Multimodal Route Choice Models of Public Transport Passengers in the Greater Copenhagen Area

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While research in sustainable transport has paid much attention to the choice between car and public transport modes and to the route choices of private car users, limited efforts have been posed toward the understanding of route choices of public transport passengers. Identifying the relevant factors affecting the route choice decisions could guide stake-holders (local governmental agencies, public transport agencies, etc.) towards improvements of the public transport networks by increasing the attractiveness of public transport services compared to cars. This paper deals with the multi-faceted challenge of modelling route choices of travellers in a metropolitan multimodal network. The analysis focuses on revealed preference data collected for the multimodal network of the Greater Copenhagen area and solves the multiple facets of the challenge concerning (i) data collection, (ii) choice set generation, and (iii) model estimation.

From the *data perspective* the paper deals with the limitations of collecting route choice observations for public transport passengers. Where literature on route choice modelling for car users has benefitted from GPS points tracked by GPS devices and mapped to GIS map to reproduce routes, observing route choices for public transport passengers using GPS devices is not straightforward because of the need to collect additional information (lines, transfers) and to overcome technical difficulties of GPS signals loss in tunnels. Head-to-head interviews (as in Hoogendoorn-Lanser, 2005) are expensive for large samples. To collect details about the actual route choice behaviour in the public transport network a new questionnaire was developed, full scale tested and added to the Danish Travel Survey (TU) which collects daily travel diaries covering activities and travels of a representative sample of the population. For public transport trip legs the new additional questionnaire collects detailed information about access modes, stations, lines, departure and arrival times, transfers and egress modes (Anderson, 2013). To analyse the route choice preferences of travellers in the multimodal network, 6,000 observations from the Greater Copenhagen area are collected and processed in this study.

From the *choice set generation perspective* attractive routes have been generated for the origin-destination pair of each traveller (Larsen et al., 2010). The dense network of the Greater Copenhagen area includes metro, trains (intercity, regional, suburban, urban and local), and buses (high-frequency, express and regular), and access and egress modes consist of both private (walking, bicycle and car) and public transport modes. This leads to a very high number of possible combinations of access modes, public transport modes, lines, transfers, and egress modes in the network. By use of a doubly stochastic approach (Nielsen, 2000) routes relevant to the travellers are generated. The method allows for both variation in the perceived costs of the network elements and heterogeneity in the preferences of the travellers. The coverage of the observed choices with the generated choice sets provides a measure of the performance of the applied route choice generation technique. The coverage is measured in percentage overlap with the observed route and is calculated on two levels; stop level and link level.

Figure 1 presents the results from the choice set generation with a variance of 1.0 for the scale parameter of the coefficients and for the error term. The link level is the most restricted measure and the results show high coverage for the generated choice sets when comparing PT lines on the same links.

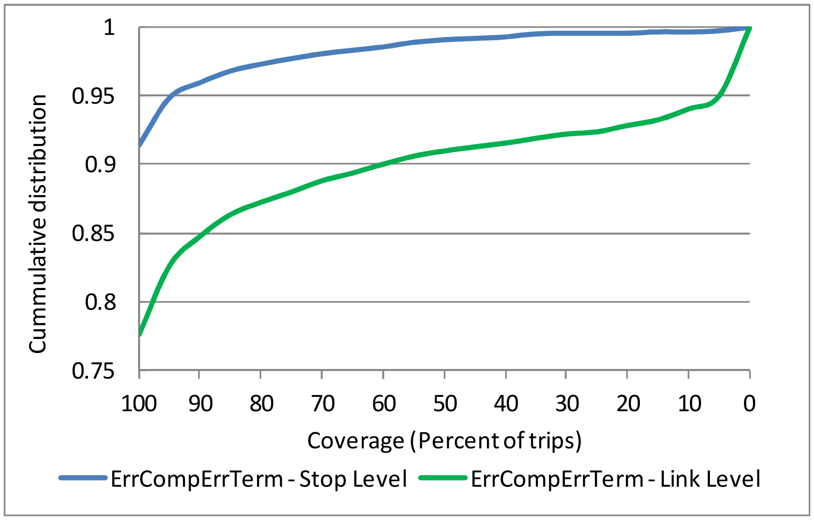

Figure 1: Coverage for variance=1.0 at stop and link level

From the *model estimation perspective* the paper presents the estimation of route choice models for public transport travellers able to account for similarities across alternatives. The simple approach of the Path Size Logit is tested and also the more elaborated approach of the Path Size Logit with distributed variance terms which considers various definitions of similarity. For both approaches the utility function is specified in order to consider the many dimensions of the problem in terms of access/egress characteristics, waiting time, in-vehicle time, and transfer characteristics. Also, travellers' characteristics and trip purposes enrich the model and offer insight to the preferences of different travellers with different motivations for travelling and trip characteristics such as trip distance impact the preferences of the travellers.

