ANALYZING ACCESS, EGRESS, AND MAIN TRANSPORT MODE OF PUBLIC TRANSIT JOURNEYS: EVIDENCE FROM THE FLEMISH NATIONAL HOUSEHOLD TRAVEL SURVEY

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ABSTRACT

The primary objective of this paper is to explore the influence of socio-demographic and contextual variables on the multimodal character of public transit journeys. Accounting for multimodality in public transit journeys is important from a demand modeling point of view, especially in the assessment of new projected public transit infrastructure. To meet the objective, data from the national household travel survey of Flanders (Belgium) is analyzed. Based on 2,202 public transit journeys, the main public transit mode choice (bus/tram/metro or train) and access/egress mode choice are simultaneously estimated using a multinomial logit model, and by explicitly making a distinction between unimodal and multimodal transit journeys. The results indicate that various socio-demographical (e.g. age, gender, level of education, household income) and contextual factors (e.g. journey distance, journey motive, urbanization degree, car availability) significantly influence the joint decision process. Total journey distance and car availability are identified as the most important explanatory variables. In terms of model performance, the model appears to yield satisfactory predictions, justifying the integration of the model in more general demand modeling frameworks.

1. INTRODUCTION

Travel behavior studies often focus on the analysis of mode choice preferences (*1-2*). De Witte et al. (*3*) provide a comprehensive overview of both objective and subjective determinants of the complex mode choice decision process, including socio-demographic indicators, spatial indicators, journey characteristics and socio-psychological indicators. Most studies concerning mode choice analysis are conducted in order to identify adequate policy measures to increase or evaluate the use of (new) sustainable transport modes or to decrease car use (*4-9*).

Although the literature on mode choice is extensive, little attention is paid to the multimodal character of journeys, even though access and egress modes have a substantial influence on the total travel disutility (*10-12*). Access and egress modes are considered as the weakest link in travel chains and are therefore often a neglected part in analyzing a person's mode choice (*13-14*).

Studies that do recognize the importance of access and egress trips are rather scarce in comparison to the multitude of studies on mode choice. They generally focus on the accessibility of public transport infrastructure (*11*,*15-16*), and on the impact assessment of changes in transport services on modal choices and CO2-emissions (*13*,*17*). Besides, existing literature documents the influence of different contribution factors on access and egress mode choice including cost elements (*18*), individual, built environment and crime characteristics (*14*), context variables (*12*,*19*), car availability (*10*), and past travel behavior (*20)*.

Most of the above studies are conducted from a policy perspective and aim to understand the factors influencing access and egress mode choice in order to improve access mode services. While these studies recognize the importance of access and egress modes, they focus on only one dimension of the public transit journey. Moreover, studies on access mode choice are often pinpointed on the walk mode as was also stated in Kim et al. (*14*). Only a few studies could be found in literature focusing on the multi-dimensional character of the public transit journey. Polydoropoulou and Ben-Akiva (*21*) jointly estimated access and main mode choice for the Tel Aviv metropolitan area. Explanatory variables of this decision process mainly focused on service attributes of the primary transit mode (e.g. in-vehicle travel time, out-of-vehicle travel time etc.) and mode specific characteristics of the access and egress modes (e.g. parking cost, car-in-vehicle travel time). Debrezion et al. (*22*) modeled simultaneously the access mode choice and departure station choice for train travelers in the Netherlands. They concluded that the choice of station depends on the accessibility of the station and on the rail services provided at the station.

Most of the studies on access and egress trips were recently conducted, implying the growing importance of access and egress trips in the literature on mode choice and underlining the necessity to consider the complete public transit journey. These studies will be elaborated in more detail in the literature review section.

The current research contributes to the mode choice literature by estimating a MNL-model to simultaneously predict the access/egress and main public transit mode and thus taking into account the complete public transit journey in the modeling process. Understanding traveler's preferences and behavior with respect to mode choice decisions in multimodal public transport journeys is necessary from a transit planning and demand modeling point of view, especially in the context of assessments of the socio-economic and environmental impact of new projected public transit infrastructure.

The paper is organized as follows. Section 2 provides a more elaborated overview of the literature with regard to access and egress mode choice. Subsequently, a description of the data used in the research is provided and complemented by a descriptive analysis (Section 3). An outline of the methodology to estimate the model is described in Section 4, followed by a discussion of the results in Section 5. Finally, Section 6 summarizes the research findings and highlights some avenues for further research.

