

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

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45

**1 ABSTRACT**

2  
3 The introduction of new public transport systems can influence society in a multitude of ways,  
4 ranging from modal choices and the environment to economic growth. This paper examines the  
5 determinants of light rail mode choice for medium/long distance trips (10-40km) for a new light  
6 rail system in Flanders, Belgium. To investigate these choices, the effects of various transport  
7 system specific factors (i.e. travel cost, in-vehicle travel time, transit punctuality, waiting time,  
8 access/egress time, transfers, and the availability of empty seats) as well as the travelers'  
9 personal traits, are analyzed using an alternating logistic regression model, which explicitly takes  
10 into account the correlated responses for binary data. The data used for the analysis stem from a  
11 stated preference survey which was conducted in Flanders, Belgium. The modeling results yield  
12 findings that are in line with literature: most transport system specific factors as well as socio-  
13 economic variables, attitudinal factors, perceptions and the frequency of using public transport  
14 contribute significantly to the preference of light rail transit. In particular, it is shown that the use  
15 of light rail is strongly influenced by travel cost and in-vehicle travel time and to a lesser extent  
16 by waiting and access/egress time. It also appeared that seat availability plays a more important  
17 role than transfers in the decision process to choose light rail transit. The findings of this paper  
18 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 where 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,

1 routes with high ridership tend to be slower. In addition, Kuby et al (24) found that high quality  
2 connections (short walking distances between modes, combined with coordinated and closely  
3 scheduled arrival and departure times) to other forms of public transport contribute to the  
4 success of the system. In addition, ticket integration (a single ticket for various transport modes)  
5 between different public transport modes is also cited a success factor (19, 23, 26). With regard  
6 to the socio-economic characteristics, Mackett and Babalik-Sutcliffe (19) illustrated that high car  
7 ownership as well as high incomes reduce light rail ridership. Concerning policy-related  
8 attributes, Mackett and Babalik-Sutcliffe (19) showed that offering (temporally) free travel for  
9 target groups increases ridership. Furthermore, they indicated that marketing campaigns enlarge  
10 the travelers' knowledge of the light rail system, which in its turn augments ridership levels.  
11 Finally with regard to regional characteristics, a number of studies emphasize the importance of  
12 land use features (see e.g. 19, 23, 24, 25). Areas with high employment, retail and residential  
13 densities generate more trips than regions with low densities. Moreover, light rail systems are  
14 more likely to be successful when they serve areas with economic growth. In its turn, the  
15 development of a light rail system contributes to the economic and urban development of the  
16 region, as it generates attractive locations for retail settlements (19).

### 17 18 **3 DATA**

19  
20 A stated preference (SP) survey was conducted to identify the determinants of light rail mode  
21 choice for medium/long distance trips for a new light rail system in Flanders (the northern part  
22 of Belgium). In 2010, the region had a population of around 6.2 million inhabitants. Flemish  
23 residents make 2.9 trips a day on average, the majority of the trips (66.8%) are carried out by  
24 car. Slow modes account for 26.4% of the trips while public transport has a share of 5.3% (27).

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

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

1 The stated preference questionnaire consisted of three parts in which the respondents had  
 2 to indicate their preference on respectively (i) car use versus light rail transit, (ii) bus transit  
 3 versus light rail transit and (iii) train transit versus light rail transit. Each part contained eight  
 4 hypothetical situations with varying trip characteristics. These trip characteristics included total  
 5 travel time, access/egress time, waiting time, travel cost, transfers and availability of empty  
 6 seats, where access/egress time is defined as the necessary time to travel to and from the station.  
 7 Unlike the trip characteristics, trip distance and trip motive remained constant across the  
 8 hypothetical situations. Trip distance was fixed at 30km as the goal of light rail transit is to  
 9 provide transport at regional level. Trip purpose was set as the most frequently performed  
 10 purpose indicated by the respondent. This could be a work trip, a shopping trip as well as a  
 11 leisure trip. In total, each respondent was confronted with 24 situations (3 x 8 situations). Figure  
 12 1 shows an example of such a hypothetical situation in the survey.  
 13

