THE BRT-LRT DILEMMA

A public transport users' and policymakers' perspective on differences in preferences and perceptions between BRT and LRT

Alessio Gaspardo

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1 November 2019

in partial fulfilment to obtain the degree of Master of Science
in Transport, Infrastructure and Logistics
at the Delft University of Technology

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Preface and acknowledgments

Dear reader,

In the past eight months I have been working on my thesis on differences in users' and policymakers' preferences and perceptions between BRT and LRT. I proposed this topic to Royal HaskoningDHV because I found it very interesting, it is a theme of recurrent debate within the public transport industry and I wanted to bring my own little contribution to provide additional understanding on what makes people prefer one mode or the other. I am very grateful the company agreed on the topic and offered me an intern position to dive into this research.

I enjoyed carrying out this work, not only for my passion and interest for public transport themes, but also because this thesis (and my studies at TU Delft in general) taught me "science". Science not in the sense of scientific subjects, such as those that are taught at school, but science referred to as the "scientific method", this extraordinary tool that allows understanding things through an investigation in a rational structured way.

I would like to express my special thanks to my entire graduation committee for guiding me throughout this period, for the advices, the academic and moral support, and to my company supervisors, managers and colleagues for introducing me into the world of transport consulting.

I am particularly grateful to Wilko Bos, Rob van de Bijl, Robert van Leusden, Erwin van Dijk, Pieter Litjens, Gert Jan Polhuijs, Niels den Hartog, Walter Etty, Maaike Adriaens that agreed to talk with me to share their thoughts and opinions on the subject.

I would like to thank my friend and PhD student Nejc Gerzinic for his detailed advice, assistance and support he provided throughout the entire period and to my friends Mehwish Ahmed, Marc Kaelani and Arjan de Ruijter for their help in the translations.

A special thanks to Maria Alonso Gonzalez for the tips and suggestions she provided for the survey design.

An immense gratitude goes to all my friends who made this period enjoyable and for keeping me motivated.

Finally, I would like to thank my family, who never stopped believing in me and constantly supported me throughout this journey.

THE BRT/LRT DILEMMA

A PUBLIC TRANSPORT USERS' AND POLICYMAKERS' PERSPECTIVE ON DIFFERENCES IN PREFERENCES AND PERCEPTIONS BETWEEN BRT AND LRT – EXECUTIVE SUMMARY/PAPER

Alessio Gaspardo – Transport, Infrastructure and Logistics – Delft University of Technology

<u>*Abstract*</u>

The discussion involving BRT and LRT is well alive among policymakers, who often rely on personal preferences or, as it is called in literature, on "blind commitment" towards one system or the other for their decision-making. The reason for choosing a system according to personal taste is also caused by the unknown preferences that public transport users have for the two systems. It is known from literature that there exists a "rail bonus", but it is not clear to what extent this applies to LRT compared to BRT. Moreover, it is not known what are the causes behind the rail bonus black-box. This study wants to put some light on the dilemma by testing the existence of an "LRT bonus" and trying to explain it by analysing perceptions and how these relate to each other. Moreover, the study tries to understand how policymakers perceive BRT and LRT and how the decision-making should be done.

<u>Keywords</u>: BRT, LRT, rail bonus, preferences, MNL model, perceptions, network psychometrics, decision-making

1. INTRODUCTION

Bus Rapid Transit (BRT) and Light Rail Transit (LRT) are two types of mass transit systems that offer similar performance in terms of speed and service capacity. Due to these similarities, it is often difficult for policymakers to decide which system should be implemented, especially because it is not clear which of the two modes is mostly preferred by public transport users, why and according to which vehicle/system characteristics. Several studies found that there exists a "rail bonus", an inherent preference that people have for rail-based systems compared to the bus [(Fell, Axhausen, Heidl, & Haupt, 2001), (Scherer & Dziekan, 2012)] but that this preference is highly related to the familiarity that people from a specific location have towards that mode (Bunschoten, Molin, & van Nes, 2013). However, it is not clear if and to what extent this bonus applies specifically to LRT compared to BRT. Unveiling the reason behind the rail bonus black-box would give information on which bus vehicle/system characteristic should be improved, or to help the policymaker decide which system to implement according to people's preferences. Literature focusing on understanding people's preferences for BRT and LRT is rather limited [(Chinnock, Routaboul, Swanson, & Gleave, 2013), (Balbontin, Hensher, Ho, & Mulley, 2006)], especially considering that preferences greatly vary between different locations (Mulley, Hensher, & Rose, 2014). To gain information about the reasons behind the "LRT bonus", if its existence is confirmed, there is the need to study more in detail which characteristics influence the difference in mode preference. To do so, perceptions should be explored [(Klein, 2017), (dell'Olio, Ibeas, & Cecin, 2011)]. Knowing how BRT and LRT are differently perceived in terms of vehicle and system characteristics, and how these perceptions influence each other, might be the key to understanding what lies inside the rail bonus black-box. Although the understanding of people's preferences and perceptions could give some clarity on what the public prefers and what their tread-offs are for their daily commute, it would not solve the political debate behind the system choice. Other than users 'preferences, there are other variables that have to be considered when deciding for a new transport system: budget available, urban renovation, new housing developments, economy. However, the political arena often does not consider these mobility-related aspects when deciding for a new transport mode. It is often an ideological choice (van Der Bijl, Bukman, & van Oort, 2018), a so-called "blind commitment" [(Kain, 1988), (Hensher & Waters II, 1994)]. Because of this blindly committed decision-making process, heated political arguments generally arise during the planning process and system choice for new transport infrastructure.

