IDENTIFYING THE DETERMINANTS OF LIGHT RAIL MODE CHOICE FOR MEDIUM/LONG DISTANCE TRIPS: RESULTS FROM A STATED PREFERENCE STUDY

Lieve Creemers[1], Mario Cools[2,3,*], Hans Tormans[1], Pieter-Jan Lateur[1], Davy Janssens[1], Geert Wets[1]

[1] Transportation Research Institute
Hasselt University
Wetenschapspark 5, bus 6
BE-3590 Diepenbeek
Belgium
Fax.:+32(0)11 26 91 99
Tel.:+32(0)11 26 91{34, 31, 58}
Email: {lieve.creemers, hans.tormans, pieter-jan.lateur, davy.janssens, geert.wets}@uhasselt.be

[2] Centre for Information, Modelling and Simulation (CIMS)
Hogeschool-Universiteit Brussel
Warmoesberg 26
BE-1000 Brussels
Belgium
Tel.: +32(0)485 42 71 55
Fax: +32(0)2 217 64 64
Email: mario.cools@hubrussel.be

[3] Research Foundation Flanders (FWO)
Egmontstraat 5
BE-1000 Brussels
Belgium

* Corresponding author

Number of words: 6446
Number of Figures: 1
Number of Tables: 3
Words counted: 6446 + 4*250 = 7446 words

Revised paper submitted: November 15, 2011

ABSTRACT

The introduction of new public transport systems can influence society in a multitude of ways, ranging from modal choices and the environment to economic growth. This paper examines the determinants of light rail mode choice for medium/long distance trips (10-40km) for a new light rail system in Flanders, Belgium. To investigate these choices, the effects of various transport system specific factors (i.e. travel cost, in-vehicle travel time, transit punctuality, waiting time, access/egress time, transfers, and the availability of empty seats) as well as the travelers' personal traits, are analyzed using an alternating logistic regression model, which explicitly takes into account the correlated responses for binary data. The data used for the analysis stem from a stated preference survey which was conducted in Flanders, Belgium. The modeling results yield findings that are in line with literature: most transport system specific factors as well as socio-economic variables, attitudinal factors, perceptions and the frequency of using public transport contribute significantly to the preference of light rail transit. In particular, it is shown that the use of light rail is strongly influenced by travel cost and in-vehicle travel time and to a lesser extent by waiting and access/egress time. It also appeared that seat availability plays a more important role than transfers in the decision process to choose light rail transit. The findings of this paper can be used by policy makers as a frame of reference to make light rail transit more successful.

1 INTRODUCTION

Nowadays, the importance of transport as one of the key prerequisites of any modern society cannot be downplayed. After all, transport enables people to reach services and to maintain contacts and social interactions. Unfortunately, next to these positive effects, transport also has many negative impacts such as safety problems (e.g. traffic casualties), environmental pressure (e.g. greenhouse-emissions), and economic losses (e.g. time lost due to congestion) *(1)*. In order to make transport more sustainable, it is necessary to develop transport systems that provide good alternatives to car use. In an attempt to alleviate the negative effects of car use and to achieve a more sustainable travel behavior, the Flemish public transport company 'De Lijn' is currently preparing an investment program to introduce a regional light rail network to provide adequate public transport at medium range distance (10-40 km) *(2,3)*. Notwithstanding, at this moment, the concept of light rail is still (relatively) unknown in Flanders (the Dutch speaking, northern region of Belgium), as this mode of transportation has not been implemented yet. Consequently, there arises a clear need to make assessments about the impact of a new light rail system in Flanders.

The development of light rail systems may have a multitude of impacts as is indicated by literature, ranging from shifts in modal split and improved accessibility, to urban development and economic growth. Billings *(4)* investigated the impact of a new light rail system on property values in Charlotte, North Carolina and demonstrated an increase in real-estate prices within a distance of 1.6 km from the stations. Light rail investments can therefore serve as an economic development tool. Senior *(5)* investigated the impacts on travel behavior of a light rail project in the Greater Manchester region (UK) and concluded that the light rail project contributed significantly to the declining share of bus trips and work trips by car. Mackett and Edwards *(6)* analyzed the impacts of 46 urban public transport systems around the world, including a series of light rail systems. In most instances, they found a reduction in car use after implementation of the transit systems. Next to the impacts on modal split, they also reported some important environmental and accessibility effects. Generally, these impacts were positive, e.g. a reduction in air pollution and improved access to the city centre. However, in a few cases, some negative effects occurred, e.g. an increase in noise pollution. Furthermore, they considered impacts on urban development and land use. Transit infrastructure stimulated industry and urban development around stations.

This paper examines the determinants of light rail mode choice for medium/long distance trips (10-40km) for a new light rail system in Flanders. To investigate these choices, the effects of a multitude of transport system specific factors such as travel cost, in-vehicle travel time, transfers, availability of empty seats, access/egress time, waiting time and transit punctuality, as well as the travelers' personal traits, are analyzed using an alternating regression model *(7,8)*

This paper is organized as follows. Section 2 provides a literature overview of the key determinants of mode choice in general, and of light rail ridership in particular. Section 3 discusses the data that was collected as part of this research, while Section 4 focuses on the statistical methods used to analyze these data. The results of these analyses are shown in Section 5 and discussed in Section 6. Section 7 formulates various policy recommendations. Finally, Section 8 summarizes the research findings and highlights some avenues for further research.

2 LITERATURE REVIEW

2.1 Key Determinants of Mode Choice in General

In this section, an overview of the factors that influence mode choice is given. This overview focuses on two categories, namely public transport systems' specific factors and personal traits and attitudes of the travelers.

