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The importance of transfer attributes in public transport passengers' route choice

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Abstract

This study provides insight into how passengers value transfer facilities compared to other components of a route when choosing their route in public transport. A thorough analysis of previously estimated parameters for public transport route choice and a selection of the best available data for describing passenger preferences for transfer attributes led to a short list of three variables, which elaborates the general transfer penalty often included in route choice models in public transport. These are *shopping availability*, *number of escalators at transfer stations* and *the difficulty of wayfinding at transfers.*

Shopping availability and the number of escalators improve the passengers' utility of a certain route while more difficult wayfinding at transfer points have a negative impact on the utility of a route. The effect of the additional transfer attributes in the model is in general only significant for trips with work related purposes (commuting and business trips). The more detailed route choice model including transfer attributes makes it possible to evaluate the effect of different station designs and improvements of existing station facilities.

Background

In a public transport network the level of service (LOS) for the passengers is determined by their route choice and how they evaluate the different parts of the trip. Typically route choice models include the different parts of a public transport trip such as access and egress time, in-vehicle time, waiting time and walking time as well as a transfer penalty, which is typically general for all transfers. This study focus on dissecting the often included transfer penalty into multiple components depending on the services and facilities at the transfer stations. This allows for more detailed analyses of passengers' route choice and makes it possible to evaluate the impact of facilities at stations, which can be used to evaluate investments in facilities at both new and existing stations.

A thorough literature review was conducted to examine which variables had previously been included in route choice models and how these variables were included. An overview of the variables already estimated and variables which have just been mentioned in the literature is shown in Table 1. Many of the variables have previously been estimated, but in many cases only one or two variables were considered at once. This study examines how the different variables can be quantified in terms of passengers' route choice and uses these to obtain more detailed knowledge of passengers' route choice.

Table 1 - Variables included in the literature on route choice in public transport

Already estimated (in separate studies)	Mentioned in literature	Other relevant factors
Level changes (a,d,g) Escalators (a,d,h) Occupancy rate (a,d) Chance of boarding (a,d,h) Riding seated (a,d) Network knowledge (a,d) Angular cost (a,d) Ramp length (b) Shelter (c) Ease of wayfinding to/from mode (c) Security (i) Station size (j)	Appearance (f,k) Seats at platform (c) Safety (f) Shop availability (e)	Weather Ticket controls

(a) Raveau et al. (2011), (b) Guo and Wilson (2011), (c) Chowdhury et al. (2014), (d) Raveau et al. (2014), (e) Anderson (2013), (f) Iseki and Taylor (2009), (g) Garcia-Martinez et al. (2018), (h) Navarrete et al. (2013), (i) Chowdhury and Ceder (2013), (j) Schakenbos et al. (2016), (k) Cascetta and Cartenì (2014)[1]

Data and methodology

The study is based on 5,121 reported trips from the National Danish Travel Survey (Transportvaneundersøgelsen) collected from 2009-2011. The trips are divided between work related trips (2,667) and leisure trips (2,454). The routes were matched to a schedule-based public transport network in Anderson (2013). In 2015 Dyrberg and Christensen collected an extensive dataset of the facilities at stations in the Greater Copenhagen area and tested different model specifications including variables about the station facilities. Dyrberg and Christensen (2015) initially made an analysis rating different variables concerning station facilities by how well they could fit into a route choice model. The ratings of the variables were evaluated based on four criteria; validity, reliability, measurability and data availability (Joumard et al., 2010). Table 2 shows the considered variables and how they were evaluated based on ratings *low*, *middle* and *high*, with *high* being the best score, which indicate how well the variable can be collected and used reliably for route choice modelling.

Table 2 - Assessment of possible variables to include in route choice models to assess the impact of transfer station facilities

	Validity	Reliability	Measurability	Data availability
Appearance	Low	Low	Low	Low
Detour	Middle	Middle	Low	Low
Seats	Middle	High	High	Low
Safety	Low	Low	Low	Middle
Security	Middle	Middle	Middle	Middle
Shops	High	High	High	High
Level changes	High	High	High	High
Occupancy	Middle	High	Middle	Low
Shelters	High	High	High	High
Ease of wayfinding	High	Middle	Middle	Middle

[1] Cascetta and Cartenì (2014) does not specifically model transfer stations, but generally describes the hedonic value of stations

Initially data were collected for the variables *Shops*, *Level changes, Shelters* and *Ease of wayfinding*. Data about station and stop facilities were collected in two ways. For the 20 largest stations, which cover 65% of the transfers in the sample, each possible transfer between attached bus stops and transfers at the station have been examined for detailed information about the transfer. The rest of the stops for each sub-mode were divided into several categories explaining the transfer attributes for the specific stop: bus (two groups), metro (four groups), S-train (eight groups), regional/intercity train (seven groups), local train (two groups). The data was collected using Google Streetview, personal knowledge of the network and through visits to some of the stations. The different variables were included in a multinomial logit route choice model and tested in different configurations. During tests it was found that the best configuration of the variables were respectively:

- if a shop of any kind was encountered at a transfer station during the route
- the number of escalators encountered on the route
- ease of wayfinding was distinguished in three levels (easy, moderate and difficult) and each transfer on the route was assigned one of the three levels

The variable describing shelters at the transfer stations was found not to be significant and therefore not included in the final model. A variable, not related to transfers, describing a sub-mode specific boarding penalty for the first leg of the trip was also tested for each sub-mode after inspiration from Varela et al (2018). During tests it was found that only the parameter for bus was significantly different from the other sub-modes and therefore it was the only parameter included in the final model.