2. BACKGROUND

In this section, an overview is provided of the influencing factors of access and egress mode choice, which can be broadly divided into three categories: socio-demographical factors, transport mode specific attributes and contextual factors. Table 1 recapitulates the different contributing factors for each of these three categories.

TABLE 1 Overview of Contributing Factors to Access/Egress Mode Choice

Contribution Factors	**Confirming studies**
Socio-demographical	
Gender	*14, 16*
Age	*14, 16, 20*
Driving License	*14*
Car ownership	*16, 18*
Employment status	*14*
Household income	*14, 16, 18*
Number of children	*20*
Number of workers	*20*
Education level	*16*
Transport mode specific	*18, 21*
Distance	*11, 12, 14, 16, 18, 20, 23*
Contextual	
Time of day	*12, 14*
Car availability	*10, 14*
Bus availability	*14*
Crime rate	*14*
Trip purpose	*12, 18*
Land use	*11, 16, 19*
Weather	*11, 12*

With respect to the first category (socio-demographical factors), various studies state the importance of personal and household characteristics in access/egress mode choice (*11*,*14*,*15*,*18*,*20*). In particular, Kim et al. (*14*) found significant impacts of gender, age, driver's license, traveler’s employment status and household income on transit access mode choice. Females appeared to be more likely to use bus as an access mode compared to males. Gender appeared also to be significant with three interaction variables: private vehicle availability, day/nighttime, and crime rates at the station. The relevance of gender was also acknowledged by Loutzenheiser (*16*), who indicated than men were more likely to walk than women. In contrast, Tran et al. (*20*) did not found a significant influence of gender on the use of slow modes. With regard to age, Kim et al. (*14*) found that travelers under the age of 25 years are more likely being picked-up/dropped off at the station. The age group of 25-34 year olds was associated with a higher probability of using motorized transport modes (e.g. park and drive, bus). In line with this study, Tran et al. (*20*) found older people to be more likely to choose slow modes as an access mode to the station. In contrast, Loutzenheiser (*16*) found that individuals older than 65 were less likely to walk. With regard to driver’s license, Kim et al. (*14*) found that individuals with a driver’s license were less likely to be picked-up/dropped off and were less intended to use bus. Related to this effect, Loutzenheiser (*16*) and Wen et al. (*18*) found a positive effect of car ownership on car access mode and a negative effect on public transport use and walking. Lower household incomes were associated with an increase in bus share and walking (*14*,*16*,*18*). However, the income effect could not be confirmed in the research of Tran et al. (*20*). Other household attributes that were identified by Tran et al. (*20*) as contributing factors, include the number of children, which was negatively associated with slow access modes, and number of workers which had a positive influence on the walking access mode choice. In addition, Loutzenheiser (*16*) indicated education level as a key factor in the decision to walk to the access station.

The second category refers to the transport mode specific attributes in the public transit journey. A multitude of studies highlight the importance of distance to (and from) the station as a primary determinant of access/egress mode choice (*11*,*12*,*14*,*16*,*18*,*20*,*23*). As expected, the probability of non-motorized modes as an access mode decreases when distance to the transit station increases. In addition, Polydoropoulou and Ben-Akiva (*21*) focused on transport-system specific factors when jointly estimating the access and main public transit mode. They identified the number-of-transfers, public transport in-vehicle travel time, cost of parking, transit fare, walk access time and delay probability as significant factors. Wen et al. (*18*) found similar factors influencing the access mode choice.

A third category relates to contextual factors. Molin and Timmermans (*12*) found a significant relation between egress mode choice and time of day: travelers were less inclined to choose slow modes and public transport as egress modes in the evening or at night. In contrast, Kim et al. (*14*) found higher probabilities of walking relative to the other modes (drive&park, pick-up/drop-off and bus) when trips were made in the evening or night. Givoni and Rietveld (*10*) and Kim et al. (*14*) both explored the effect of car availability. While Kim et al. (*14*) found an increased probability on the drive&park alternative, Givoni and Rietveld (*10*) did not found a strong effect of car availability on access mode choice. With regard to bus availability, Kim et al. (*14*) indicated a positive relationship with the likelihood of bus use. In addition, they found that females were more likely to be picked-up/dropped off at stations with higher crime rates. The significance of trip purpose and urbanization degree was also tested, but these factors did not influence access mode choice. However, the latter could be due to the fact that the model already controlled for other land use variables. Other studies also stated the relevance of land-use on access mode choice (*11*,*16*,*19*). Individuals living in urban areas are more likely to walk than those living downtown. Jiang et al. (*19*) specifically focused on the impact of the built environment on the probability of walk access mode choice and concluded that people are prepared to walk longer distances to the station when the environment has a specific atmosphere, e.g. busy and interesting. Although trip purpose was not significant according to Kim et al. (*14*), Molin and Timmermans (*12*) and Wen et al. (*18*) did find a significant influence. Molin and Timmermans (2010) showed that in the context of work-related trips, costly modes like taxis are more preferred than in the context of recreational trips. A last contextual factor was reported by Krygsman et al. (*11*) and Molin and Timmermans (*12*), who highlighted the role of weather conditions on access/egress mode choice.