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.

|                          | <u>Alternative 1</u><br>Bus | <u>Alternative 2</u><br>Light rail |
|--------------------------|-----------------------------|------------------------------------|
| <b>Total Travel Time</b> | 43min – 59min               | 25min – 35min                      |
| <b>Egress Time</b>       | 5 min                       | 5 min                              |
| <b>Waiting Time</b>      | 6 min                       | 5 min                              |
| <b>Cost</b>              | 2 EUR                       | 5 EUR                              |
| <b>Transfers</b>         | No                          | Yes                                |
| <b>Seats</b>             | Free Seats                  | No Free Seats                      |

Bus                       Light rail

14  
 15 **FIGURE 1 Example of alternatives in a hypothetical situation.**  
 16

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

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

1 Table 1 gives an overview of the definitions and the corresponding measurements units  
 2 of the variables that were collected in the survey. Due to the large number of variables, only the  
 3 variables that are included in the final models (Tables 2 and 3 of the results section) are  
 4 presented here.  
 5

6 **TABLE 1 Overview of Variables collected in the Survey**

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

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

#### 6 4 METHODOLOGY

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

$$20 \quad \log\left(\frac{\pi_i^*}{1-\pi_i^*}\right) = \theta^* + X_i'\beta^*, \quad (1)$$

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

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

$$26 \quad \pi_i^* = \frac{\exp(\theta^* + X_i'\beta^*)}{1 + \exp(\theta^* + X_i'\beta^*)} \quad (2)$$

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

40 GEE models take into account the correlation between different observations of the same  
 41 subject (i.e. repeated answers by the same respondent) by explicitly modeling the correlation

1 structure of the repeated observations. Correlation structures specify how observations within a  
 2 subject or cluster are correlated with each other. For binary data, the correlation between the  $j^{\text{th}}$   
 3 and  $k^{\text{th}}$  response is by definition (18):

$$4 \quad \text{Corr}(Y_{ij}, Y_{ik}) = \frac{\Pr(Y_{ij} = 1, Y_{ik} = 1) - \mu_{ij}\mu_{ik}}{\sqrt{\mu_{ij}(1 - \mu_{ij})\mu_{ik}(1 - \mu_{ik})}} \quad (3)$$

6  
 7 However, the above formula shows one important disadvantage. The correlation is constrained  
 8 to be within limits that depend in a complicated way on the means of the data. In contrast, the  
 9 odds ratio, which is defined as (8):

$$10 \quad \text{OR}(Y_{ij}, Y_{ik}) = \frac{\Pr(Y_{ij} = 1, Y_{ik} = 1)\Pr(Y_{ij} = 0, Y_{ik} = 0)}{\Pr(Y_{ij} = 1, Y_{ik} = 0)\Pr(Y_{ij} = 0, Y_{ik} = 1)} \quad (4)$$

12  
 13 is not constrained by the means and therefore preferred. The latter implementation of GEE is  
 14 called alternating logistic regression (ALR). In general, ALR models the association between  
 15 responses with log odds ratios instead of with correlations, as ordinary GEEs do (8).

16 Three models were estimated in order to assess the impact of various transport system  
 17 specific factors: the binary choice between car use and light rail transit (model 1), between bus  
 18 transit and light rail transit (model 2) and between train transit and light rail transit (model 3). As  
 19 transport system specific attributes may not suffice to fully explain mode choice, other variables  
 20 (such as personal traits and attitudes) that may have an influence were added as control  
 21 variables. When building the models, forward selection was used to find the most relevant  
 22 variables in the model. Forward selection adds variables to the model one at a time. At each step,  
 23 each variable that was not already in the model is tested for inclusion. The most significant  
 24 variable is then added to the model, as long as its P-value remains below the significance level of  
 25 0.05. The final models were assessed for multicollinearity using tolerance and VIF-values, but  
 26 no problems occurred. The results of the model estimations are presented in the next section.