This research aims at contributing the literature by studying to what extent the rail bonus applies to LRT compared to BRT and by giving insights into which factors might cause the bonus in terms of perceptions and how these perceptions relate to each other. Moreover, it aims at understanding how policymakers perceive BRT and LRT and which aspects they consider for their decision-making. In the following sections, an overview of the methodologies used in this study will be given, followed by the model estimations, interpretation of the results and conclusions.

2. METHODOLOGY AND SURVEY DESIGN

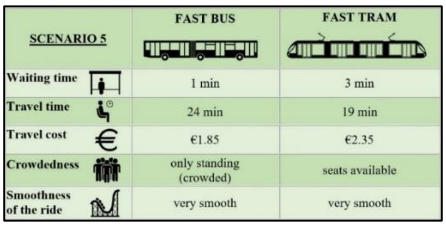
This research touches various aspects of the BRT/LRT dilemma and different methodologies need to be used. Peoples' preferences and perceptions are captured via a survey, while policymakers' perceptions are assessed qualitatively via one-to-one interviews.

One of the objectives of this research is to understand to what extent the rail bonus applies to LRT compared to BRT and how peoples' preferences vary between those two modes. To do so, a stated preference approach is used to estimate a discrete choice model. The attributes varied in the model are: waiting time, travel time, travel cost, crowdedness and smoothness of the ride. These attributes are varied into three levels. The selection of the attributes follows from an intense literature review of the most commonly used attributes in mode choice experiments. Moreover, the selection is also the result of the interviews with policymakers/experts, in particular for the latest two attributes (crowdedness and smoothness of the ride), which seem to be rather relevant when considering rail- versus bus-based systems. The attributes included in the experiment and their levels are shown in **TABLE 1**.

waiting time	1 min	3 min	5 min
travel time	14 min	19 min	24 min
travel cost	€1.35	€1.85	€2.35
crowdedness	seats available	only standing (not crowded)	only standing (crowded)
smoothness of the ride	very smooth	generally smooth	jerky

TABLE 1: ATTRIBUTE LEVELS CHOICE EXPERIMENT

The design of the stated preference choice experiment is carried out within the software Ngene (ChoiceMetrics, 2018). The experiment consists of a labelled and simultaneous fractional factorial orthogonal design. The two alternatives included in the experiment are BRT (presented to the respondents as "fast bus") and LRT (presented as "fast tram"). The design consists of 27 choice sets, which are divided into three blocks such that each respondent faces 9 choice scenarios. **FIGURE 1** displays an example of a choice scenario included in the survey.



SCENARIO 5	FAST BUS	FAST TRAM
Waiting time	1 min	3 min
Travel time	24 min	19 min
Travel cost	€1.85	€2.35
Crowdedness	only standing (crowded)	seats available
Smoothness of the ride	very smooth	very smooth

FIGURE 1: EXAMPLE OF CHOICE TASK FROM THE FINAL SURVEY

The results of the choice experiment are used to estimate a multinomial logit model (Train, 2002).

Perceptions are captured with likert-type statements on a scale from one (totally disagree) to five (totally agree). The statements are derived from literature, inputs from interviews and brainstorming sessions. **TABLE 2** lists the statements used for perception analysis.

1	**The vehicle has easy and fast boarding**
2	The vehicle provides enough capacity for passengers transferring from train
3	The service feels reliable (every time almost equal travel time and is punctual)
4	During peak hours the vehicle feels uncomfortably crowded
5	The vehicle has enough seats
6	The route has many bumps making the ride not enjoyable
7	The vehicle rides smoothly on curves
8	The vehicle is often delayed
9	The vehicle looks modern and appealing
10	The vehicle is fast
11	The vehicle has a sufficient number of doors
12	The vehicle waits too long at stops
13	If this vehicle is driverless (automated), I would be willing to use it
14	The vehicle is comfortable
15	The vehicle accelerates and brakes smoothly
16	The vehicle is environmentally friendly
17	The vehicle rides without making noise
18	The vehicle has enough leg space to sit comfortably
19	The vehicle has enough standing space
20	From the inside the vehicle feels spacious and has a pleasant design
21	It is a frequent service

TABLE 2: STATEMENTS PERCEPTION ANALYSIS

The interrelations that exist between perceptions are analysed using a psychological network model (Epskamp & Fried, 2018): the structure of the networks and the possible presence of clusters can give an indication about the perceptions construct and might explain certain behavioural characteristics not captured by the discrete choice model.

The final survey, other than including the choice experiment and the perceptions, also includes a section with socio-demographic questions: gender, age, highest level of education completed, transport mode most frequently used on an average day and frequency of using bus line 28 and tram lines 60/61. The main target group of this research consists of public transport users, since they are mostly affected by new public transport infrastructure and services and mostly affected by policymakers decision.

Policymakers' perceptions are captured via one-to-one interviews, that also provided valid inputs for the survey design since many policymakers are also public transport experts. The interview protocol used consists of a semi-structured conversation, favouring a more natural flow of ideas exchange rather than a more impassive Q&A that would create a colder environment. The only structure relates to the main themes presented to the interviewee: different perceptions between BRT and LRT, existence of a "blind commitment" among policymakers, the decision making approach that they would follow to decide between BRT and LRT and, finally, the importance of involving the citizens into the decision making process.