Regarding the first category, it was found that reliable travel times contribute significantly to public transport choice. Schramm et al *(9)* and Van Loon et al *(10)* indicated that more reliable travel times lead to an increase in transit ridership. In addition, Zhang et al *(11)* and Outwater et al *(12)* found that punctuality of transit systems add significantly to the mode choice decision process. In contrast, only one study could be found were the effect of reliable travel times on mode choice turned out to be not significant *(13)*. Next to reliable travel times, also other transport system specific factors such as travel cost, in-vehicle travel time, waiting time, access/egress time, transfers and availability of empty seats, affect mode choice. Mattson et al *(14),* Outwater et al *(12)* and Hensher and Rose *(15)* underlined the importance of travel costs (i.e. transit fares). Ben-Akiva and Morikawa *(16)* illustrated that the different travel time components (i.e. access/egress time, in-vehicle time and waiting time) all contribute significantly in explaining mode choice. Furthermore, they indicated that travelers prefer modes that offer sufficient comfort (heating, air conditioning, sufficient legroom etc.). Moreover, Outwater et al *(12)* underlined the decreasing effect of transfers on transit choice. Finally, the importance of seat availability was stressed by Bierlaire et al *(17)* who indicated that (sufficient) free seats increase transit use. Besides the transport system's specific factors, various personal traits and attitudes of travelers significantly influence mode choice. Age, gender, car ownership and income are often reported as influential factors for transit ridership (see e.g. *18-20*). Besides, it has been cited that personal attitudes influence the mode choice decision process (see e.g. *21, 22*). These studies show that people with negative attitudes towards public transport and positive attitudes towards car use are less inclined to use public transit. Finally, Mattson et al *(14)* found that individuals with at least some transit experience are more likely to choose public transit and other alternative modes.

2.2 Key Determinants of Light Rail Ridership

After highlighting the key factors that influence modal choice in general, the driving characteristics for the specific case of light rail ridership are pinpointed in this section. The driving characteristics can basically be classified into 4 categories: system-specific, socio-economic, policy-related and regional characteristics. This paper focuses on the first and second category. Nonetheless, to make the implementation of the light rail system successful it is also required taking into account the other factors.

With respect to the system-specific attributes, one of the most important factors is the service level, measured as the frequency or the time span covered. In general, the higher the level of service, the higher the light rail ridership *(19, 23, 24, 25)*. Furthermore, travel costs have also been cited as one of the key drivers: Kain and Liu *(25)* reported that ticket costs are negatively related to light rail ridership. Next, speed also contributes to the ridership, where lower speed is related with higher ridership *(23, 26)*. This negative relation appears to be illogical, but can be explained by the fact dwell times increase as loadings rise. Accordingly, routes with high ridership tend to be slower. In addition, Kuby et al *(24)* found that high quality connections (short walking distances between modes, combined with coordinated and closely scheduled arrival and departure times) to other forms of public transport contribute to the success of the system. In addition, ticket integration (a single ticket for various transport modes) between different public transport modes is also cited a success factor *(19, 23, 26)*. With regard to the socio-economic characteristics, Mackett and Babalik-Sutcliffe *(19)* illustrated that high car ownership as well as high incomes reduce light rail ridership. Concerning policy-related attributes, Mackett and Babalik-Sutcliffe *(19)* showed that offering (temporally) free travel for target groups increases ridership. Furthermore, they indicated that marketing campaigns enlarge the travelers' knowledge of the light rail system, which in its turn augments ridership levels. Finally with regard to regional characteristics, a number of studies emphasize the importance of land use features (see e.g. *19*, *23*, *24*, *25*). Areas with high employment, retail and residential densities generate more trips than regions with low densities. Moreover, light rail systems are more likely to be successful when they serve areas with economic growth. In its turn, the development of a light rail system contributes to the economic and urban development of the region, as it generates attractive locations for retail settlements *(19)*.

3 DATA

A stated preference (SP) survey was conducted to identify the determinants of light rail mode choice for medium/long distance trips for a new light rail system in Flanders (the northern part of Belgium). In 2010, the region had a population of around 6.2 million inhabitants. Flemish residents make 2.9 trips a day on average, the majority of the trips (66.8%) are carried out by car. Slow modes account for 26.4% of the trips while public transport has a share of 5.3% *(27)*.

In stated preference approaches, respondents have to indicate their preferences among a set of alternatives for different hypothetical situations *(28-30)*. SP-surveys are common in the field of travel behavior research and have been extensively applied to the analysis of modal choices *(28)*. Stated preference approaches allow researchers to identify behavioral responses towards new transport options and inexperienced travel conditions, which are not (yet) revealed on the market *(30)*. However, there is one major drawback of stated preference data. The data only describe what an individual claims he would do in a given scenario, which does not always correspond to the actual or revealed behavior *(28, 30)*. One reason for this mismatch is the fact that respondents might give socially-desirable answers. Despite this disadvantage, the use of stated preference approaches has already proven to be successful to capture individual preferences under new choice situations. Louviere et al (*31*) showed that stated behavior is a good approximation of actual (revealed) behavior when controlling for socially desirable answers. In the current research, social desirable answers are mitigated by using the frequency of public transit use and the attitudes towards the various transport modes as controls for inherent preferences.

The SP-survey was conducted on a person based level from early December 2010 to late January 2011 and was filled out by random individuals over 18 years of age. The majority of the questionnaires were distributed over the internet. Nonetheless, similar traditional paper-and-pencil questionnaires were handed out to counteract the sample bias that would arise when only web-based data would have been collected *(32, 33)*. In total, the survey collected valuable information of 492 respondents.