## 27 28 **5 RESULTS**

### 29 30 **5.1 Overall Results**

31  
 32 The overall significance tests for the final models are displayed in Table 2. From this table, it  
 33 can be concluded that, in all three models, almost all transport system specific factors  
 34 significantly affect the choice of light rail transit (P-values are below 0.05). An exception is the  
 35 punctuality of light rail transit, which appears not to be significant in any of the three models.  
 36 Also the variable ‘transfers’ shows no significant effect when the choice between bus transit and  
 37 light rail transit is modeled.

38 Next to the transport system specific variables of light rail transit, other factors that  
 39 influence mode choice were taken into account in the models as well. From Table 2, it can be  
 40 concluded that various socio-economic variables, attitudinal factors and perceptions as well as  
 41 the frequency of using public transport (only model 1) significantly influence the preference for  
 42 light rail transit. Sex and age are not always significant, but were kept in the final models to  
 43 control for type I errors (also known as ‘false positives’) (35). It was also found that the expected

1 waiting time for light rail transit for a 30km-trip was significant when modeling the choice  
 2 between bus transit and light rail transit. This expected waiting time is relative: it is the  
 3 difference between the expected waiting time for bus and the expected waiting time for light rail.  
 4 If the value is greater than zero, it means the waiting time of bus transit is larger than the waiting  
 5 time for light rail transit for the same trip and vice versa.

7 **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 |         |       |
|--|----|--------------------|---------|-------|--------------------|---------|-------|----------------------|---------|-------|
|  |    | Chi <sup>2</sup>   | P-value | Sign. | Chi <sup>2</sup>   | P-value | Sign. | Chi <sup>2</sup>     | P-value | Sign. |
| <b>1) Transport system specific variables</b>    |    |                    |         |       |                    |         |       |                      |         |       |
| 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  | ***   |
| <b>2) Socio-economic variables</b>               |    |                    |         |       |                    |         |       |                      |         |       |
| 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  | *     | /                  | /       | /     | /                    | /       | /     |
| <b>3) Attitudinal variables</b>                  |    |                    |         |       |                    |         |       |                      |         |       |
| 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  | *     | /                    | /       | /     |

