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Title and Abstract

Title: Incorporating the impact of congestion in public transport into project appraisal

Abstract

As the trend in urban development has turned from sprawl to densification, investments in public transport infrastructure are gradually becoming more focused on capacity increase rather than travel time savings. Travel time metrics obtained from static transport assignment models – which is commonly used as input for cost-benefit analysis to evaluate long-term planning decisions - is expressed in terms of average performance measures. Static assignment models are thus incapable of capturing the impact of capacity increases on the distribution of passengers over different vehicles and hence their implications on experienced congestion.

The value of travel time savings due to capacity increase depends on the on-board crowding level, as well as many other factors (Prud'homme et al., 2012). Destination choice, mode choice, route choice and the choice whether to board a full bus or wait for the next one are all part of travel behaviour, where value of time (VoT) and value of crowding (VoC) are key determinants (Li and Hensher, 2011). Crowding also affects the experienced in-vehicle time, waiting time and travel time variability (Tirachini et al., 2013). Since the on-board load factor is constant in static assignment models, the full congestion effects are typically underestimated in public transport cost-benefit analysis.

The need to account for congestion effects in public transport project appraisal was raised in the evaluation of a highly-contested underground line in Stockholm, Sweden. A plan to extend an existing underground network into the south-east was motivated by the congestion effects which occur on the existing high-frequency bus corridor which terminates in a major transfer hub (Slussen). Furthermore, the expansion plan is consider a prerequisite for future land-use developments in the respective areas. Hence, the evaluation of project benefits require a method which enables the assessment of travel costs induced by congestion, including perceived in-vehicle time due to crowding, service regularity and its impacts on uneven loads and waiting times and even denied boarding due to vehicle capacity constraints.

BusMezzo, a dynamic public transport operations and assignment model, was used as an evaluation tool in this study (Toledo et al., 2010; Cats et al., 2011). The multi-agent simulation model represents the progress of individual vehicles and travellers. The model allows investigating the crowding distribution and how it evolves due to various sources of service uncertainty. Furthermore, capacity constraints are strictly enforced in the model. Disaggregate path choices are then used for calculating travel time components and the respective value-of-time and their incorporation in the cost-benefit analysis.

The case study analyses two scenarios: (a) do-nothing scenario with travel demand and corresponding bus supply for the year 2030, and; (b) underground extension scenario. Both scenarios were simulated during the morning peak period. In the scenario with the new underground, the travellers in the most crowded bus corridor towards the transfer hub were predicted by BusMezzo to be less than half as many as in the do-nothing scenario. The disaggregated simulation results show a large variation in bus departure time in the corridor, leading to a large variation in on-board crowding in the do-nothing scenario. As expected, this variation is less prevalent in the case of underground extension.

Due to the underground extension, travellers on average are able to reach their destinations doing fewer transfers, having shorter walking distances and experiencing shorter in-vehicle time. The decrease in number of overloaded buses leads to both less in-vehicle time (due to shorter dwell times for crowded buses) and to less on-board discomfort. Moreover, the decrease in number of overloaded buses results also with less denied boarding.

The total benefit for one day is estimated to 1.8 million SEK, compared to 1.1 million SEK resulting from the original static assignment model. Hence, the dynamic crowding effects as estimated by BusMezzo amount to an increase of 65 per cent in total benefits. The analysis of the simulation results indicates that the most important factors involved are the decrease in waiting time due to improved service reliability and the lower in-vehicle value-of-time due to crowding.

This study demonstrates that using a dynamic transport assignment model for long-term public transport planning is possible and exposes benefits that would not be possible to make tangible and quantify in a traditional static assignment model. Travellers were assumed to minimize the generalized travel cost function in the lack of knowledge of prevailing crowding levels. Future study may consider the impact of crowding experience on travellers' path choice within a day-to-day learning framework.

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