3. DATA DESCRIPTION

The basic data source used for simultaneously predicting the access/egress and main public transit mode stems from the Flemish National Household Travel Survey. This survey collects data on daily travel behavior by using household questionnaires, person questionnaires and travel diaries. Respondents are sampled using a stratified random cluster sample of the population older than 6 years in Flanders, the northern region of Belgium. In 2014, this region counted about 6.4 million inhabitants, corresponding to an average population density of 470 inhabitants per square km.

The results of the survey indicate that Flemish residents make on average 2.72 journeys a day. The average number of trips per journey is 1.12, indicating a rather low degree of multimodality. Most of the journeys are carried out by car (67.75%). Slow modes account for 25.08% and the share of public transport equals 5.7% (*24*). This modal split is confirmed by a similar research focusing on the Belgian context, indicating validity of the data (25). In order to have sufficient records for model estimation, survey-data of several years were merged (2007-2013). In total, data from 50,899 journeys of in total 13,616 persons was collected. Each journey contains a maximum of 5 trips. Recall that the data is derived from reported travel diaries and therefore enclose revealed preference data, and that information on travel alternatives is not available. Therefore the explanatory factors in the model estimation process are limited to socio-demographical and contextual variables.

This paper focuses on public transit journeys. Therefore, the journeys with public transit as main mode were selected from the original 50,899 journeys. The main mode was delineated as the transport mode with the longest distance travelled in the journey. Moreover, only journeys which had its origin and destination within the Flemish region were considered. Due to the small share of public transit in the Flemish context, the final dataset consists of 2,202 journeys. For each journey, access and egress modes were determined.

When studying the sequence of trips within public transit journeys in more detail, numerous combinations could be identified. After all, access and egress trips are not necessarily limited to one mode. Take as an example the following sequence: walk – bus/tram/metro (BTM) – train – car, where train was defined as the main public transport mode. Consequently, the access mode is the combination of walk and BTM, whereas car is the egress mode. In total 72 combinations were detected in the data of which 20 combinations had BTM as main public transit mode and 52 combinations had train as main public transit mode. In order to estimate access/egress mode and main public transit mode simultaneously, a distinction was made between unimodal journeys made by BTM and train and multimodal journeys made by BTM and train. To ensure model convergence (see also Section 5), the number of combinations was reduced to 7, taken into account following considerations:

- Walking access and egress trips with a travel time less than 10 minutes were neglected, as these access and egress trips are not considered to be substantial (*25*).
- A public transit journey was defined as unimodal when no access and no egress trips were reported.
- In all other cases, a public transit journey was defined as multimodal. For each journey, the main access/egress mode was determined based on the heuristic rule that prioritizes the mode with the largest environmental impact. If one of the access/egress trips was made by car, than access/egress mode was defined as car. Consequently, if no access/egress trips were made by car, but by BTM, then the latter was considered as access/egress mode. Note that this only occurs in the case of public transit journeys with train as main mode. Finally, if neither car nor BTM was used, then slow modes could be defined as access/egress mode.

Table 2 provides an overview of the frequencies of the 7 possible combinations of access/egress and main transport mode choices. The results show that half of the journeys are unimodal. In almost all of these journeys (95.44%), BTM was chosen as the main public transit mode. A logic result, since the proximity of BTM-stops is generally higher in comparison to the proximity of train stations which are geographically more spread. Therefore, the requirement of access/egress trips for journeys with BTM as main transport mode is less in comparison to journeys with train as main transport mode. This is confirmed by the percentage of multimodal journeys that are carried out by train (59.96% = 650/1084) in comparison to the ones carried out by BTM (40.04%). Furthermore, the occurrence of car travel in access/egress trips in journeys with train as main mode is higher than in journeys with BTM as a main transport mode, indicating the larger distance to train stations.