3. CASE STUDY AND DATA COLLECTION

Utrecht has been selected as case study, since it operates both a BRT and LRT service. The BRT consists of bus line 28 between the central station and the Utrecht Science Park (USP), while the LRT consists of the tramlines to Nieuwegein and Ijsselstein. For the choice experiment, the respondents are asked to imagine the hypothetical situation in which bus line 28, in its section through the city centre, is replaced by a light rail service (**FIGURE 2**). Since the 80s, discussions about introducing a tramway in the city centre of Utrecht are regularly feeding the local political debate. This is an additional reason for choosing Utrecht as a case study, because due to the numerous discussions and rumours about this possibility, the case study becomes more realistic for the respondents, who might be more willing to give a truthful answer following their personal needs and preferences.

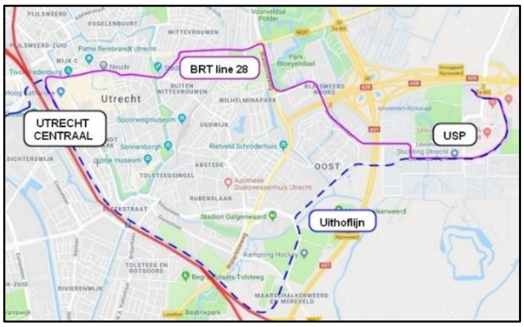


FIGURE 2: ROUTE OF BUS LINE 28 VIA THE CITY CENTRE

Respondents have been recruited at bus and tram stops by distributing flyers with a link and QR-code directing to the online survey. The flyers have been distributed during 5 working days between the 17th and 28th of June alternating peak and off-peak hours. The days were average, with mixed weather conditions of sunny warm days and colder rainy days. About 4000 flyers have been handed out and a total of 370 individuals completed the survey, with a response rate varying between 10% and 12%, according to the location and time of the distribution. About 92% of the respondents that completed the survey have been recruited from the flyers, while the residual 8% of the responses comes from personal social networks.

4. DATA ANALYSIS

The data gathered is carefully analysed to exclude responses which are believed not to be reliable due to the repetitive response pattern or because the age of the respondents is below 16: in total, 19 respondents are removed and excluded from the analysis. 351 is the number of observations used for all the analysis. **TABLE 3** summarizes the descriptive statistics of the socio-demographic questions.

Variable	Category	Sample
Language	English	10%
	Dutch	90%
Gender	Female	46%
	Male	53%
	Prefer not to say	1%
Age	<18	5%
	18-24	37%
	25-34	28%
	35-54	19%
	>54	11%
Highest level of education completed	Basisschool	0%
	MO	5%
	MBO	17%
	HBO	25%
	WO and post HBO	52%
Transport mode used on an average day	Walk	3%
	Bike	28%
	Car	5%
	Train	26%
	Bus	21%
	Tram	16%
	Other	1%
Frequency of use bus line 28	4 or more days per week	8%
	1-3 days per week	16%
	1-3 days per month	11%
	1-11 days per year	20%
	Never	45%
Frequency of use tram lines 60/61	4 or more days per week	25%
	1-3 days per week	16%
	1-3 days per month	7%
	1-11 days per year	16%
	Never	36%

TABLE 3: DESCRIPTIVE STATISTICS

For the stated choice experiment, 9 choices per respondent are observed and their distribution between the two alternatives BRT and LRT are summarized in **TABLE 4** and **FIGURE 3**.

	BRT	LRT
COUNT	1304	1855
PERCENTAGE	41%	59%

TABLE 4: DISTRIBUTION OF CHOICES

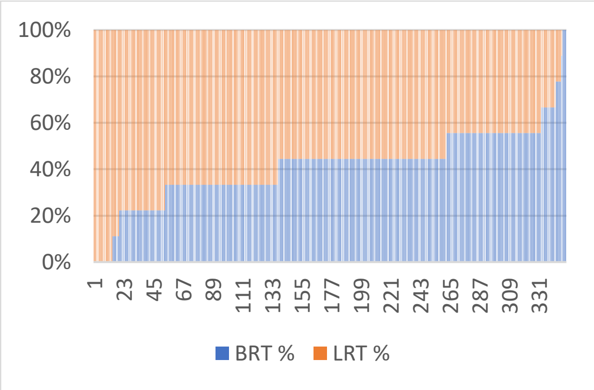


FIGURE 3: DISTRIBUTION OF THE CHOICES FOR ALL RESPONDENTS

14 respondents always choose LRT, irrespective of the attribute levels, while only three respondents selected BRT as their preferred mode for all nine scenarios.

The results of the perceptions are analysed in terms of difference of average scores between LRT and BRT to verify to what extent the total average score for BRT differs from the one of LRT. To do so, some adjustments are needed: four of the 21 statements, in fact, are presented with a negative phrasing, thus, in order to analyse the average appreciation for the two modes, the scores of these statements are reversed (1→5, 2→4, 3→3, 4→2, 5→1). The average score is calculated and the results are displayed in **TABLE 5**. In bold are indicated the statements for which the score is reversed. The statements are ordered based on the percentage difference between the average scores for LRT and BRT, according to the following formula:

$$\Delta_{\%} = \frac{|LRT - BRT|}{\left(\frac{\overline{LRT} + \overline{BRT}}{2}\right)} \cdot 100$$

Where LRT and BRT are the average score for the single statements, while $\overline{LRT}$ and $\overline{BRT}$ are the total average of all scores.