The stated preference questionnaire consisted of three parts in which the respondents had to indicate their preference on respectively (i) car use versus light rail transit, (ii) bus transit versus light rail transit and (iii) train transit versus light rail transit. Each part contained eight hypothetical situations with varying trip characteristics. These trip characteristics included total travel time, access/egress time, waiting time, travel cost, transfers and availability of empty seats, where access/egress time is defined as the necessary time to travel to and from the station. Unlike the trip characteristics, trip distance and trip motive remained constant across the hypothetical situations. Trip distance was fixed at 30km as the goal of light rail transit is to provide transport at regional level. Trip purpose was set as the most frequently performed purpose indicated by the respondent. This could be a work trip, a shopping trip as well as a leisure trip. In total, each respondent was confronted with 24 situations (3 x 8 situations). Figure 1 shows an example of such a hypothetical situation in the survey.

You live in the center of a small city called 'A'. You want to perform a work activity. For this, you need to travel to the center of a larger city called 'B'. Both towns are 30km apart.
Which alternative do you prefer, given following trip characteristics.

	Alternative 1 Bus	Alternative 2 Light rail
Total Travel Time	43min – 59min	25min – 35min
Egress Time **Waiting Time**	5 min 6 min	5 min 5 min
Cost **Transfers** **Seats**	2 EUR No Free Seats	5 EUR Yes No Free Seats

O Bus O Light rail

FIGURE 1 Example of alternatives in a hypothetical situation.

For each hypothetical situation, the respondents had to choose between exactly two alternatives. This was a conscious choice, as research had shown that augmenting the number of alternatives in the experiment, would enlarge the cognitive burden of the survey and the respondents would ignore some of the information *(34)*.

In addition to the stated preference questions, the survey queried some socio-economic variables in a personal questionnaire (e.g. age, gender, income, household size, number of children, owned vehicles). Next to the socio-economic variables, information about the frequency of using different transport modes was obtained. In addition, the attitudes towards various transport modes were surveyed as well as the importance which the respondents attach to respectively a fast, a convenient, an inexpensive, an environmentally friendly and a safe trip. Next to this information, the perceptions towards the different modes with regard to comfort, environment, safety and speed were queried. Also the respondents' expected values of travel time, waiting time, access/egress time, cost and number of transfers in a trip of 30km were surveyed and used as a basis for comparison of the values offered in the hypothetical situations. Finally, information was gathered about the importance that respondents attach to specific features of the station/stop locations such as lighting, guarded bike parks, dynamic information etc.

Table 1 gives an overview of the definitions and the corresponding measurements units of the variables that were collected in the survey. Due to the large number of variables, only the variables that are included in the final models (Tables 2 and 3 of the results section) are presented here.

TABLE 1 Overview of Variables collected in the Survey

Variable	Definition	Measurement Unit
	1) Transport system specific variables	
Cost	Total cost for the traveler when using LRT (incl. access and egress mode costs)	€
Access/Egress Time	The necessary time to travel to and from the LRT-station	Minutes
Seat availability	The availability of sufficient free seats on the LRT-vehicle.	Yes / No
Transfers	The need to make transfers during the trip	Yes / No
In Vehicle Travel Time	Total travel time on the LRT-vehicle	Minutes
Transit Punctuality	Variation in travel times (e.g. due to delays)	Minutes
Waiting Time	The total time spent waiting at the boarding station	Minutes
	2) Socio-economic variables	
Age	Years passed since birth	Years
Sex	Gender	Man / Woman
Number of cars	The number of cars in the household	Absolute values
Frequency of using Public Transport	Regularity of public transport use	Daily, weekly, monthly, several times a year, never.
	3) Attitudinal variables	
Attitude towards car	Feelings/mindset towards the car	7-point Likert scale (1= very positive, …, 7 =very negative)
Attitude towards train	Feelings/mindset towards the train	7-point Likert scale (1= very positive, …, 7 =very negative)
Attitude towards tram	Feelings/mindset towards the tram	7-point Likert scale (1= very positive, …, 7 =very negative)
Perception bus/tram/metro with regard to comfort	To what extent do people find a bus/tram/metro trip comfortable?	7-point Likert scale (1=very comfortable, …, 7= not comfortable at all)
Perception train with regard to cost	To what extent do people find a train trip inexpensive?	7-point Likert scale (1=very cheap, …, 7=not cheap at all)
Importance of fast travelling	How important is fast travelling to the traveler?	7-point Likert scale (1=very important, …, 7=not important at all)
Importance of inexpensive travelling	How important is inexpensive travelling to the traveler?	7-point Likert scale (1=very important, …, 7=not important at all)
Expected waiting time of a 30km trip (relative)	Expected waiting time of an imaginary 30km trip	Relative values (difference in expected waiting times between bus and LRT)

To attain an optimal correspondence between the survey sample composition and the Flemish population, the observations in the sample were weighted. These weights were calculated by matching the marginal distributions of the sample with the marginal distributions of the population, based on the key person-level attributes age, sex and marital status.