Resulting passenger preferences

The estimations of the full model including the transfer related variables were based on multiple specification tests which started out from a base model including the well-known parameters in route choice models; sub-mode specific in-vehicle time, transfer waiting time, transfer walking time, transfer penalty and access and egress time. Additionally for the base model, the hidden waiting time was computed for each alternative based on the actual departure time of the performed trip, as the preferred departure (or arrival) time was not included for the reported trips. The value of hidden waiting time has previously been estimated to halve of the value of in-vehicle time for bus (Nielsen, 2000), and this was included in this model as well, as the identification of this parameter was otherwise not possible. The final route choice model including transfer attributes is shown in Table 3. The log-likelihood estimates changed respectively for the two purposes (work/leisure) from -2,735/-3,276 in the base models to -2,697/-3,258, which, using likelihood ratio tests, shows that the models including the transfer variables significantly better describe the route choice behavior of the passengers for both trip purposes.

The results show that the passengers with trip purposes depending on their work value shopping availability and escalators at transfers positively and prefer easier wayfinding at stations (base level compared to the two other levels of ease of wayfinding). For leisure passengers only the parameter for number of escalators at transfer points is significant, while shopping availability and ease of wayfinding is not significant for their route choice. This indicates, that only passengers who travel regularly, i.e. mostly commuters, take these transfer attributes into account when they choose their route. For leisure passengers it indicates that these transfer attributes are not part of their route choice, which could either be because of lack of knowledge about the different alternatives they have in their route choice and therefore can't include the transfer attributes in their choice or that they simply do not value any of the attributes compared to the other variables included in the model.

The rates of substitution show how the different parameters are valued by the passengers compared to in-vehicle time in bus. The model includes a general transfer penalty, which is equivalent to around 5 minutes of bus in-vehicle time, which indicates that transfers are a large component of the route choice. The waiting times at transfers are divided into groups for the different sub-modes and this shows that passengers value waiting time for metro the worst, while waiting for the bus and trains are a smaller disutility to the passengers. The waiting time at transfers is weighted as a lower disutility compared to the bus in-vehicle time, because the general transfer penalty and other transfer attributes also has to be included to assess the full impact of a transfer on the utility for the passenger. The parameter penalizing boarding a bus on the first leg is significant for both trip purposes and is equivalent to around two minutes of in-vehicle time, which makes routes using bus on the first leg less attractive compared to routes with first leg on another sub-mode.

Table 3 - Estimated parameter coefficients (robust t-tests) and values scaled to bus in-vehicle time for the extended model with transfer attributes

	Work		Leisure		Rate of substitution (to bus IVT)	
Parameters	Coef.	*Rob. t-test*	Coef.	*Rob. t-test*	Work	Leisure
In-vehicle time:						
Bus + ½ * hidden waiting time	-0.371	*-26.06*	-0.336	*-27.15*	1.00	1.00
Local train	-0.360	*-6.97*	-0.289	*-6.14*	0.97	0.86
Metro	-0.292	*-12.52*	-0.274	*-11.49*	0.79	0.81
Reg. and intercity train	-0.353	*-14.24*	-0.434	*-14.94*	0.95	1.29
S-train	-0.347	*-21.87*	-0.316	*-20.03*	0.94	0.94
Transfer components:						
Transfer penalty	-2.088	*-13.09*	-1.814	*-12.01*	5.64	5.40
Transfer waiting time Bus	-0.026	*-4.50*	-0.026	*-4.56*	0.07	0.08
Transfer waiting time Train	-0.050	*-8.23*	-0.035	*-5.03*	0.14	0.10
Transfer waiting time Metro	-0.137	*-5.14*	-0.170	*-4.90*	0.37	0.51
Transfer walking time	-0.147	*-5.71*	-0.186	*-6.35*	0.40	0.55
Shop available at any transfer	0.332	*2.47*	0.115	*0.85**	-0.90	-0.34
Ease of wayfinding - Moderate	-0.306	*-2.61*	-0.150	*-1.12**	0.82	0.45
Ease of wayfinding - Difficult	-0.811	*-2.44*	-0.165	*-0.59**	2.19	0.49
Escalators encountered on route	0.376	*4.48*	0.278	*2.67*	-1.02	-0.83
Other components:						
Access/egress	-0.523	*-19.41*	-0.460	*-20.98*	1.41	1.37
First boarding is on a bus	-0.897	*-4.60*	-0.607	*-2.36*	2.42	1.81
No. of est. parameters:	16		16			
Number of observations:	2,667		2,454			
Null log-likelihood:	-13,063		-11,659			
Final log-likelihood:	-2,697		-3,258			
Likelihood ratio test:	20,733		16,803			
Adjusted rho-square:	0.792		0.719			

*Parameter estimate not significantly different from zero at a 90% confidence level

Conclusions and implications of the study

The study has shown that especially passengers with work related trip purposes take transfer attributes into account when choosing their routes in the public transport network. Availability of shopping at any transfer station on the route and the number of escalators encountered on the route have a positive impact on the passengers perception of the routes utility, while more difficult wayfinding at stations have a negative impact on the passengers' utility of a route.

The more detailed description of the route choice in public transport can help when evaluating the effect of new station designs and investments in upgrades of existing stations. Evaluating these designs or changes in station layouts require an assignment model to evaluate the change in number of passengers transferring at each station as well as the level of service for the passengers. In this way investments in station facilities can be compared to changes in level of service for example lower headways of the public transport services which is often a significantly higher investment.

The work is proposed to be included under the “Public transport” or “Transport models and their application” themes.

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