Statement	Avg. BRT	Avg. LRT	Δ_%
The route has many bumps making the ride not enjoyable	3.18	4.16	30.1%
The vehicle provides enough capacity for passengers transferring from train	2.73	3.58	26.1%
The vehicle is environmentally friendly	2.68	3.52	25.6%
The vehicle rides smoothly on curves	2.87	3.68	24.9%
During peak hours the vehicle feels uncomfortably crowded	2.02	2.79	23.5%
If this vehicle is driverless (automated), I would be willing to use it	2.79	3.56	23.4%
The service feels reliable (every time almost equal travel time and is punctual)	2.95	3.70	23.2%
The vehicle has enough seats	2.59	3.32	22.3%
The vehicle accelerates and brakes smoothly	2.70	3.40	21.6%
The vehicle has enough standing space	2.90	3.60	21.4%
The vehicle has a sufficient number of doors	3.21	3.89	20.8%
The vehicle has easy and fast boarding	3.40	4.03	19.5%
The vehicle is fast	3.11	3.69	17.9%
The vehicle is often delayed	2.99	3.57	17.9%
The vehicle is comfortable	3.01	3.58	17.5%
The vehicle has enough leg space to sit comfortably	2.93	3.45	16.0%
From the inside the vehicle feels spacious and has a pleasant design	2.94	3.42	14.6%
The vehicle rides without making noise	2.77	3.16	12.1%
The vehicle looks modern and appealing	3.18	3.53	10.7%
The vehicle waits too long at stops	3.76	3.85	2.6%
It is a frequent service	3.53	3.60	1.9%
Tot. Average	2.96	3.58	18.75%

TABLE 5: PERCEPTION SCORE DIFFERENCES LRT-BRT

According to the results, LRT scores higher than BRT on all statements, and on total average it scores about 19% higher than BRT (3.58 versus 2.96 on a one to five likert scale). This result seems in line with the higher number of preferences obtained by LRT in the choice experiment, suggesting that it is reasonable to claim the existence of an "LRT bonus". The Mann-Whitney U-test (specifically used for likert type ordinal data) is performed to have a statistical confirmation that the difference between two scores is indeed different from zero in the population. The test confirms that for all statements but two, the differences are statistically different from zero. The BRT and LRT scores for the statements "the vehicle waits too long at stops" and "it is a frequent service" are not statistically different. Therefore, it can be concluded that in the Utrecht population BRT and LRT do not differ in terms of perceptions for stop waiting time and service frequency.

It can be seen that the statement "*The route has many bumps making the ride not enjoyable*" is the one that shows the highest difference between BRT and LRT. This means that compared to LRT, the ride of a BRT is perceived as much more bumpy. This result is not surprising, since rail vehicles are known to have a smoother ride due to the more regular surface of the rails. The perceived high difference between the two modes might also be influenced by the experience of riding busses operating on particular roads with irregular surface. The second item in the list indicates that LRT is perceived to be much more suitable as a transport mode able to accommodate the passengers transferring from train. This might be due to the high capacity of trains: when the train arrives at the station, passengers leave the train at the same time and many of them transfer from train to the local public transport. These transfer passengers, direct themselves towards the stop all at the same time and, even though the bus has a higher frequency than the tram, all passengers expect to board on the first bus available. Since the capacity of a bus vehicle is much lower than the capacity of a tram, the users perceive that all these passengers cannot be accommodated on a bus. This item suggests that passengers transferring from train have a much stronger perception for the “vehicle capacity” rather than for the “service capacity” and it might have implications for the service design. It is interesting to notice that at the third position on the list there is the perception for environmental friendliness. According to the observed responses, LRT is perceived to be 26% more environmentally friendly than BRT. In the specific case of Utrecht, this might be determined by the different power source of bus and tram vehicles: bus line 28 is operated with diesel vehicles, while the trams are electrically powered.

5. USERS PREFERENCES AND TRADE-OFFS

The MNL model is estimated using the following utility specifications:

$$V_{BRT} = \beta_{WT\_BRT} \cdot WT_{BRT} + \beta_{TT_{BRT}} \cdot TT_{BRT} + \beta_{TC_{BRT}} \cdot TC_{BRT} + \beta_{CR1_{BRT}} \cdot CR1_{BRT} + \beta_{CR2_{BRT}} \cdot CR2_{BRT} + \beta_{SR1_{BRT}} \cdot SR1_{BRT} + \beta_{SR2_{BRT}} \cdot SR2_{BRT}$$

$$V_{LRT} = \beta_{WT\_LRT} \cdot WT_{LRT} + \beta_{TT_{LRT}} \cdot TT_{LRT} + \beta_{TC_{LRT}} \cdot TC_{LRT} + \beta_{CR1_{LRT}} \cdot CR1_{LRT} + \beta_{CR2_{LRT}} \cdot CR2_{LRT} + \beta_{SR1_{LRT}} \cdot SR1_{LRT} + \beta_{SR2_{LRT}} \cdot SR2_{LRT} + ASC$$

Where WT: waiting time, TT, travel time, TC: travel cost, CR1 and CR2: the two dummy variables used for coding crowdedness, SR1 and SR2: the two dummy variables used for coding smoothness of the ride, ASC: alternative specific constant. The model is estimated using the freely available software package Python Biogeme (Bierlaire, 2016). The results are reported in **TABLE 6** and **TABLE 7**.