Besides, it can be concluded that in the majority (65.50%) of the multimodal journeys a sustainable transport mode (slow modes or BTM) was used as an access/egress mode. This highlights the overall sustainable character of public transit journeys in Flanders and is in line with the research of Givoni and Rietveld (*10*) and Bhandari et al. (*13*).

TABLE 2 Descriptive Results of Public Transit Journeys

Uni/multi	Main transport mode	Access/egress mode	Label	Observed Frequency	Percentage (%)
Unimodal	BTM	/	Uni_BTM	1067	48.46%
	Train	/	Uni_Train	51	2.32%
Multimodal	BTM	Car	Multi_BTM_Car	98	4.45%
		Slow	Multi_BTM_Slow	336	15.26%
	Train	Car	Multi_Train_Car	276	12.53%
		BTM	Multi_Train_BTM	162	7.36%
		Slow	Multi_Train_Slow	212	9.63%

Table 3 gives an overview of the variables that were collected in the survey and which were used as potential explanatory factors in the model building process (see Section 4). For each variable, basic descriptive statistics are provided. Categorical variables have been dichotomized, e.g. journey motive can either be non-work or work related.

TABLE 3 Overview of Variables used in the Model Building Process

Parameter	**Label**	**Definition**	**Descriptive statistics**[1]
Socio-demographics			
Age	Age	Years past since birth	Mean: 38.08, Std. Dev.: 20.60
Gender	Sex	Whether person is male or female	Male: 44.96%, Female:55.04%
Household size	HH_Size	Number of members in the household	Mean: 3.13, Std. Dev.: 1.59
Number of cars	Nr_cars	Number of cars in the household	Mean:1.11, Std. Dev.: 0.81
Education	Ed	Highest degree of diploma	Secondary degree or less: 75.02% Higher education: 24.98%
Professional status	Prof	Whether or not the person is professional active	No: 59.90%, Yes:40.10%
Household income	HH_Inc	The total net monthly income of a household in EUR	< 2000 EUR: 40.15% , > 2000 EUR: 59.85%
Driver's license	Dl	Whether or not the person has a driver's license	No: 48.32%, Yes:51.68%
Partner	Partner	Living together with a partner	No: 59.13%, Yes:40.87%
Children	Kids	Presence of children in the household	No: 77.84%, Yes: 22.16%
Contextual attributes			
Car availability	Car_av	Car available at the beginning of the journey	No: 68.07%, Yes: 31.93%
Journey distance	Dist	Total distance of journey from origin to destination (in km)	Mean: 25.34, Std. Dev.: 36.58
Journey motive	Motive	Journey purpose	Non-work/school: 46.55%, Work/school:53.45%
Urbanisation degree	Urb	Degree of urbanisation of departure municipality	Urban: 67.26%, Rural: 32.74%
Weekend	Wknd	Journey carried out on a weekday or in the weekend	Weekday: 87.10%, Weekend: 12.90%
Peak hour	Peak	Departure time of journey starts between 7h-9h or 16h-18h.	No peak hour: 52.32%, Peak hour: 47.68%
Starts at home	Home	Journey starts at home location	No: 57.27%, Yes:42.73%

[1] For the dichotomous variables, the first category occurring in Table 3 is used as reference category

The possible explanatory factors have been subdivided into socio-demographics and contextual variables according to the literature review. Recall that transport mode specific attributes are not envisaged as they were not collected in the national household travel survey. Note that in addition to the factors identified in literature, in this study also the possible effect of different indicators of household composition (household size, partner) as well as departure specific information (weekend, peak hour, starts at home) is assessed.

The most striking descriptive statistic concerns car availability. In 31.93% of the public transit journeys, the traveler had a car available at the beginning of the journey, but opted for public transport. This means that at least one third of the public transit users are not 'transit captive' but had a clear car alternative.