4 METHODOLOGY

As stated before, the main research objective of this paper is the assessment of the impact of various transport system specific factors such as travel cost, in-vehicle travel time, transfers, availability of empty seats, access/egress time, waiting time and transit punctuality, as well as the travelers' personal traits on the modal choice in the presence of light rail transit. In the previous section, it was expounded that each respondent had to indicate the preferred mode (a binary choice) for a number of hypothetical situations. This implies that multiple answers for a single respondent were recorded, and that correlation among these repeated observations cannot be disregarded. Therefore, a modeling approach is needed which takes into account correlated responses for binary data. The model adopted to fulfill this requirement is a GEE model for binary data with the logit link function. The mean response is modeled as a logistic regression model, which is defined as follows *(7)*:

$$\log\left(\frac{\pi_i^*}{1-\pi_i^*}\right) = \theta^* + X_i^{'}\beta^*, \qquad (1)$$

where $\frac{\pi_i^*}{1-\pi_i^*}$ denotes the odds, θ^* the intercept, the vector of model parameters to be estimated and a vector of explanatory variables.

The above equation can be rewritten to the well-known likelihood function of a binary logit model:

$$\pi_i^* = \frac{\exp(\theta^* + X_i^{'}\beta^*)}{1+\exp(\theta^* + X_i^{'}\beta^*)} \qquad (2)$$

Equation 1 shows that the estimated parameters have to be interpreted as the change in the predicted logged odds for a one unit change in the corresponding explanatory variable. An odds can be defined as the probability of an event divided by the probability of no event. In this paper, the probability of an event equals the likelihood to choose light rail transit. The most common way to interpret the parameter estimates is the interpretation according to the odds ratios (OR). An OR can be obtained by taking the exponent of the parameter estimate (e^{β}). If the OR is smaller (greater) than 1, than it represents a decrease (increase) in the odds of an event (i.e. choosing light rail or not). This implies that the probability decreases (increases) significantly for every unit raise in the corresponding explanatory variable. The parameter estimates can also be construed by looking at the sign of the parameter estimate. A positive (negative) sign implies an increase (decrease) in the likelihood of an event for every increase in the corresponding explanatory variable.

GEE models take into account the correlation between different observations of the same subject (i.e. repeated answers by the same respondent) by explicitly modeling the correlation structure of the repeated observations. Correlation structures specify how observations within a subject or cluster are correlated with each other. For binary data, the correlation between the jth and kth response is by definition *(18)*:

$$Corr(Y_{ij}, Y_{ik}) = \frac{\Pr(Y_{ij} = 1, Y_{ik} = 1) - \mu_{ij}\mu_{ik}}{\sqrt{\mu_{ij}(1-\mu_{ij})\mu_{ik}(1-\mu_{ik})}} \quad (3)$$

However, the above formula shows one important disadvantage. The correlation is constrained to be within limits that depend in a complicated way on the means of the data. In contrast, the odds ratio, which is defined as *(8)*:

$$OR(Y_{ij}, Y_{ik}) = \frac{\Pr(Y_{ij} = 1, Y_{ik} = 1)\Pr(Y_{ij} = 0, Y_{ik} = 0)}{\Pr(Y_{ij} = 1, Y_{ik} = 0)\Pr(Y_{ij} = 0, Y_{ik} = 1)} \quad (4)$$

is not constrained by the means and therefore preferred. The latter implementation of GEE is called alternating logistic regression (ALR). In general, ALR models the association between responses with log odds ratios instead of with correlations, as ordinary GEEs do *(8)*.

Three models were estimated in order to assess the impact of various transport system specific factors: the binary choice between car use and light rail transit (model 1), between bus transit and light rail transit (model 2) and between train transit and light rail transit (model 3). As transport system specific attributes may not suffice to fully explain mode choice, other variables (such as personal traits and attitudes) that may have an influence were added as control variables. When building the models, forward selection was used to find the most relevant variables in the model. Forward selection adds variables to the model one at a time. At each step, each variable that was not already in the model is tested for inclusion. The most significant variable is than added to the model, as long as its P-value remains below the significance level of 0.05. The final models were assessed for multicollinearity using tolerance and VIF-values, but no problems occurred. The results of the model estimations are presented in the next section.

5 RESULTS

5.1 Overall Results

The overall significance tests for the final models are displayed in Table 2. From this table, it can be concluded that, in all three models, almost all transport system specific factors significantly affect the choice of light rail transit (P-values are below 0.05). An exception is the punctuality of light rail transit, which appears not to be significant in any of the three models. Also the variable ‘transfers’ shows no significant effect when the choice between bus transit and light rail transit is modeled.

Next to the transport system specific variables of light rail transit, other factors that influence mode choice were taken into account in the models as well. From Table 2, it can be concluded that various socio-economic variables, attitudinal factors and perceptions as well as the frequency of using public transport (only model 1) significantly influence the preference for light rail transit. Sex and age are not always significant, but were kept in the final models to control for type I errors (also known as ‘false positives’) *(35)*. It was also found that the expected waiting time for light rail transit for a 30km-trip was significant when modeling the choice between bus transit and light rail transit. This expected waiting time is relative: it is the difference between the expected waiting time for bus and the expected waiting time for light rail. If the value is greater than zero, it means the waiting time of bus transit is larger than the waiting time for light rail transit for the same trip and vice versa.