Name	Full parameter name	Value	Robust Std err	Robust t-test	p-value
ASC	Alternative Specific Constant LRT	1.8	0.54	3.34	0
$\beta_{CR1_{BRT}}$	Crowdedness 1 BRT	-0.523	0.126	-4.16	0
$\beta_{CR1_{LRT}}$	Crowdedness 1 LRT	-1.25	0.159	-7.89	0
$\beta_{CR2_{BRT}}$	Crowdedness 2 BRT	-0.69	0.153	-4.5	0
$\beta_{CR2_{LRT}}$	Crowdedness 2 LRT	-2.31	0.14	-16.47	0
$\beta_{SR1_{BRT}}$	Smoothness of the ride 1 BRT	-0.551	0.15	-3.68	0
$\beta_{SR1_{LRT}}$	Smoothness of the ride 1 LRT	0.249	0.136	1.83	0.07*
$\beta_{SR2_{BRT}}$	Smoothness of the ride 2 BRT	-1.27	0.136	-9.37	0
$\beta_{SR2_{LRT}}$	Smoothness of the ride 2 LRT	-0.746	0.127	-5.86	0
$\beta_{TC_{BRT}}$	Travel Cost BRT	-1.44	0.145	-9.95	0
$\beta_{TC_{LRT}}$	Travel Cost LRT	-1.56	0.161	-9.71	0
$\beta_{TT_{BRT}}$	Travel Time BRT	-0.263	0.0143	-18.35	0
$\beta_{TT_{LRT}}$	Travel Time LRT	-0.271	0.0154	-17.58	0
$\beta_{WT_{BRT}}$	Waiting Time BRT	-0.189	0.0368	-5.15	0
$\beta_{WT_{LRT}}$	Waiting Time LRT	-0.322	0.0348	-9.24	0

TABLE 6: RESULTS OF THE MNL ESTIMATION

Number of estimated parameters:	**15**
Sample size:	3159
Excluded observations:	0
Init log likelihood:	-2189.652
Final log likelihood:	-1266.177
Likelihood ratio test for the init. model:	1846.95
Rho-square for the init. model:	0.422
Rho-square-bar for the init. model:	0.415

TABLE 7: ESTIMATION REPORT

The first important result that can be noticed is that the alternative specific constant for LRT (ASC) is large, positive and significant. This means that excluding travel time, travel cost, waiting time, smoothness of the ride and crowdedness, people prefer the LRT, and it confirms the existence of a rail bonus. This also means that the attributes included in the utility function do not explain the rail bonus, but that there is something else causing it. The statements that analyse the perceptions might partially explain this inherent rail preference. Waiting time is weighted more negatively for LRT than for BRT, meaning that the disutility for waiting an LRT is lower than the one for waiting a BRT, while the parameters for travel time and travel cost do not differ between BRT and LRT. Both dummy parameters for crowdedness (CR1 and CR2) are much more negative for LRT, with a large difference compared to the values for BRT. This means that respondents weight crowdedness much more negatively for LRT than for BRT. On the other hand, the two dummies SR1 and SR2 for smoothness of the ride are negatively larger for BRT. The dummy SR1 for LRT is interestingly positive, but not significant at 5% level. Thus, the parameter for SR1 can be considered equal to zero for LRT, meaning that respondents do not perceive any difference between a very smooth ride and a generally smooth with sudden brakings ride on an LRT. Only the difference between a very smooth and a jerky ride plays a role. For BRT, instead, both levels are large, negative and significant, meaning that users perceive the bus rides as not comfortably smooth.

The estimated parameters for time and cost allow to determine the value of time (VoT) both for waiting and travelling, using the following formula:

$$VoT = \frac{\beta_{Time}}{\beta_{Cost}} \qquad [€/hour]$$

The results are displayed in **TABLE 8**.

		BRT	LRT
Value of Travel Time	VoTT [euro/hour]	10.96	10.42
Value of Waiting Time	VoWT [euro/hour]	7.88	12.38

TABLE 8: VALUES OF TIME

It can be seen that the values of travel time are similar for BRT and LRT. These two VoTT are slightly higher than the average VoT of 7.42 euro/hour found for the Netherlands (Kennisinstituut voor Mobiliteitsbeleid, 2017). The values for waiting time are particularly interesting and deserve further explanation. People generally perceive the time spent waiting at the stop as much slower compared to the time spent on a vehicle (Jara-Díaz & Tirachini, 2013). This seems true for LRT, but not for BRT, whose VoWT is lower than the VoTT. According to this result, respondents would rather spend time waiting at the stop than travelling on a bus, most probably because travelling on a bus is perceived as quite uncomfortable compared to LRT, as also shown from the perception analyses before.

In the same way as for deriving the values of times, by dividing the estimate of the ASC with the (absolute value of the) parameter for cost, it can be calculated the monetary value of the LRT bonus:

$$VoLRT_{bonus} = \frac{ASC}{\beta_{TC_{LRT}}} = 1.15\ euro$$

The monetary value of the rail bonus is found to be 1.15 euro. This means that a traveller in the (Utrecht) population have an additional monetary utility of 1.15 euro when deciding for an LRT. In other words, €1.15 is the price a traveller is willing to pay additionally to the ticket fare to travel on an LRT instead of a BRT. In the same way, it can also be determined the non-monetary value of the tram bonus expressed in terms of waiting and travel time. It is found that the waiting time value of the rail bonus is 5.59 minutes, while the travel time value is 6.64. People are willing to wait about six minutes longer or travel almost seven minutes longer if the journey is made on a tram vehicle instead of a bus.

6. Relations between users perceptions

To analyse the construct of the users perceptions and their mutual relations, psychological network modelling is applied. The networks are estimated by importing the perception scores into the freely available statistical software Jasp (Department of Psychological Methods, University of Amsterdam, 2018). The statement "*if this vehicle is driverless (automated), I would be willing to use it*" is found to have little relations with all other variables, and is therefore excluded from the analysis. In total 20 statements are included in the network modelling. Keeping the tuning parameter at the value of 0.5, two networks are estimated: one for BRT and one for LRT (**FIGURE 4** and **FIGURE 5**). For BRT, 111 over 190 edges are found significant, while for LRT the non-zero edges are 105. In the figures, to ease the visualization, only edges with partial correlations higher than 0.05 are visualized.

