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Including passengers' response to crowding in the Dutch national train passenger assignment model

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ABSTRACT

Transit passengers' response to crowded conditions has been studied empirically, yet is limitedly included in transport models currently used in the design of policy and infrastructure investments. This has consequences for the practical applicability of these models in studies on, for instance, timetabling, train capacity management strategies, project appraisal, and passenger satisfaction. Here we propose four methods to include the effect of crowding, based on existing studies on passengers' perception and response as well as often-used crowding indicators. These four alternative methods are implemented in the train passenger assignment procedure of the Dutch national transport model, and evaluated with respect to their impacts on the model results for the Dutch railway network. The four methods relate to four different ways in which an additive trip penalty and/or time-multiplier can be incorporated in the train utility function for different travel purposes, to capture the disutility of crowding as measured by the load factor. The analyses of the test case favor the hybrid method using both a boarding penalty (capturing seat availability upon boarding) and a time-multiplier (capturing physical comfort and safety throughout the trip). This method produces consistent results, while the additional computational effort that it imposes is acceptable. Further empirical underpinning is needed to conclusively show which of these methods best captures passengers' response behavior quantitatively (for different travel purposes and conditions).

1. Introduction

The Dutch Railways service half a million daily commuters, of which 50% indicate that they travel by train in order to relax while traveling (NS Marktonderzoek en Advies and NS Customer Insight, 2011). An acceptable level of (in-vehicle) crowding is evidently a prerequisite for this. To facilitate passengers in this regard the Dutch Railways have recently launched a smartphone application that provides basic information on the expected level of crowding in their trains. Crowding, and the discomfort caused by it, is clearly not unique to The Netherlands, with studies on commuters' trip valuation and satisfaction carried out, for instance, in Paris (Prud'homme et al., 2012; Leurent and Liu, 2009; Haywood and Koning, 2013; Significance, 2012), London (Passenger Focus, 2006; Wardman and Whelan, 2011), Sydney (Douglas and Karpouzis, 2006;

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Hensher et al., 2011), Los Angeles (Davidson et al., 2011; Vovsha et al., 2014), San Francisco (Zorn et al., 2012), Hong Kong (Lam et al., 1999), and Mumbai (Basu and Hunt, 2012). In these studies crowding and crowding-related factors, such as the probability of acquiring a seat, are consistently given high importance by transit passengers, while occasionally are even the dominating factors in customer satisfaction particularly for leisure trips. Besides transit operators, also policy makers are showing a gradually increasing interest in the influence of crowding on public transit service quality and its relation to project appraisal (Li and Hensher, 2011). This is understandable from the fact that typically 60–80% of the benefits in cost-benefit analyses on transit investments are derived from user travel time savings, as shown by Litman (2008), while the perceived value of travel and waiting times increase with a higher level of crowding. Haywood and Koning (2013), for instance, explicitly show for the Paris metro system how overlooking the marginal benefits due to a reduction in the level of crowding in transit has serious implications for the results of net present value calculations. Apart from the customer satisfaction and operating costs, other concerns with overcrowding (that will not be discussed in this paper) include transit delays and associated costs (Oxford Economic Forecasting, 2003), increased travel stress/strain and related losses in economic productivity (House of Commons Transport Committee, 2003; Mackie et al., 2001; MVA Consultancy, 2008), health and safety (Cox et al., 2006; Passenger Focus, 2006), and pickpocketing (Litman, 2008).

A number of studies have investigated passengers' choice behavior when confronted with crowded transit services through observed and surveyed preferences. These studies aim (1) to identify appropriate and measurable determinants for passengers' perception of crowding, (2) to quantify the relationship between these attributes and the value of crowding, and (3) to incorporate the role of crowding in transit passenger assignment models. Despite these efforts, in practice planners generally still lack the guidance and tools to evaluate the role of crowding in transit assessment studies. The same holds for The Netherlands, where the train passenger assignment procedure in the national transport model considers aspects such as the various travel time components, fare costs (including discount schemes), number of transfers, and preferences depending on the trip purpose, but neglects the level of crowding while modeling transit passenger choice behavior. The consequence is that the results of this (such) model(s) may not be appropriate in studies on, for example, timetabling, train capacity management strategies, project appraisal, and passenger satisfaction (Zorn et al., 2012).

To this end, this paper addresses how travelers' behavioral response to crowding, with respect to the scope of transport models used in policy-making, can be pragmatically included in existing transportation models in practice. In this regard, we address this gap in the current state-of-the-practice by evaluating how the effect of crowding can be introduced in the train passenger assignment model of the Dutch National Model System (in Dutch: Landelijk Model Systeem – LMS), and how this may impact model results. It is noteworthy to mention here that in the ensuing, we focus on crowding as a high level of demand relative to the vehicle capacity, and particularly how this relates to aspects of, for instance, traveler comfort and travel time valuation as well as passenger choice behavior towards departure time, entry station, and train decision. Hence, we do not discuss the issues pertaining to capacity constrained assignment (for a systematic review of capacity constraints in mass transit systems see Leurent, 2011). For a review on transit assignment with vehicle capacities, see Hamdouch et al. (2011) for schedule-based transit, and Schmocker et al. (2011) and Nuzzolo et al. (2012) for frequency-based transit.

The paper is structured as follows: We first review prior studies on passenger response to crowding and corresponding methods that are proposed to model the effect of crowding on train passenger choice behavior, in Sections 2 and 3, respectively. These methods are then implemented into the Dutch National Model System. Section 4 discusses the evaluation of the various methods through a test case using the Dutch railway network. The paper ends with concluding remarks on how the findings from this explorative study may assist in facilitating the assessment of crowding in transit model studies carried out in practice.

2. Passenger response to crowding

In order to (qualitatively) assess the various approaches to model the effect of crowding, this section summarizes observed passengers' responses to the phenomenon of crowding in the transit system. First in Section 2.1 we review passengers' perception of crowding and how it depends on a number of trip and passenger characteristics, after which in Section 2.2 we discuss how passengers may react regarding their travel decisions.

2.1. Passengers' perception of crowding

The Association of Train Operating Companies (ATOC) in the UK has produced a handbook (ATOC, 2002) for passenger demand forecasting in which it is stated that passengers start to experience a disutility for crowding when the demand exceeds 70% of the seating capacity, while the study by Wardman and Whelan (2011) suggests crowding penalties when the demand exceeds 50% of the seating capacity. Also the survey by Vovsha et al. (2014) shows that discomfort of crowding is experienced once the probability of acquiring a seat drops below 40%. The study by MVA Consultancy (2008) confirms this by showing that negative aspects related to crowding arise due to privacy issues when more passengers have to sit (closely) next to each other. In case of higher demand, other factors such as reduced physical comfort and productivity during the trip also play a role. How passengers' perceived disutility then scales with excess passenger demand is ambiguous, although typically found to be exponential.