4. METHODOLOGY

Recall that the main objective of this paper is to simultaneously predict the choice of access/egress mode and the main public transit mode, focusing on socio-demographical and contextual variables. A discrete choice model is a suitable way to analyze such mode choice behavior, as shown in previous studies related to this topic (*14*,*21*,*22*). In particular, the multinomial logit model (MNL-model) was chosen as i is typically being used to model relationships between a polytomous response variable and a set of regression variables related to the individual. The MNL-model is specified as follows (*26*):

$$PROB_i(j) = \frac{Exp(V_{ij})}{\sum_{j \in J} \exp(V_{ij})}, \tag{1}$$

where $PROB_i(j)$ is the probability for individual i to choose alternative j from the choice set J, and V_{ij} the non-stochastic part of the utility function of choice alternative j. When this probability is calculated for each alternative, the alternative with the highest probability is the most likely to be chosen by the individual. The non-stochastic part of the utility function depends on a number of covariates and is typically specified by a linear function, which can be defined as follow:

$$V_{ij} = \hat{\beta}_j X_{ij}, \tag{2}$$

where $\hat{\beta}_j$ is a vector of parameters to be estimated and X_{ij} the vector of explanatory variables.

Recall that the choice set consists of 7 alternatives, for which the frequencies were displayed in Table 2. In this study, the unimodal journeys with BTM as main transport mode (Uni_BTM) was chosen as the reference category, to which the parameter estimates of the 6 other categories should be compared. The coefficients of the model can therefore be interpreted through their impact on the log-odds ratio of each alternative to the reference category Uni_BTM. Table 3 provided the list of the possible explanatory variables in the model.

During the model building process, forward selection was used to identify the most relevant variables in the model. This process consists of a number of iterations in which each variable, which was not yet included in the model, was tested for inclusion. After each iteration, the most significant variable was added to the model, as long as its P-value was below the significance level of 0.05. In this way, only significant variables were retained in the final model. The final model was tested for multicollinearity, but no problems occurred. Variance Inflation Factors (VIF's) were all below 2 and thus below the critical threshold of 4.

5. MODEL RESULTS

5.1 Overall Results

The results of the overall significance tests are displayed in Table 4. Note that these tests evaluate the simultaneous impact of all coefficients related to one particular explanatory variable on the outcome variable.

TABLE 4 Wald Statistics for Type 3 Analysis

Parameter	DF	Chi²	P-value
Socio-demographics			
Age	6	43.20	<0.001
Sex	6	18.97	0.004
Ed	6	38.69	<0.001
Prof	6	27.41	<0.001
HH_Inc	6	23.55	<0.001
Dl	6	19.97	0.003
Partner	6	23.02	0.001
Contextual attributes			
Car_av	6	86.37	<0.001
Dist	6	277.30	<0.001
Motive	6	25.88	<0.001
Urb	6	16.92	0.010

Almost all socio-demographical factors significantly influence public transport mode choice sequences. This is in line with literature which pinpointed similar socio-demographical factors significantly influencing access/egress mode choice. Household size, number of cars and the presence of children in the household did not have a significant effect. Although, the number of cars was identified in literature as being a factor significantly influencing access/egress mode (*16*,*18*), the lack of significance in this paper can be explained by the fact the model already controls for driver's license and car availability. In addition, the significant effect of having a partner could not be validated by literature, since no studies discussed in the literature review examined this effect. Besides, various interaction variables were tested (e.g. the interaction effects between gender and car availability and motive and car availability), however none of these interaction effects appeared to be significant. Therefore, the results of Kim et al. (*14*) with regard to the interaction effects could not be confirmed in this study.

With regard to the contextual factors, car availability, total distance of the journey, journey purpose and urbanization degree all significantly influence access/egress and main public transit mode choice, which is again in line with literature. Distance is identified as the most significant factor (highest chi²-value and the same degrees of freedom), as was also indicated in literature (*11*,*12*). With respect to car availability, Kim et al. (*14*) found a clear effect, whereas Givoni and Rietveld (*10*) did not found a strong effect. Our model indicates that car availability is the second strongest determinant of the public transport mode choices (indicated by the second highest chi²-value and the same degrees of freedom for all attributes). In addition, whether the origin of the journey starts at the home location did not have a significant impact. This was rather surprising as it was expected that different transport modes are available at the home location in comparison to the transport modes available at the activity locations. However, the insignificance of this variable can further be accounted for by the effect of car availability.

5.2 Parameter Estimates

The parameter estimates of the MNL-model of access/egress and main public transit mode choice are presented in Table 5. In general, the signs of the parameter estimates are in line with common sense, which provides at least some evidence of the validity of the model. Recall that Uni_BTM was chosen as the reference category and therefore no parameter estimates related to this reference category are displayed in the table (parameter estimates assumed to be equal to zero). Therefore, the remaining parameters in the model should be interpreted in comparison to this reference category.