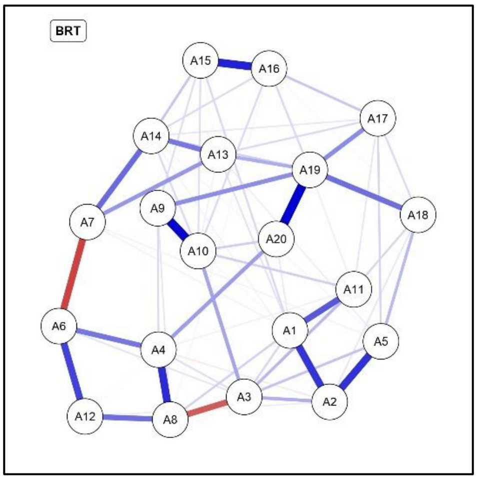


FIGURE 4: BRT PERCEPTIONS NETWORK

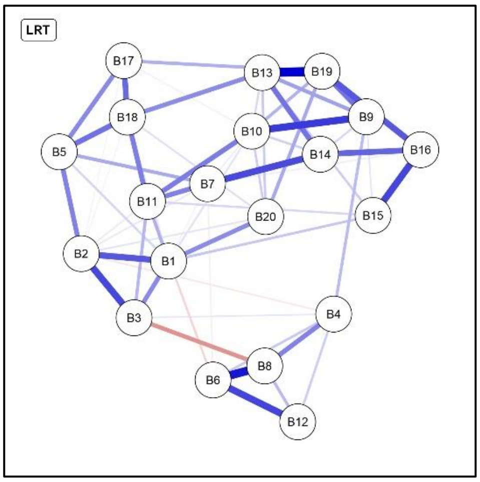


FIGURE 5: LRT PERCEPTIONS NETWORK

Looking at the network structures, it appears that the BRT network is more sparse than LRT one. While the strength of the relation between single nodes is displayed by the strength of their edges, the level of sparsity reveals the strength of relation between the nodes as a group: the higher the relations (i.e. the partial correlations) between a certain group of nodes, the closer these nodes are to each other.

In the case of LRT, it is observed a group composed by the nodes 9, 10, 13, 14 and 19 related to characteristics such as the look of the vehicle (from the inside and outside), speed, smoothness of the ride, comfort and internal space. These perceptions seem highly related to each other. More in particular, it seems that node 9 (The vehicle looks modern and appealing) is very much related to 10 (The vehicle is fast) and 19 (From the inside the vehicle feels spacious and has a pleasant design), while node 13 (The vehicle is comfortable) seems more related also with 19 and 14 (The vehicle accelerates and brakes smoothly). It is not possible from these networks to determine what is causing what, but only the extent to which items are related to each other. However, it can be speculated that an LRT that is perceived as modern, is also perceived fast and spacious, and an LRT perceived as comfortable is also perceived as spacious and riding smoothly. For BRT, this cluster disappears and these same relations are weaker, except the partial correlation between 9 and 10, meaning that a modern bus can also be perceived as fast (and vice versa).

These networks are evaluated with centrality measures derived from graph theory. Degree, closeness and betweenness are plotted for BRT and LRT in **FIGURE 6**.

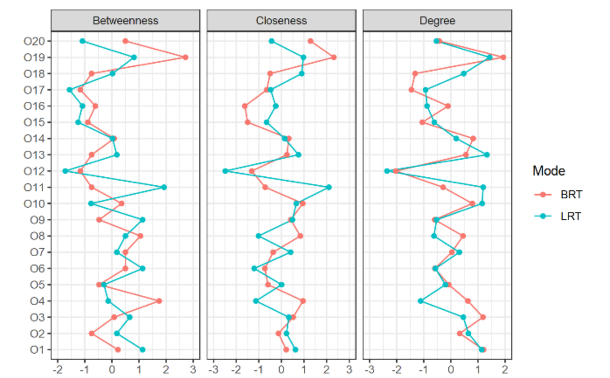


FIGURE 6: CENTRALITY INDICATORS

On a high level, it can be observed that the centrality measures follow a similar pattern both for BRT and LRT networks, meaning that overall, there are some similarities in terms of nodes centrality. It appears, however, that number of doors (11), internal environment (19) and comfort (13) are the three items that mostly relate with most of the other perceptions. 19 is found to have a high centrality for BRT as well, together with statement 10 (the vehicle is fast), while Item number 4, which is found to be quite central for BRT, was found to be the least central for LRT. This tells that, while for LRT the perception of travelling on a crowded vehicle during peaks do not influence other perceptions, for BRT crowding during peaks seems to have an impact on the general perceptions people have for BRT.

The reliability of the networks is evaluated looking at the stability of the CS (coefficient stability) index by performing 1000 bootstraps and the results are reported in **FIGURE 7** for BRT and **FIGURE 8** for LRT.

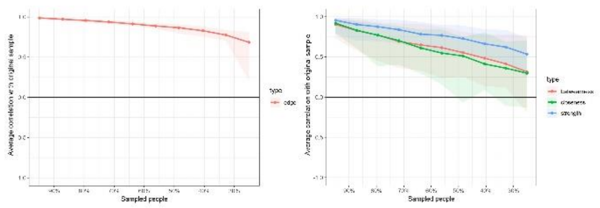


FIGURE 7: BOOTSTRAPPING RESULTS FOR BRT NETWORK STABILITY

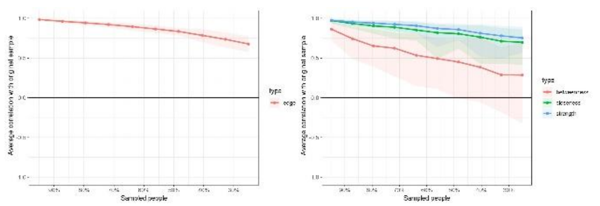


FIGURE 8: BOOTSTRAPPING RESULTS FOR LRT NETWORK STABILITY

It can be observed that the edge stability function remains fairly stable for both BRT and LRT networks, starting to decline slightly after more than 50% of the sample is removed, but never reaching correlation values lower than 0.6.

