Transport Policy 47 (2016) 94–104

Contents lists available at ScienceDirect

Transport Policy

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

Valuation of sitting and standing in metro trains using revealed preferences

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A R T I C L E I N F O

Article history:
Received 26 September 2014
Received in revised form
18 November 2015
Accepted 9 December 2015
Available online 21 January 2016

Keywords:
Revealed preference
Sitting
Standing
Crowding
Public transport
Metro

A B S T R A C T

The estimation of differences in the value of in-vehicle time sitting and standing is usually made with stated choice (SC) data, partly due to the lack of revealed preference data. In this paper, we use the observed behaviour of a subset of metro users in Singapore, who are willing to travel a longer time (into the opposite direction or backwards) to secure a seat for the actual trip in the direction towards their destination. We use smart card transactions to estimate the share of users who are willing to travel in the opposite direction during the first part of their trip and the average train occupancy per section to estimate differences in the valuation of travel time sitting and standing – translated into a standing multiplier or standing premium, which is analogous to the crowding multiplier that is usually found in the crowding valuation literature. We find that the standing multiplier is between 1.18 and 1.24 with the current crowding levels in the morning peak and can be as much as 1.55 with a density of 3 standing passengers per square metre. The results are compared to previous SC studies from other countries. The values found here are an indication of a standing premium that can be used to assess the social benefit of increasing the seat capacity of a public transport system and of applying peak spreading strategies.

1. Introduction

Mode and route choice decisions in transport have traditionally been modelled and evaluated according to cost and various elements related to travel time. Going beyond monetary cost and time, additional factors associated with the riding comfort and service reliability of public transport systems have shown to be relevant for mode, route and activity scheduling choices in various studies (e.g., Bates et al., 2001; Kim et al., 2009; Li and Hensher, 2011; Raveau et al., 2011; Wardman and Whelan, 2011; Börjesson et al., 2012; Theler and Axhausen, 2013; Tirachini et al., 2013; Batarce et al., 2015). Among the factors capturing riding comfort, seat availability and perceptions of crowding levels are regarded to have significant behavioural impacts. As such factors are decisive mostly in urban contexts, for which continuous growth is expected globally (United Nations Department of Economic and Social Affairs 2010), it is fair to assume that those behavioural aspects will become even more relevant for transport policy in the future. Additionally, increasing income levels in both developing and developed countries also suggest that more weight will be assigned to the quality and comfort features of public transport trips.

For users, standing is usually less comfortable than sitting, especially for long trips; therefore, we would expect users to be willing to pay more to reduce travel time when standing rather than sitting. Such an outcome has been shown in the literature on users' valuation of sitting, standing and crowding.[1] Numerous studies, such as Douglas and Karpouzis (2005), Whelan and Crockett (2009), Kim et al. (2009), Hensher et al. (2011), Fröhlich et al. (2012), Tirachini et al. (2013) and Batarce et al. (2015), show the crowding disutility that arises when the occupancy levels of vehicles and stations increase over a particular threshold. The most common procedure to estimate this crowding disutility is the use of discrete choice models with for stated choice (SC) data.

In this paper, we estimate the differences in the valuation of sitting and standing during public transport trips using revealed preferences (RP) of a subset of metro users in Singapore, who are willing to take a train in the opposite direction of their destination (backwards) to secure a seat during their travel towards their destination (forwards) after the train changes directions at the

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[1] In general, some passengers might prefer to travel standing rather than sitting, particularly for short trips; nonetheless, the literature shows that, on average, there is a travel time disutility associated with crowding and standing.

http://dx.doi.org/10.1016/j.tranpol.2015.12.004
0967-070X/

terminal stop of the line. This is a novel choice situation for analysing standing and crowding disutilities based on observed behaviours. In other words, some passengers are willing to spend more time in transit for a more comfortable ride, which differs from previous RP studies that analysed the substitution between waiting time and in-vehicle time when studying crowding externalities (LT Marketing, 1988; Kroes et al., 2014). In particular, we use these RP data to estimate the impact of crowding and the valuation of seat availability for mass rapid transit (MRT) route choice decisions, and we find a standing multiplier or standing premium that depend on the load factor and density of standees per time period and section – similar to the crowding multiplier usually found in the crowding valuation literature based on SP experiments. Multinomial logit (MNL) route choice models are estimated based on peak hours observations, where a share of commuters prefer to travel a short distance in the opposite direction to ensure a more comfortable, seated ride to the final destination. Individual choices are not modelled; instead, they are used to estimate the share of passengers who decide to travel backwards depending on the origin, destination and length of the trip.

Second, we present a methodology to infer the routes actually taken and the vehicle loads expected in situations in which smart card transaction cannot be directly traced back to the individual vehicles and are only observed at the level of public transport stops, as is usually the case of MRT systems. This methodology allows us to take advantage of the smart card transactions database, which contains all the records of entries (tap-ins) and exits (tap-outs) to and from stations in Singapore's MRT system. Reliable high-resolution RP data are very valuable as a way to obtain the economic values of service quality attributes, such as the value of avoiding crowded travel time, as it is based on estimations of actual behaviours rather than reported behaviours.

The remainder of the article is organised as follows. Section 2 presents a literature review on crowding and standing valuations. In Section 3, we describe our smart card dataset and the methodology to estimate travel times, trainloads and the proportion of passengers who initially travel backwards (away from their final destination to secure a more comfortable ride). Section 4 presents and discusses the choice models that are used for the estimation of the disutilities of time sitting and time standing. The results are compared with previous outcomes from studies in the United Kingdom and France. Regarding policy implications, Section 5 analyses the influence of observed standing and crowding externalities on supply levels of public transport services. Finally, Section 6 provides a summary and the main conclusions of the study.

2. Literature review

A common objective of crowding valuation studies is the estimation of a *crowding multiplier,* that is, the ratio between travel time parameters under crowded and uncrowded conditions. In crowding valuation studies, the standard procedure is to define a crowding attribute that interacts with travel time in linear or non-linear functional forms to capture the effect of increased crowding discomfort during longer trips. As the crowding phenomenon relates to station and vehicle occupancy, constructs that assess occupancy levels are used, such as the load factor (i.e., the total number of passengers over the number of seats) and the density of standees per square metre.[2] An example of utility function that can be used to assess the crowding discomfort in public transport vehicles is the following:

$$U=\alpha_0+\beta_1\bullet t+\beta_2\bullet t\bullet S+\beta_3\bullet t\bullet Cr+\beta_4\bullet t\bullet Cr\bullet S+\varepsilon \quad (1)$$

where α_0 is an alternative specific constant; t is in-vehicle time; S is a dummy variable that equals 1 if the passenger has to stand and 0 if the passenger is able to sit; Cr is a variable that describes the occupancy level of passengers; β_i are the passenger taste parameters; and ε is a random error. If choice follows a multinomial logit (MNL) model, with expression (1), the crowding multiplier is defined as follows:

$$CM=\frac{\beta_1+\beta_2\bullet S+\beta_3\bullet Cr+\beta_4\bullet Cr\bullet S}{\beta_1} \quad (2)$$

The crowding multiplier increases in value as crowding worsens. Some studies aim to estimate average crowding multipliers that increase with occupancy levels, regardless of whether the concerned passenger is sitting or standing (e.g., Hensher et al., 2011; Basu and Hunt, 2012; Tirachini et al., 2013). Other studies – such as Douglas and Karpouzis (2006) on trains in Sydney, Australia, Kroes et al. (2014) on trains and buses in the Paris region, and several papers and reports on the rail industry in Britain (for a review and meta-analysis, see Wardman and Whelan, 2011) – estimate different in-vehicle time parameters for passengers who are sitting and standing, as a function of a measure of vehicle occupancy levels. For example, Whelan and Crockett (2009) estimated crowding multipliers for rail services in Great Britain, focusing on London and the Southeast; for seated passengers, the crowding multiplier increases from 1.0 to 1.54 as the density of standing passengers increases from 0 to 6 passengers per square metre (pax/m^2), whereas the crowding multiplier is between 1.43 and 2.21 for standing passengers. Therefore, standing passengers in uncrowded conditions value travel time savings 43% more than seated passengers.[3] Lower crowding multipliers have recently been found by Kroes et al. (2014) in the Paris region (Île-de-France), with maximum values of 1.4 for sitting and 1.6 for standing combining data from all public transport modes (metro, train and bus).

Beyond these articles and reports, crowding penalties have also been included by a handful of countries in their official guidelines for transport project assessment, as reviewed by OECD/ITF (2014). For example, in Australia, the crowding multiplier is up to 1.3 for sitting and up to 2.0 for standing at maximum occupancy. In France, crowding multipliers increase linearly as a function of the passenger density per square metre, with values of 1.3 for sitting and 1.6 for standing with 4 passengers per square metre (pax/m^2). In Sweden, the crowding multiplier is up to 3.0, whilst in the United Kingdom it is up to 2.1 for sitting and 2.8 for standing, with 3 pax/m^2.

[2] The load factor is more commonly used due to the easiness of its computation. However, it does not provide a clear indication of the degree of crowding suffered by passengers, which can be more accurately captured by estimating the density of standees per square metre. For example, a load factor of 200%, relative to the seating capacity, indicates that one of two passengers is standing, but it is not clear how uncomfortable the situation is for those standing. However, a standing density of five passengers per square metre is a very likely indicator of crowding discomfort, regardless of the size of the vehicle or the number of seats. On the other hand, crowding disutility may also be present before all seats are occupied; see Wardman and Whelan (2011) and Tirachini et al. (2013).

[3] In busy metro systems in Latin America and Asia, the passenger density inside trains can reach beyond 6 pax/m^2. Basu and Hunt (2012) provide images of 4, 7 and 12 men standing inside a square metre, which were used in a stated preference study to estimate the value of time savings on increasing crowding conditions in Mumbai, India. In reality, maximum passenger densities in public transport services are constrained by the fact that some passengers carry bags, suitcases, rucksacks, etc., which increase the projected floor area that a passenger occupies (TRB, 2003).