 5.

2. Literature review

2.1. Crowding

Crowding (crowdedness) is attributed to high passenger density in the public transport vehicles. The common quantitative measures for crowding can be categorized into two groups: the load factor (Oldfield and Bly, 1988; Pel et al., 2014; Whelan and Crockett, 2009) and the standing passenger density (Batarce et al., 2016; Pel et al., 2014; Wardman and Whelan, 2011). The load factor is defined as the number of on-board passengers divided by the number of seats (capacity) in the vehicle, and is thus having a unit of a percentage. The standing passenger density is defined as the number of standing on-board passengers divided by the area in the vehicle, and is thus having a unit of passengers per square meter. Crowding is a crucial factor in mode choice behavior (Litman, 2008; Tirachini et al., 2013). The users have the concerns with overcrowding, including transit delays and associated costs, increased level of travel stress/strain, a feeling of invasion of privacy, and related losses in economic productivity, health, security and safety, and pickpocketing (refer to Pel et al. (2014) and Tirachini and Hensher (2011)). The valuations of crowding (Haywood and Koning, 2015; Liu and Wen, 2016) are investigated and its impact on demand estimations and cost-benefit analyses (Batarce et al., 2016) have been examined. Modeling transit passenger choices without taking the level of crowding into account, results in poor timetabling, inefficient train capacity management, ineffective project appraisal, and biased passenger satisfaction estimates (Raveau et al., 2014; Zorn et al., 2012). Time multipliers have been used to represents the impacts of crowding on the value of travel time savings (VTTS), which has been found ranging from 1.0 to 3.0 from literature (we refer to Haywood and Koning (2015), ITF-OECD (2014), and Tirachini et al. (2016) for detailed reviews).

2.2. Reliability

Travel time reliability is considered to be one of the key indicator for the performance of transport systems (Tu et al., 2012). Based on the distributions of travel times (Tu et al., 2012), a large number of travel time reliability measures for road networks have been proposed (refer to e.g. (Taylor, 2013; van Lint et al., 2008)), such as percentile travel time, standard deviation, buffer index, planning time index, failure rate. Reliability measures are typically used within performance regimes to