TABLE 2 Results of the Overall Significance Type III-Test of the Travel Mode Choice Model

Parameter	DF	Car vs. light rail			Bus vs. light rail			Train vs. light rail		
		Chi²	P-value	Sign.	Chi²	P-value	Sign.	Chi²	P-value	Sign.
1) Transport system specific variables										
Cost	1	120.04	<.0001	***	133.76	<.0001	***	90.42	<.0001	***
Access/Egress Time	1	31.90	<.0001	***	99.31	<.0001	***	5.57	0.0183	*
Seat availability	1	65.34	<.0001	***	66.46	<.0001	***	64.09	<.0001	***
Transfers	1	33.09	<.0001	***	1.96	0.1615	NS	27.37	<.0001	***
In Vehicle Travel Time	1	76.47	<.0001	***	140.69	<.0001	***	17.36	<.0001	***
Transit Punctuality	1	2.29	0.1306	NS	3.04	0.0814	NS	0.25	0.6169	NS
Waiting Time	1	33.64	<.0001	***	44.93	<.0001	***	13.45	0.0002	***
2) Socio-economic variables										
Age	1	2.63	0.1047	NS	2.85	0.0915	NS	1.46	0.2276	NS
Sex	1	0.07	0.7871	NS	6.70	0.0096	**	4.50	0.0340	*
Frequency of using Public Transport	4	13.42	0.0094	**	/	/	/	/	/	/
Number of cars	1	3.86	0.0496	*	/	/	/	/	/	/
3) Attitudinal variables										
Attitude towards car	1	38.85	<.0001	***	/	/	/	/	/	/
Attitude towards tram	1	9.83	0.0017	**	5.28	0.0216	*	/	/	/
Attitude towards train	1	/	/	/	/	/	/	3.64	0.0565	*
Importance of inexpensive travelling	1	/	/	/	12.46	0.0004	***	/	/	/
Importance of fast travelling	1	/	/	/	4.08	0.0433	*	/	/	/
Perception train with regard to Cost	1	/	/	/	/	/	/	9.39	0.0022	**
Perception bus/tram/metro with regard to comfort	1	6.94	0.0084	**	/	/	/	5.23	0.0222	*
Expected waiting time of a 30km trip (relative)	1	/	/	/	5.10	0.0240	*	/	/	/

* P-value <.05, ** P-value < .01, *** P-value < 0.001, NS = not significant

5.2 Parameter Estimates

The parameter estimates for the binary mode choice models are shown in Table 3. As already stated in Section 4, the most common way to interpret these parameter estimates is the interpretation according to the odds ratios (OR). The OR of travel cost in the car vs. light rail model equals = 0.635845. This represents a decrease in the odds for light rail use with 36% for every €1 increase in ticket price. This implies that the probability of choosing the light rail option decreases significantly for every raise in ticket price and that people will be more likely to take the car. Similar conclusions can be drawn for the remaining two models. When ticket prices rise, people are less likely to choose the light rail option and are more likely to choose the bus/train alternative. Next, the OR for the variable access/egress time shows that a one minute increase in access/egress time will decrease the odds for light rail with 7.5% , 16% and 6% for the car-, bus- and train model respectively. Thus, every increase in light rail's access/egress time significantly lowers the likelihood to use light rail. Similar conclusions can be drawn for light rail's in-vehicle travel time and waiting time. It can be derived from the OR that an increase in these time components leads to a significantly lower probability of light rail use. Moreover, when light rail vehicles have sufficient empty seats available, people's probability to opt for light rail increases in all three models. The odds of using light rail when seats are available are 1.7, 2.4 and 5.2 times the odds when no seats are available for the car, bus and train model respectively. The opposite holds for the variable 'transfers'. An interpretation of the OR shows that the likelihood to use light rail decreases significantly when one has to make transfers. This is not the case in the bus versus light rail model, where the reverse is true. However, as mentioned above, this effect is not significant.

TABLE 3 Parameter Estimates for the Binary Travel Mode Choice Model

Parameter	**Model 1: Car (0) vs. light rail (1)**			**Model 2: Bus (0) vs. light rail (1)**			**Model 3: Train (0) vs. light rail (1)**		
	Estimate	S.E.	OR	Estimate	S.E.	OR	Estimate	S.E.	OR
Intercept	3.6237	0.6729	/	5.6812	0.4734	/	4.6443	0.5884	/
1) Transport system specific variables									
Cost	-0.4528	0.0336	0.63582	-0.3784	0.0274	0.68502	-0.3545	0.0409	0.70152
Access / Egress Time	-0.0776	0.0131	0.92532	-0.1721	0.0152	0.84192	-0.0620	0.0220	0.93992
Free Seats									
Yes	0.5316	0.0526	1.70171	0.8812	0.0933	2.41381	1.6582	0.1623	5.24991
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Transfers									
Yes	-0.3137	0.0468	0.73072	0.1110[1]	0.0790	1.11741	-0.5463	0.1275	0.57912
No	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
In Vehicle Travel Time	-0.0567	0.0059	0.94492	-0.0851	0.0058	0.91842	-0.0693	0.0065	0.93302
Transit Punctuality	-0.0551[1]	0.0362	0.94642	-0.0589[1]	0.0332	0.94282	-0.0281[1]	0.0550	0.97232
Waiting Time	-0.0816	0.0143	0.92162	-0.1056	0.0143	0.89982	-0.0663	0.0150	0.93592
2) Socio-economic variables									
Age	-0.0086[1]	0.0053	0.99142	-0.0074[1]	0.0043	0.99262	-0.0057[1]	0.0048	0.99432
Sex									
Man	-0.0241[1]	0.0897	0.97622	0.3837	0.1457	1.46771	0.3660	0.1712	1.44201
Woman	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Frequency of using Public Transport									
Daily	1.3893	0.3907	4.01201	/	/	/	/	/	/
Weekly	0.6559[1]	0.3402	1.92691	/	/	/	/	/	/
Monthly	0.4820[1]	0.3466	1.61931	/	/	/	/	/	/
Several times a year	0.3888[1]	0.2941	1.47521	/	/	/	/	/	/
Never	Ref.	Ref.	Ref.	/	/	/	/	/	/
Number of cars	-0.2537	0.1279	0.77592	/	/	/	/	/	/
3) Attitudinal variables									
Attitude towards car	0.5872	0.0817	1.79891	/	/	/	/	/	/
Attitude towards tram	-0.2305	0.0743	0.79412	-0.1344	0.0580	0.87422	/	/	/
Attitude towards train	/	/	/	/	/	/	0.1258	0.0671	1.13411
Perception bus-tram-metro with regard to comfort	-0.1731	0.0649	0.84111	/	/	/	-0.1560	0.0660	0.85562
Perception train with regard to cost	/	/	/	/	/	/	0.1799	0.0578	1.19711
Importance of inexpensive travelling	/	/	/	0.2545	0.0721	1.28981	/	/	/
Importance of fast travelling	/	/	/	-0.1583	0.0746	0.85362	/	/	/
Expected waiting time of a 30km trip (relative)	/	/	/	0.0301	0.0129	1.03061	/	/	/