TABLE 5 Parameter Estimates for the MNL–model

Parameter	Unimodal		Multimodal									
	Train		BTM				Train					
			Car		Slow		Car		BTM		Slow	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
Intercept	***-4.50***	*0.59*	-19.56	223.60	***-1.49***	*0.23*	***-8.71***	*0.83*	***-4.48***	*0.40*	***-3.24***	*0.36*
Socio-demographics												
Age	***-0.03***	*0.01*	0.01	0.01	0.01	<0.01	***-0.02***	*0.01*	-0.01	0.01	***-0.04***	*0.01*
Sex	-0.05	0.30	***0.55***	*0.26*	-0.22	0.13	***0.45***	*0.20*	-0.18	0.20	***-0.38***	*0.18*
Ed	-0.19	0.39	***0.74***	*0.31*	0.36	0.19	***0.75***	*0.25*	***0.72***	*0.24*	**1.27**	*0.23*
Prof	0.65	0.42	-0.37	0.35	-0.02	0.17	***0.76***	*0.30*	***0.92***	*0.27*	**0.80**	*0.26*
HH_Inc	***0.80***	*0.38*	***0.68***	*0.32*	***0.31***	*0.15*	***0.77***	*0.27*	***0.91***	*0.25*	0.41	0.21
Dl	***0.93***	*0.39*	0.43	0.36	0.06	0.15	***0.67***	*0.30*	0.42	0.24	***0.83***	*0.22*
Partner	0.60	0.46	***-0.90***	*0.35*	***-0.52***	*0.17*	-0.52	0.28	***-0.74***	*0.27*	-0.24	0.25
Contextual attributes												
Car_av	0.05	0.35	16.75	223.60	***-0.53***	*0.19*	***5.89***	*0.72*	***-0.64***	*0.25*	-0.41	0.23
Dist	***0.06***	*0.01*	***0.04***	*0.01*	0.01	0.01	***0.06***	*<0.01*	***0.06***	*<0.01*	***0.06***	*<0.01*
Motive	-0.38	0.33	-0.05	0.31	0.23	0.15	0.45	0.25	***0.68***	*0.24*	***0.87***	*0.22*
Urb	0.07	0.32	***0.85***	*0.26*	0.11	0.14	***0.61***	*0.22*	-0.21	0.21	0.22	0.19

Bolds indicate parameters significant at the 5% level

With regard to the socio-demographics, it appears that an increase in age is associated with lower odds for the Uni_Train, Multi_Train_Car and Multi_Train_Slow alternatives, indicating older people are less likely to choose train as main public transit mode. This can be partially explained by the fact that, at the time of the data collection, elderly (65+) could travel for free on BTM-modes but still had to pay a small amount for train trips. Every year increase in age was associated with a decrease in the odds of choosing car (-1.98% = exp(-0,02) and choosing slow modes (-3.92%) as access/egress mode when train was chosen as the main public transit mode. This is in line with the research of Kim et al. (*14*) and Loutzenheiser (*16*).

The parameter estimates for gender indicate that females are more likely to choose car as an access/egress mode compared to males, independently whether the main public transit mode is BTM or train. In addition, females were also less likely to choose slow modes to access/egress the train station. The latter effect was confirmed by Loutzenheiser (*16*).

With regard to education, it is shown that the odds of choosing train as a main public transit mode in multimodal journeys increase with higher education levels for all access/egress mode combinations. Similar results were found for the professional status. One possible explanation for these effects is that people with a higher education level or with a professional occupation travel further (i.e. longer commuting distances). In addition, an increase in the odds of choosing the Multi_BTM_Car alternative for higher educated people was found.

Concerning household income, one could notice an increase in the odds for all alternatives compared to the uni_BTM reference category, except for the effect on Multi_Train_Slow, which was not significant. With regard to driver's license, the odds of conducting a multimodal journey with car as an access/egress mode and train as main public transit mode increases with 95.42% when the traveler is in possession of a driver's license. With respect to having a partner, it is shown that having a partner significantly decreases the odds in the multi_BTM_Car, Multi_BTM_slow and Multi_Train_BTM category, with respectively 59.34%, 40.55% and 52.29%.