The centrality indexes, on the other hand, seem to decrease more steeply. For BRT, betweenness and closeness are the indexes that decline more quickly, while strength always remains over 0.5 correlation values. Somewhat different is the situation for the network related to LRT, where closeness and strength perform very well, keeping their correlation values solidly above 0.6, while betweenness performs worse declining at under 0.5 already with 65% of the sample removed. This basic stability analysis shows that edge strengths are reliable and can be interpreted, while the interpretation of centrality indicators requires more caution.

A network of the score differences is generated as well to analyse to what extent the differences in perceptions for BRT and LRT are related to each other. In this network, the reversed scores of the statements formulated with negative phrasing are included. This is done because all score differences between LRT and BRT are positive. After several iterations, the final estimated network includes the 14 nodes, while the other even nodes are excluded due to the low centrality indexes and low edge strengths with the other nodes. In total, 61 out of 91 edges result to be non-zero. To ease the visualization (**FIGURE 9**), only edges with a partial correlation higher than 0.05 are displayed.

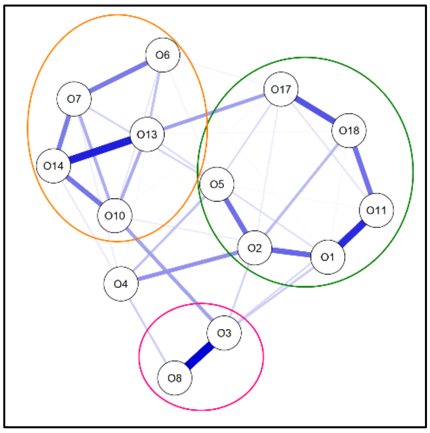


FIGURE 9: NETWORK OF THE SCORE DIFFERENCES

Three main groups of nodes can be identified and are highlighted in the figure with different colours. Groups are identified by looking at their position in the network, the structure of the edges construct, and by identifying similarities. It is then possible to give a name to each group as follows: purple (reliability), green (capacity/ease of boarding) and orange (ride experience). The commonality in the green group relates to the difference in perceived capacity (seats, internal space) and ease of accessing the vehicles (which seems strongly related to the perceived difference in the number of doors). This strong interrelation between vehicle capacity and the ease of boarding confirms what was found in the networks of absolute scores, that a reduced queue and time required to board the vehicle seems to influence the perception of available internal space. In the orange group comfort is particularly strongly linked to smoothness of acceleration and brake, suggesting that that node is more than the others strongly related to the difference in perceived comfort. To notice that node 4 (perceived crowding during rush hours) is not included in either group. Its location in the network and its links suggest that this perception is related to all three groups: crowding during peaks might have effects on delays and reliability, it might have effects on capacity and ease of boarding and it might also influence the perception of smoothness of the ride, causing its location to be "equidistant" to some extent to these three groups.

7. Policymakers and Decision-Making

Six policymakers have been interviewed with the main goal to understand how they perceive BRT and LRT and how the decision-making for their realization should take place. It appears that for policymakers the main difference in perception between BRT and LRT refers to two main points: first, the infrastructure is seen as a landmark for the city, which is perceived to stay there for longer time compared to bus systems; second, rail-based systems are seen as being higher in the status hierarchy, while busses are considered of lower image and quality. From the interviews it seems that this blind commitment mentioned in the introduction is present among policymakers, but that this commitment is not only related to rail, but also to other systems and relations with industrial lobbies. Regarding the decision making, the main point is that the question about which technology between BRT and LRT should be implemented is essentially wrong, especially during the early planning phases. Before discussing about the technology, it should be discussed about the vision that the city or region has, about what it is wanted to achieve in terms of urban aspects, economy and quality of the public transport service. Costs appear to be a factor that policy makers are increasingly considering when deciding for a new systems, in particular because the national government is not willing anymore to invest for new transport infrastructures within cities, which have to be funded in other ways. Finally, the interviews show that citizens should be involved into the decision making process only up to a certain extent and that not all their wishes can be accommodated if the goal is the benefit for the collectivity, because often people are not familiar with certain systems and do not always know what they truly want.

8. Conclusions

This study wanted to put some light behind a topic which is highly controversial among policy makers, which is the decision between BRT and LRT. These two systems are very similar and could both be used to serve the same transport demand. Therefore, additional information that could help the decision making is to try understanding what people prefer and why. This research confirms the existence of the rail bonus, which is rather large, but also that travel time, waiting time, travel cost, crowdedness and smoothness of the ride do not explain it. The perception analysis shows that LRT is perceived 19% better than BRT on a one to five scale. The three characteristics that mostly seem to determine the difference in perception are crowding during peak hours, capacity for passengers transferring from train and environmental friendliness. The analysis of the network models show a cluster for LRT composed by modern and appealing look of the vehicle, speed, comfort, smoothness of the ride, and internal space and atmosphere. These items are not the ones that obtained the highest absolute score difference, but the fact that they are so much clustered and related in the network model could partially explain the existence of the rail bonus for LRT over BRT. The results of the MNL model also suggest that crowdedness is perceived highly negative in LRT vehicles and smoothness of the ride particularly negative for BRT ones. This result is confirmed in the perception analysis as well, where the items relative to crowding during peaks, capacity for people transferring from train, seats available and standing space are evaluated for LRT between 22% and 32% higher than for BRT, while the items relative to smoothness in general (bumpiness, smoothness on curves, smoothness during acceleration and braking) determined a perception difference between BRT and LRT varying between 23% and 27%, being among the items with the highest perception difference between the two modes.