[1] Not significant at the 0.05 level

Next to the transport system specific factors, a number of attitudinal factors and perceptions contributed significantly to the choice of light rail transit. It can be derived from the OR that a positive attitude towards the car (model 1) will decrease the likelihood to use light rail and will increase the probability of car use. Similar conclusions can be drawn for the attitude towards train (model 3), whereas the opposite is true for the attitude towards tram (model 1 and model 2). A positive attitude towards tram will enhance the likelihood to use light rail. Moreover, people who believe travelling with bus/tram/metro is not comfortable (model 1 and model 3), are less likely to travel by light rail. People who believe train is expensive (model 3) are more likely to use light rail, while people who attach great importance to inexpensive travelling (model 2) are more likely to take the bus and are less inclined to use light rail. People who attach great importance to fast travel (model 2) have higher probabilities to use light rail.

Concerning the socio-economic factors, it appears that men are more inclined to use light rail than women (model 2 and 3) and that a high number of cars in the household (model 1) will lower the probability to use light rail. Finally, it appears that current frequent public transport users (model 1) are more inclined to choose light rail and have a lower probability to choose the car.

6 DISCUSSION

In the previous section, it was shown that the relationship between transit punctuality and mode choice was not significant at the 0.05 level. This was a rather surprising effect since the majority of studies in literature indicated the opposite. The insignificance of transit punctuality in the current study can be accounted for the fact that the deviations of the travel times in the survey were defined relatively small (3 – 5 minutes) in comparison to the overall travel time of the 30km trips. The effect of larger deviations on light rail mode choice is not explored in this paper. Thus the conclusion is confined to the fact that small deviations in travel times have no significant influence on light rail mode choice for medium/long distance trips.

In contrast to transit punctuality, the results of the other transport system's specific factors (i.e. travel cost, in-vehicle travel time, waiting time, access/egress time, transfers, and availability of empty seats) are in line with literature: these factors all affect mode choice significantly in the way one would expect. Only the variable 'transfers' shows no significant effect when the choice between bus transit and light rail transit is modeled. A possible reason is that people might implicitly assume that if a transfer for light rail is required, they also have to make one for using the bus, negating the overall effect of transfers. Moreover, it can be derived from Table 2 that travelers are strongly influenced by the cost of light rail (large Chi²-values, same degrees of freedom). Travel cost turns out to be the most important factor when modeling the choices between car use and light rail transit and between train transit and light rail transit. From the Chi²-values of the time components, it can be inferred that people are mostly influenced by in-vehicle travel time, and to a lesser extent by waiting and access/egress time (although still highly significant). Furthermore, it appears that travelers pay more attention to the availability of empty seats than to transfers (larger Chi²-values, same degrees of freedom). The latter findings can be explained by the fact that the corresponding in-vehicle travel time is relatively large compared to the total travel time, and by the fact that for medium/long distance trips a lack of empty seats is perceived as very unfavorable.

Besides the transport system specific factors, various personal traits of the travelers proved to contribute significantly to the choice for light rail transit. This again is in accordance with general literature concerning transit mode choice. Literature demonstrated that, next to age, gender and car ownership, income is also one of the main determinants of public transit mode choice. Notwithstanding, income was not included in the final models presented in this paper. After all, income and number of cars are closely correlated, implying that higher incomes make owning a car more feasible. As a result, the income effect is indirectly included in the models by means of the variable 'number of cars'.

In addition, the findings with regard to attitudes are also confirmed by literature. It could be derived from Table 3 that a positive attitude towards the car (model 1) will decrease the likelihood to use light rail, whereas a positive attitude towards tram (model 1 and model 2) will enhance the likelihood to use light rail. This can be explained by the fact that a tram is also a public transport mode which might be seen as a good approximation of light rail.

Moreover, the results indicated that persons who attach great importance to fast traveling are more inclined to use light rail transit instead of bus service. This is confirmed by Scherer *(36)*, who found that travelers are more attracted to light rail transit than to bus transit, even if both services offer the same level of service. Scherer explains this difference in ridership by suggesting that light rail transit is considered as faster than bus services, because of its own right-of-way. In addition, the results indicated that travelers who regard train as expensive (model 3) are more likely to use light rail, while travelers who attach great importance to inexpensive travelling (model 2) are more likely to take the bus and are less inclined to use light rail. These results may indicate that people see light rail as an expensive but fast public transportation mode.

7 POLICY RECOMMENDATIONS

The findings in this paper provide insight in the success factors of a (new) light rail system for medium/long distance trips and can be used by policy makers as an important frame of reference to make light rail more successful. Travel cost and in-vehicle travel time were identified as the most decisive factors for travelers in their choice of using light rail.