Regarding the contextual attributes, investigation of the parameter estimates of car availability reveals a negative influence on the odds of Multi_BTM_Slow and Multi_Train_BTM alternatives, while a positive influence was identified on the odds of the Multi_Train_Car alternative. These results are in line with expectations and are in the same direction as the research of Kim et al. (*14*).

With regard to journey distance, it appears that train is preferred over BTM as a main transport mode for longer distances. One possible explanation is the higher suitability of train transport for longer distances. In addition, it could be derived that for every km increase in total distance, the odds for choosing car, BTM and slow modes as an access/egress mode increases with 6.18% when train is chosen as the main public transport mode. The effect of distance in the case of BTM as a main public transport mode is less obvious. No significant effect could be noticed for the impact on slow modes and the impact on car use (+4.08%) is less pronounced compared to the odds of car in the train main mode combination. The latter confirms the results of the descriptive analysis, which showed that a more substantial access/egress trip is needed when train is the main public transit mode.

Concerning the effect of journey motive on the choice of access/egress and main public transport mode, one could notice an increase in the odds for the the Multi_Train_Slow and the Multi_Train_BTM alternative with respectively 138.69% and 97.39% for work/school-related journeys. The odds for choosing one of the other alternatives appear to remain unaffected.

Finally, with respect to the degree of urbanization, one could denote public transit journeys originating in a rural area have increased odds of choosing the Multi_BTM_Car alternative (+133.96%) and a 84.04% increase in the odds of choosing the Multi_Train_Car alternative. In general, rural areas are more car dependent, explaining the previous effects. In addition, train stations are often located in urban areas and rural areas are not well served by bus transit, implying the need of an access mode suitable for longer distances. These effects are in line with literature (*11*,*16*,*19*), which indicated a higher use of non-motorized modes in urban areas compared to the outer area.

5.3 Model Performance

In the preceding section, the different determinants of access/egress and main public transit mode choice were identified and it was discussed how each parameter contributed to the likelihood of an alternative to be chosen. In the current section, it is explored whether the model performs sufficiently in terms of the quality for demand predictions. The model's goodness-of-fit in terms of pseudo R^2 indices equals 0.64 for the Nagelkerke R^2 criterion, and 0.30 for McFadden R^2, indicating a satisfactory fit. This is confirmed by the likelihood ratio lack-of fit test, for which the P-value < 0.001, implying the null hypothesis indicating lack of fit is rejected.

To evaluate the predictive capability of the model, predictions were calculated for each observation using the model parameters as displayed in Table 5. Note that the comparison is based on the same dataset as was used for the calibration of the parameters.

Then, for each alternative, predicted outcomes were compared to the observed outcomes and a deviation factor was computed. The results are shown in Table 6 and indicate a good predictive quality of the model as deviations are relative small.

TABLE 6 Deviation between Observed and Predicted Values

Uni/multi	Main transportmode	Access/egress mode	Observed	Predicted	% Deviation
Unimodal	BTM	/	1067	1088	+ 1.97%
	Train	/	51	54	+ 5.88%
Multimodal	BTM	Car	98	91	- 7.14%
		Slow	336	336	+ 0.00%
	Train	Car	276	286	+ 3.62%
		Btm	162	141	- 12.96%
		Slow	212	206	- 2.83%

6. CONCLUSIONS

This study contributes to the existing literature on public transit mode choice by jointly estimating the access/egress and main public transit mode choice, since most studies do not acknowledge the multi-dimensional character of public transit journeys. For this purpose, a MNL-model was estimated. Results are important in the context of more complete and reliable demand predictions and the final model could be integrated in general demand modeling frameworks, like for instance activity based models. Estimation results are in line with expectations of common sense and are in line with recent studies indicating validity of the model. Moreover, it was shown that the predictive capability of the model was satisfactory, justifying an implementation of the model in an activity based framework.

Further research should focus on the implementation of the discussed modeling framework in the context of the socio-economic and environmental assessment of new public transit infrastructure. To this end, an integration of the discussed methodology within activity-based modeling frameworks such as the Feathers model (*27*), could be a promising avenue for further research. In addition, the role of other contextual variables influencing the multimodal character of public transit journeys could be explored. One important contextual variable in this regard, is the impact of weather on multimodal journeys (*28*,*29*). To this end, revealed preference data should be complemented with information stemming from other data sources (e.g. weather stations or stated preference data).

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