The traveller *k* is assumed to maximize his utility for route *n* according to the formula:

$$\begin{aligned} V_{kn} = {} & \beta_{IVT,Bus} * IVT_{Bus,kn} + \beta_{IVT,RegICTrain} * IVT_{RegICTrain,kn} \\ & + \beta_{IVT,Metro} * IVT_{Metro,kn} + \beta_{IVT,LocalTrain} * IVT_{LocalTrain,kn} \\ & + \beta_{IVT,Sub.Train} * IVT_{Sub.Train,kn} + \beta_{WalkTime} * TT_{WalkTime,kn} \\ & + \beta_{WaitTime} * TT_{WaitTime,kn} + \beta_{TransferPen} * N_{Transfer,kn} \\ & + \beta_{Acc/Egr.Time} * TT_{Agr/Egr.Time,kn} + \beta_{Headway} * TT_{Headway,kn} + \beta_{PSC} * PSC_{kn} \end{aligned} \quad \textbf{(1)}$$

where $TT_{WalkTime}$ and $TT_{WaitTime}$ are the walking times to and waiting for the public transport mode, $N_{Transfer}$ is the number of transfers, $TT_{ConnTime}$ is the travel time spent on the access/egress link between zone and public transport stop/station, $TT_{WaitZone}$ is the waiting time in the zone (hidden), and IVT_q are the in-vehicle times for public transport mode *q*. The *β*'s are the respective parameters to be estimated.

The estimated parameter coefficients for a Path Size logit model specification are shown in Table 1. Work travellers (commuters, business, and educational purposes) prefer in-vehicle time in all train types (except local trains) over buses, whereas leisure travellers find regional and IC trains more cumbersome than bus. This reluctance to trains is not expected and distance bands show that leisure travellers on short trips (the majority of leisure trips) avoid regional trains whereas travellers on longer trips have a higher preference for the trains. One transfer is equivalent to 12-19 bus minutes implying the extra time travellers are willing to travel to a transfer.

The estimation results confirm the expected importance of waiting and transfer times, show different preferences for bus, metro, train etc., emphasize the importance of trip distance, show the effect of specific modes for access/egress, and indicate the relevance of individual preferences within and across trip purposes.

The results show the importance of coordination between the different public transport modes, the relevance of transfer locations that allows seamless transfer from one vehicle to another, and the significance of access and egress modes in terms of parking availability for both cars and bicycles. The parameters estimated in the study both provide parameters to enlighten the necessary improvements in the public transport networks to increase the attractiveness of public transport options and provide input to the Danish National Transport Model.

Table 1: Estimated parameter coefficients and (t test) for Work and Leisure Trips for PS Logit model

Parameter	Work	Leisure + Other
Headway		
½ of Highest	-0.065 (-9.80)	-0.057 (-8.28)
In vehicle Time		
Bus	-0.149 (-20.0)	-0.090 (-12.0)
Local Train	-0.150 (-9.85)	-0.082 (-4.76)
Metro	-0.050 (-4.54)	-0.016 (-1.33)
Regional + IC Train	-0.132 (-11.5)	-0.111 (-7.67)
S Train	-0.100 (-12.3)	-0.043 (-5.93)
Access/Egress	-0.336 (-25.4)	-0.260 (-14.8)
Path Size Factor		
PSC	-0.722 (-9.27)	-0.719 (-9.27)
Transfers		
Waiting Time	-0.078 (-25.1)	-0.079 (-19.3)
Walking Time	-0.111 (-13.6)	-0.087 (-6.87)
No. Transfer	-1.79 (-6.11)	-1.74 (-4.68)
Number of estimated parameters:	11	11
Number of obs:	3,016	2,751
Null log-likelihood:	-10,960	-9,683
Final log-likelihood:	-6,387	-6,163
Rho-square:	0.417	0.364
Adjusted rho-square:	0.416	0.362

Keywords: Route choice modelling, behavioural modelling, Multimodal transport, Passengers' preferences, Path generation, Path Size Logit

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