Assuming that policy makers will primarily aim at shifting car users to light rail transit for trips of a moderate length (10-40km) and with (sub)urban destinations, the findings of this research suggest that their flanking measures when introducing the light rail network should be oriented at the cost-effectiveness and congestion-immunity of this travel mode. Travelers can be convinced to exchange their cars for a light rail train by drawing their attention to the fairly low travel cost per kilometer when compared to the real cost of car driving (including fixed costs such as insurance and depreciation). To this end, (temporarily) subsidizing light rail trips for particular target groups (e.g. commuters, large families, low incomes, etc.) can be a good measure to increase the chances of a successful introduction of a light rail system *(19)*. The regional authorities can play a major part in this respect by supporting the novice travel mode by intensive promotional campaigns and by stimulating (destination) cities to participate in a system of third party payers *(37)*. In addition to the policy measures above, it may be appropriate to accompany the introduction of a light rail network with a car restraint policy to elevate the success of the introduction even further *(19)*. Road pricing and higher road taxes may be part of such a policy. After all, the bundling of road pricing with improved (public) transportation alternatives increases the acceptability and consequently the effectiveness of road pricing *(38)*.

Constraining the in-vehicle travel time is also important to policy makers in making light rail transit more successive. In addition to its insensitivity to road congestion, limiting the number of stops to the absolute minimum and careful consideration of stop-locations can make important contributions hereto. In addition, reducing the dwell time at stops by eliminating onboard ticket sales by the driver can significantly lower the total run time *(39)*. Onboard ticket vending machines and vending machines at stations can be good alternatives as well as ticket sales by new technologies such as SMS (Short Message Service), RFID (Radio Frequency Identification) and electronic cash systems.

8 CONCLUSIONS AND FURTHER RESEARCH

This study investigated the impact of various transport system related factors as well as socio-demographic variables on the use of light rail transit for medium/long distance trips in Flanders, Belgium. Results from an alternating logistic regression model confirm that most of these factors significantly influence the use of light rail. Moreover, it was found that these results are in line with international literature. Hence, the key variables for light rail mode choice appear to be stable across very different contexts implying that best-practice examples might be applicable across different geographical contexts.

The research findings can be used by policy makers as an important frame of reference to make the implementation of light rail transit more successful. Moreover, the results of the paper indicate there would be a shift towards light rail, but it is not sure if it can be characterized as major, unless the additional policies that were brought up in the policy recommendation section are also implemented. However, the effects of these measures are not analyzed in the paper, but make up a key challenge for further research. Furthermore, one can also expect important changes in land use and urban development around the stations. Hence, it can be intriguing to develop a model that integrates travel impacts with these land use and urban developments.

REFERENCES

1. Steg, L. Can Public Transport compete with the Private Car? *IATSS Res*, Vol. 27, 2003, pp 27-35.

2. De Lijn. *Regionet Limburg. Regionaal Openbaar Vervoer in de Provincie Limburg. Conceptstreefbeeld.* Vervoersmaatschappij De Lijn, Mechelen, Belgium, 2002.

3. Varinia. *Ontwerpstreefbeeld Spartacus Sneltramlijn 1.* Vervoersmaatschappij De Lijn, Hasselt, Belgium, 2008.

4. Billings, S.B. Estimating the Value of a New Transit Option. *Regional Science and Urban Economics*, In press. doi: 10.1016/j.regsciurbeco.2011.03.013.

5. Senior, M.L. Impacts on Travel Behaviour of Greater Manchester’s Light Rail Investment (Metrolink Phase 1): Evidence from Household Surveys and Census Data. *Journal of Transport Geography*, Vol. 17, 2009, pp. 187-197.

6. Mackett, R.L., and M. Edwards. The Impact of New Urban Public Transport systems: Will the Expectations Be Met? *Transportation Research part A*, Vol. 32, No. 4, 1998, pp. 231-245.

7. Allison, P.D. *Logistic regression using SAS: Theory and application.* Cary, NC: SAS Institute Inc, USA, 2001.

8. SAS Institute Inc. *SAS/STAT 9.1.3 User's Guide.* Cary, NC: SAS Institute Inc, USA, 2008.

9. Schramm, L.R., K. Watkins, and S. Rutherford. Features that Affect Variability of Travel Time on Bus Rapid Transit Systems. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2143, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 77-84.

10. Van Loon, R., P. Rietveld, and M. Brons. Travel-time Reliability Impacts on Railway Passenger Demand: a Revealed Preference Analysis. *Journal of Transport Geography*, Vol. 19, 2011, pp. 917-925.

11. Zhang, J., A. Fujiwara, and S. Thein. Capturing Travelers' Stated Mode Choice Preferences Under Influence of Income in Yangon City, Myanmar. *Journal of Transportation Systems Engineering and Information Technology,* Vol. 8, No. 4, 2008, pp. 49-62.

12. Outwater, M.L., G. Spitz, J. Lobb, M. Campbell, B. Sana, R. Pendyala, and W. Woodford. Characteristics of Premium Transit Services that Affect Mode Choice. *Transportation,* Vol. 38, No. 4, 2011, pp. 605-623.

13. Ahern, A.A., and N. Tapley. The Use of Stated Preference Techniques to Model Modal Choices on Interurban Trips in Ireland. *Transportation Research Part A*, Vol. 42, 2008, pp. 15-27.

14. Mattson, J., D. Peterson, D. Ripplinger, W. Thoms, and J. Hough. An Assessment of Demand for Rural Intercity Transportation Services in a Changing Environment. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2145, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 108-114.

15. Hensher, D.A., and J.M. Rose. Development of Commuter and Non-Commuter Mode Choice Models for the Assessment of New Public Transport Infrastructure Projects: A Case Study. *Transportation Research Part A*, Vol. 41, No. 5, 2007, pp. 428-443.