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

## 9 5.2 Parameter Estimates

12 The parameter estimates for the binary mode choice models are shown in Table 3. As already  
 13 stated in Section 4, the most common way to interpret these parameter estimates is the  
 14 interpretation according to the odds ratios (OR). The OR of travel cost in the car vs. light rail  
 15 model equals = 0.635845. This represents a decrease in the odds for light rail use with 36% for  
 16 every €1 increase in ticket price. This implies that the probability of choosing the light rail  
 17 option decreases significantly for every raise in ticket price and that people will be more likely to  
 18 take the car. Similar conclusions can be drawn for the remaining two models. When ticket prices  
 19 rise, people are less likely to choose the light rail option and are more likely to choose the  
 20 bus/train alternative. Next, the OR for the variable access/egress time shows that a one minute  
 21 increase in access/egress time will decrease the odds for light rail with 7.5% , 16% and 6% for  
 22 the car-, bus- and train model respectively. Thus, every increase in light rail's access/egress time  
 23 significantly lowers the likelihood to use light rail. Similar conclusions can be drawn for light  
 24 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:<br>Car (0) vs. light rail (1) |        |         | Model 2:<br>Bus (0) vs. light rail (1) |        |         | Model 3:<br>Train (0) vs. light rail (1) |        |         |
|---|--|--------|---------|--|--------|---------|--|--------|---------|
|   | Estimate                               | S.E.   | OR      | Estimate                               | S.E.   | OR      | Estimate                                 | S.E.   | OR      |
| <b>Intercept</b>  | 3.6237                                 | 0.6729 | /       | 5.6812                                 | 0.4734 | /       | 4.6443                                   | 0.5884 | /       |
| <b>1) Transport system specific variables</b>           |  |        |         |  |        |         |  |        |         |
| <b>Cost</b>   | -0.4528                                | 0.0336 | 0.63582 | -0.3784                                | 0.0274 | 0.68502 | -0.3545                                  | 0.0409 | 0.70152 |
| <b>Access / Egress Time</b>                             | -0.0776                                | 0.0131 | 0.92532 | -0.1721                                | 0.0152 | 0.84192 | -0.0620                                  | 0.0220 | 0.93992 |
| <b>Free Seats</b>                                       |  |        |         |  |        |         |  |        |         |
| <i>Yes</i>  | 0.5316                                 | 0.0526 | 1.70171 | 0.8812                                 | 0.0933 | 2.41381 | 1.6582                                   | 0.1623 | 5.24991 |
| <i>No</i>   | Ref.                                   | Ref.   | Ref.    | Ref.                                   | Ref.   | Ref.    | Ref.                                     | Ref.   | Ref.    |
| <b>Transfers</b>  |  |        |         |  |        |         |  |        |         |
| <i>Yes</i>  | -0.3137                                | 0.0468 | 0.73072 | 0.1110 <sup>1</sup>                    | 0.0790 | 1.11741 | -0.5463                                  | 0.1275 | 0.57912 |
| <i>No</i>   | Ref.                                   | Ref.   | Ref.    | Ref.                                   | Ref.   | Ref.    | Ref.                                     | Ref.   | Ref.    |
| <b>In Vehicle Travel Time</b>                           | -0.0567                                | 0.0059 | 0.94492 | -0.0851                                | 0.0058 | 0.91842 | -0.0693                                  | 0.0065 | 0.93302 |
| <b>Transit Punctuality</b>                              | -0.0551 <sup>1</sup>                   | 0.0362 | 0.94642 | -0.0589 <sup>1</sup>                   | 0.0332 | 0.94282 | -0.0281 <sup>1</sup>                     | 0.0550 | 0.97232 |
| <b>Waiting Time</b>                                     | -0.0816                                | 0.0143 | 0.92162 | -0.1056                                | 0.0143 | 0.89982 | -0.0663                                  | 0.0150 | 0.93592 |
| <b>2) Socio-economic variables</b>                      |  |        |         |  |        |         |  |        |         |
| <b>Age</b>  | -0.0086 <sup>1</sup>                   | 0.0053 | 0.99142 | -0.0074 <sup>1</sup>                   | 0.0043 | 0.99262 | -0.0057 <sup>1</sup>                     | 0.0048 | 0.99432 |
| <b>Sex</b>  |  |        |         |  |        |         |  |        |         |
| <i>Man</i>  | -0.0241 <sup>1</sup>                   | 0.0897 | 0.97622 | 0.3837                                 | 0.1457 | 1.46771 | 0.3660                                   | 0.1712 | 1.44201 |
| <i>Woman</i>  | Ref.                                   | Ref.   | Ref.    | Ref.                                   | Ref.   | Ref.    | Ref.                                     | Ref.   | Ref.    |
| <b>Frequency of using Public Transport</b>              |  |        |         |  |        |         |  |        |         |
| <i>Daily</i>  | 1.3893                                 | 0.3907 | 4.01201 | /                                      | /      | /       | /  | /      | /       |
| <i>Weekly</i>   | 0.6559 <sup>1</sup>                    | 0.3402 | 1.92691 | /                                      | /      | /       | /  | /      | /       |
| <i>Monthly</i>  | 0.4820 <sup>1</sup>                    | 0.3466 | 1.61931 | /                                      | /      | /       | /  | /      | /       |
| <i>Several times a year</i>                             | 0.3888 <sup>1</sup>                    | 0.2941 | 1.47521 | /                                      | /      | /       | /  | /      | /       |
| <i>Never</i>  | Ref.                                   | Ref.   | Ref.    | /                                      | /      | /       | /  | /      | /       |
| <b>Number of cars</b>                                   | -0.2537                                | 0.1279 | 0.77592 | /                                      | /      | /       | /  | /      | /       |
| <b>3) Attitudinal variables</b>                         |  |        |         |  |        |         |  |        |         |
| <b>Attitude towards car</b>                             | 0.5872                                 | 0.0817 | 1.79891 | /                                      | /      | /       | /  | /      | /       |
| <b>Attitude towards tram</b>                            | -0.2305                                | 0.0743 | 0.79412 | -0.1344                                | 0.0580 | 0.87422 | /  | /      | /       |
| <b>Attitude towards train</b>                           | /                                      | /      | /       | /                                      | /      | /       | 0.1258                                   | 0.0671 | 1.13411 |
| <b>Perception bus-tram-metro with regard to comfort</b> | -0.1731                                | 0.0649 | 0.84111 | /                                      | /      | /       | -0.1560                                  | 0.0660 | 0.85562 |
| <b>Perception train with regard to cost</b>             | /                                      | /      | /       | /                                      | /      | /       | 0.1799                                   | 0.0578 | 1.19711 |
| <b>Importance of inexpensive travelling</b>             | /                                      | /      | /       | 0.2545                                 | 0.0721 | 1.28981 | /  | /      | /       |
| <b>Importance of fast travelling</b>                    | /                                      | /      | /       | -0.1583                                | 0.0746 | 0.85362 | /  | /      | /       |
| <b>Expected waiting time of a 30km trip (relative)</b>  | /                                      | /      | /       | 0.0301                                 | 0.0129 | 1.03061 | /  | /      | /       |