The interviews with policymakers showed that the "blind commitment" exists and that relates to two main points: first, the infrastructure is seen as a landmark for the city, which is perceived to stay there for longer time compared to bus systems; second, rail-based systems are seen as being higher in the status hierarchy, while busses are considered of lower image and quality. Moreover, BRT and LRT are perceived differently also in terms of costs, which is becoming an increasingly considered decision-making factor due to the lack of available funds for new transport infrastructures, although this difference in costs also depends on the quality that the system aims to achieve.

Further research should continue exploring which other perceptions might be the cause of the rail bonus for LRT systems and if this bonus is verified in other cities as well, in particular where people are not familiar with neither BRT and LRT. Moreover, a higher number of respondents would be required to estimate larger network models that could contain other clusters. Finally, further methodological research would be required to combine the results of network modelling within choice modelling, in particular to further verify to what extent network models can give insights into the alternative specific constant black-box.

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Glossary

ASC	Alternative Specific Constant
BRT	Bus Rapid Transit
CBA	Cost-Benefit Analysis
CBS	Centraal Bureau voor de Statistiek
CR1	First level of Crowdedness
CR2	Second level of Crowdedness
CS	Coefficient Stability (index)
DCM	Discrete Choice Modelling
EBIC	Extended Bayesian Information Criterion
HBO	Hoger Beroepsonderwijs
I.I.D. EV	independent and identically distributed extreme value
LASSO	Least Absolute Shrinkage and Selection Operator
LL	Log Likelihood
LRS	Likelihood Ratio Statistics
LRT	Light Rail Transit
MNL	Multinomial Logit Model
PT	Public Transport
RI	Relative Importance (attribute)
RP	Reviled Preferences
RUM	Random Utility Maximization
SP	Stated Preferences
SR1	First level of Smoothness of the Ride
SR2	Second level of Smoothness of the Ride
TC	Travel Cost
TT	Travel Time
TTCR1	Additional travel time for the first level of crowdedness
TTCR2	Additional travel time for the second level of crowdedness
TTSR1	Additional travel time for the first level of smoothness of the ride
TTSR2	Additional travel time for the second level of smoothness of the ride
UR	Utility Range
USP	Utrecht Science Park
VOCR1	Value of first level of crowdedness
VOCR2	Value of second level of crowdedness
$VOLRT_{BONUS}$	Value of the LRT bonus
VOSR1	Value of first level of smoothness of the ride
VOSR2	Value of second level of smoothness of the ride
VOT	Value of Time
VOTT(S)	Value of Travel Time (Savings)
VOWT(S)	Value of Waiting Time (Savings)
WO	Wetenschappelijk Onderwijs
WT	Waiting Time
WTCR1	Additional waiting time for the first level of crowdedness
WTCR2	Additional waiting time for the second level of crowdedness
WTSR1	Additional waiting time for the first level of smoothness of the ride
WTSR2	Additional waiting time for the second level of smoothness of the ride

1. INTRODUCTION

This chapter gives an introduction to the problem addressed in this study, the reasons for its relevance and the approach used to answer the research questions. More in particular, 1.1 provides background information to guide the reader to the problem definition, which is addressed with higher detail in 1.2. Section 1.3 defines the research objectives and the main research question and relative sub-questions. In 1.4 it is briefly described the approach used to answer the research questions and 1.5 explains why this research is relevant for science, society and for the company. 1.6 shows the structure of the report and 1.7 concludes the introductive chapter.

1.1. Background

Cities are facing growing population. According to the United Nations, 68% of the world population is expected to live in urban areas by 2050 (UN Department of Economic and Social Affairs, 2018). This expected growth poses challenges for the future mobility, and cities are working to find solutions to accommodate the growing demand. This challenge is even bigger considering the new standards that cities aim to pursue: less cars, more active modes and reduced emissions (Gössling, 2013). Mass transit is one of the solutions available to the problem and various alternatives are available according to the local financial, economic and urban situation. Larger cities with high population densities tend to opt for metro systems, which usually run underground with no interactions with the external environment. This solution is expensive, but for urban environments where population densities are high enough, the benefits for choosing such a system outweigh the costs due to the high travel time savings (Guerra & Cervero, 2011), with the hope that more car users would shift to public transport. In other cities, on the other hand, the demand is not high enough to justify an expensive metro system: in those situations a bus service might do the job if well planned and operated with high reliability. However, bus systems are often operating with low standards (low comfort levels and long travel times due to the operations in mixed traffic and without priority at the intersections) and numerous cities have been forced to enact programs to improve the quality of their bus services (Currie & Wallis, 2008).

In the 70s, a new concept for bus systems has been introduced: the first Bus Rapid Transit (BRT) systems started their operations in Ottawa (Canada, 1973) and Curitiba (Brazil, 1974). This new concept of bus operations originally included only dedicated lanes and platforms at the stops. The system quickly developed by including off-board payment systems, priority at the intersections, more capacious vehicles, and even viaducts and tunnels for those systems aiming for greater separation. In the Netherlands, BRT systems inspired the concept of High Quality Public Transport (known as HOV: Hoogwaardig Openbaar Vervoer), which is characterized by high accessibility, higher commercial speed, high reliability and general high attractiveness (Böhler, 2010) and they can be found in Eindhoven, