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Estimation of crowding discomfort in public transport: Results from Santiago de Chile

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ABSTRACT

The relationship between train occupancy, comfort and perceived security is analysed, using data from a survey and stated choice (SC) study of users of Santiago's Metro (subway) system. Mode choice models where crowding is one of the main explanatory variables are estimated and crowding multipliers to measure its relevance on travel time disutility for sitting and standing are computed. An international comparison with previous studies from London, Paris, Singapore and Sweden is presented. The type of estimated models include Multinomial Logit, Mixed Logit, and Latent Class models. Results show that there is significant heterogeneity in crowding perception across the population. Users classes with low and high crowding multipliers are identified, in which gender, age and income play a role. In the SC survey, occupancy levels were shown with three alternative forms of representation (text, 2D diagram or photo), however we did not find relevant influences of the different forms of representation on crowding perception.

1. Introduction

In public transport, crowding refers to a subjective perception of the physical phenomenon represented by a high density of passengers in vehicles and at stations, stops and access-ways. In-vehicle crowding is, after price and travel time, one of the most important explanatory variables of mode choice. This is particularly true for public transport modes where high levels of crowding can result in physical discomfort, psychological burden and perceived risk and insecurity (Cox et al., 2006; Cheng, 2010; Mahudin et al., 2012). Moreover, crowding externalities (e.g. slower boarding and alighting from vehicles, increasing waiting times) have an important effect on the overall level of service and optimal fare of public transport systems (Tirachini et al., 2014).

Crowding in public transport is a common phenomenon in Santiago, Chile. Its city-wide integrated public transport system launched in February 2007, also known as the Transantiago system (Muñoz et al., 2014; Munizaga and Palma, 2012), deploys full fare integration between buses and Metro through the use of a single (smartcard) payment method. The implementation of Transantiago heavily loaded the metro network, making it the main artery of the system (Gómez-Lobo, 2012; Muñoz et al., 2014). The total number of daily passengers served by metro duplicated overnight and crowding conditions in

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the trains became extreme, reaching 6 passengers per square meter or more during peak hours.[1] This triggered many behavioural responses from the users ranging from selecting different modes of transport (there has been an increase in car and bicycle use) to route choices that, in regular crowding conditions, would be classified as being counter-intuitive or irrational (Raveau et al., 2014). For example, it may happen that users opt for longer routes in order to increase the chance of obtaining a seat in the train, or prefer not to board a train or bus because it is considered *too full* (although not reaching yet its full capacity). These behavioural responses reveal the extent to which users dislike crowding in public transport. A further case in point is provided by a user survey revealing that the attribute *comfort*, related to overcrowding, was the worst evaluated attribute of Transantiago (Yáñez et al., 2010), a critical issue if we consider that comfort has been reported as a factor that reduce stress of public transport commuters (Legrain et al., 2015).

Despite the large impact of crowding on quality-of-service, the optimization model to design the Transantiago network (Fernández et al., 2008) did not consider quality-of-service factors such as passenger density and service reliability valuation by users in the design of routes, optimal frequencies and vehicle sizes.[2] Instead the optimization model minimised the summation of users and operator costs. In other words, one minute travelling with five passengers per square meter was assumed to have the same weight in the users' cost function as one minute travelling with one passenger per square meter, thereby ignoring the discomfort of crowding on users.

Understanding and measuring the willingness to trade an increase in travel time for improved travel conditions in terms of reduced crowding levels, and vice versa, is not only relevant for the planning of new public transport services, but also for the management of currently operating routes and services and cost-benefit analysis of policy interventions aimed at reducing crowding levels, either as a primary or secondary goal. Crowding multipliers (Wardman and Whelan, 2011; Tirachini et al., 2013) can be used for this objective. Crowding multipliers can be interpreted as a measure of how the disutility of travel time under different crowding levels relate to each other. Subsequently, they can be used to amplify the (monetary) value of in-vehicle time savings in order to account for the fact that reductions of travel time in crowded conditions are worth more than reducing travel time on a similar but less crowded trip.

The literature on crowding valuation has progressed quickly during the past ten years, and today we are aware of studies estimating the sensitivity of the value of travel time savings (VTTS) to different vehicle or station crowding conditions in Great Britain (Whelan and Crockett, 2009; Wardman and Whelan, 2011), the Paris region (Kroes et al., 2014; Haywood and Koning, 2015), Sydney (Hensher et al., 2011), Mumbai (Basu and Hunt, 2012), Los Angeles (Vovsha et al., 2013), Singapore (Tirachini et al., 2016), Hong Kong (Lam et al., 1999; Hörcher et al., 2017) and Santiago (Batarce et al., 2015, 2016), amongst other cities. Even in cycling research it was recently found that crowding (with other bicyclists) significantly influence route choice for bicyclists in Copenhagen (Vedel et al., 2017).

This paper makes a number of contributions to the crowding valuation literature. First, we test the impact of the crowding representation format on the perceived level of crowding, resulting travel behaviour and corresponding crowding valuation measures. To this end a stated choice survey is designed in which occupancy levels are presented to respondents either in the form of text, 2D diagrams or photos. Other studies have also used images (2D diagrams and photos) to describe crowding levels. Use of images has shown to influence the perception of attributes of the alternatives on stated preferences surveys (Rizzi et al., 2012) and facilitates the description of complex choice scenarios, where an exhaustive text-based description of the attributes would over-complicate the choice task (Motoaki and Daziano, 2015; Hurtubia et al., 2015). However, some evidence indicates that the form of representation used to describe single attributes has no effect on the perception of the respondent (Arentze et al., 2003).

Second, in this study the usual way to determine crowding externalities by means of a stated choice model is complemented by questions on the relationship between train occupancy and perceived levels of comfort and security, providing a link between subjective user perceptions and observable train occupancies.

Third, this paper follows the recommendations of Basu and Hunt (2012) who argue that significant care is required when establishing crowding multipliers based on Mixed Multinomial Logit (ML) models. In previous crowding valuation studies, user preferences have been estimated using Multinomial Logit (MNL) and ML models. In the realm of MNL models, Wardman and Whelan (2011) develops a meta-analysis of crowding multipliers using MNL values from 17 studies in Great Britain. Ease of application in optimal public transport supply models is one argument that has been used to support the use of MNL models in crowding valuation (Tirachini et al., 2014). Most studies, however, highlight that (unobserved) heterogeneity in crowding and time sensitivities is important to take into account.

Whelan and Crockett (2009)'s ML model assumes a normal distribution to introduce unobserved heterogeneity in user preferences towards crowding levels in trains, and find that around 25% of respondents have 'wrong signed' taste parameters. The authors, however, discard the use of the lognormal distribution as a solution, given that it may shift the mean of the (crowding sensitive) VTTS parameter. The referred study of Basu and Hunt (2012) for crowding valuation in Mumbai, compares MNL and ML models using a triangular distribution for travel time parameters for different crowding levels, as a way to avoid the issue of large spreads in unconstrained distributions. In this study, we acknowledge the limitations of the

[1] There are three reasons for this sudden increase in Metro usage: an integrated fare system in which users pay a very low fee for a bus-metro transfer; the redesign of parts of the bus network to serve as feeders of the metro network; and the noticeable reduction of bus service quality in terms of longer waiting and in-vehicle times, especially at the beginning of Transantiago.

[2] In the design model, high occupancy of vehicles does not influence the perception of time but may increase the extension of waiting time through limited capacity considerations (Fernández et al., 2008).