16. Ben-Akiva, M., and T. Morikawa. Comparing Ridership Attraction of Rail and Bus. *Transport Policy*, Vol. 2, 2002, pp. 107-116.

17. Bierlaire, M., K.W. Axhausen, and G. Abay. The Acceptance of Modal Innovation: the Case of Swissmetro. *Presented at the 1st Swiss Transport Research Conference.* Monte Verità/Ascona, 2001.

18. Chatterjee, K., Modelling the dynamics of Bus Use in a Changing Travel Environment Using Panel Data. *Transportation,* Vol. 38, No. 3, 2011, pp. 487-509.

19. Mackett, R., and E. Babalik-Sutcliffe. New Urban Rail Systems: a Policy Based Technique to Make them More Successful. *Journal of Transport Geography*, Vol. 11, No. 2, 2003, pp. 151-164.

20. Popuri, U., K. Proussaloglou, C. Ayvalik, F. Koppelman, and A. Lee. Importance of Traveler Attitudes in the Choice of Public Transportation to Work: Findings from the Regional Transportation Authority Attitudinal Survey. *Transportation,* Vol. 38, No. 4, 2011, pp. 643-661.

21. Murray, S.J., D. Walton, and J.A. Thomas. Attitudes towards Public Transport in New Zealand. *Transportation*, Vol. 37, No. 6, 2010, pp. 915-929.

22. Domarchi, C., A. Tudela, and A. González. Effect of Attitudes, Habit and Affective Appraisal on Mode Choice: an Application to University Workers. *Transportation*, Vol. 35, No. 5, 2008, pp. 585-599.

23. Currie, G., A. Ahern, and A. Delbosc. Exploring the Drivers of Light Rail Ridership: an Empirical Route Level Analysis of Selected Australian, North American and European Systems. *Transportation*, Vol. 38, No. 3, 2011, pp. 545-560.

24. Kuby, M., A. Barranda, and C. Upchurch. Factors influencing light-rail station boardings in the United States. *Transportation Research Part A*, Vol. 38, 2004, pp. 223-247.

25. Kain, J., and Z. Liu. Secrets of Success: the Large Increases in Transit Ridership achieved by Houston and San Diego Transit Providers. *Transportation Research Part A*, Vol. 33, 1999, pp. 601–624.

26. Hass-Klau, C., and G. Crampton. Future of urban Transport: Learning from Success and Weakness: Light Rail. *Environment and Transport Planning*, Brighton (UK), 2002.

27. Cools, M., K. Declercq, D. Janssens, and G. Wets. Onderzoek Verplaatsingsgedrag Vlaanderen 4.2 (2009-2010): Tabellenrapport (Travel Behavior Research Flanders 4.2 (2009-2010): Table report). Hasselt University, Diepenbeek, Belgium, 2010.

28. Hensher, D.A. Stated Preference Analysis of Travel Choices: the State of Practice. *Transportation*, Vol. 21, No. 2, 1994, pp. 107-133.

29. Faivre D'Arcier, B., O. Andan, and C. Raux. Stated Adaptation Surveys and Choice Process: Some Methodological Issues. *Transportation*, Vol. 25, No. 2, 1998, pp. 169-185.

30. Wardman, M. A Comparison of Revealed Preference and Stated Preference Models of Travel Behaviour. *Journal of Transport Economics and Policy,* Vol. 22, No. 1, 1998, pp. 71-91.

31. Louviere, J.J., D.A. Hensher, and J.D. Swait. *Stated Choice Methods: Analysis and Application*, Cambridge University Press, New York, 2000.

32. Couper, M.P., A. Kapteyn, M. Schonlau, and J. Winter. Noncoverage and Nonresponse in an Internet Survey. *Social Science Research,* Vol. 36, No. 1, 2007, pp. 131-148.

33. Hayslett, M.M., and B.M. Wildemuth. Pixels or Pencils? The Relative Effectiveness of Web-Based Versus Paper Surveys. *Library and Information Science Research*, Vol. 26, No. 1, 2004, pp. 73-93.

34. Hensher, D.A. How Do Respondents Process Stated Choice Experiments? Attribute Consideration Under Varying Information Load. *Journal of Applied Econometrics,* Vol. 21, 2006, pp. 861-878.

35. Frank, K.A. Impact of a Confounding Variable on a Regression Coefficient. *Sociological Methods Research*, Vol. 29, No. 2, 2000, pp. 147-194

36. Scherer, M. Is Light Rail More Attractive to Users Than Bus Transit? Arguments Based on Cognition and Rational Choice. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2144, Transportation Research Board of the National Academies, Washington, D.C., 2010, pp. 11-19.

37. De Witte, A., C. Macharis, P. Lannoy, C. Polain, T. Steenberghen, and S. Van de Walle. The Impact of “Free” Public Transport: The case of Brussels. *Transportation Research Part A,* Vol. 40, No. 8, 2006, pp. 671-689.

38. Cools, M., K. Brijs, H. Tormans, E. Moons, D. Janssens, and G. Wets. The Socio-Cognitive Links Between Road Pricing Acceptability and Changes in Travel-Behavior. *Transportation Research Part A*, Vol. 45, No. 8, 2011, pp. 779-788.

39. Dorbritz, R., M. Lüthi, U. Weidmann, and A. Nash. Effects of Onboard Ticket Sales on Public Transport Reliability. *Transportation Research Record: Journal of the Transportation Research Board*, No. 2110, Transportation Research Board of the National Academies, Washington, D.C., 2009, pp. 112-119.