<sup>1</sup> Not significant at the 0.05 level

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

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

## 17 18 **6 DISCUSSION**

19  
20 In the previous section, it was shown that the relationship between transit punctuality and mode  
21 choice was not significant at the 0.05 level. This was a rather surprising effect since the majority  
22 of studies in literature indicated the opposite. The insignificance of transit punctuality in the  
23 current study can be accounted for the fact that the deviations of the travel times in the survey  
24 were defined relatively small (3 – 5 minutes) in comparison to the overall travel time of the  
25 30km trips. The effect of larger deviations on light rail mode choice is not explored in this paper.  
26 Thus the conclusion is confined to the fact that small deviations in travel times have no  
27 significant influence on light rail mode choice for medium/long distance trips.

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

45 Besides the transport system specific factors, various personal traits of the travelers  
46 proved to contribute significantly to the choice for light rail transit. This again is in accordance

1 with general literature concerning transit mode choice. Literature demonstrated that, next to age,  
2 gender and car ownership, income is also one of the main determinants of public transit mode  
3 choice. Notwithstanding, income was not included in the final models presented in this paper.  
4 After all, income and number of cars are closely correlated, implying that higher incomes make  
5 owning a car more feasible. As a result, the income effect is indirectly included in the models by  
6 means of the variable ‘number of cars’.

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

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

## 22 23 **7 POLICY RECOMMENDATIONS** 24

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

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

45 Constraining the in-vehicle travel time is also important to policy makers in making light  
46 rail transit more successive. In addition to its insensitivity to road congestion, limiting the

1 number of stops to the absolute minimum and careful consideration of stop-locations can make  
2 important contributions hereto. In addition, reducing the dwell time at stops by eliminating  
3 onboard ticket sales by the driver can significantly lower the total run time (39). Onboard ticket  
4 vending machines and vending machines at stations can be good alternatives as well as ticket  
5 sales by new technologies such as SMS (Short Message Service), RFID (Radio Frequency  
6 Identification) and electronic cash systems.

## 8 CONCLUSIONS AND FURTHER RESEARCH

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

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

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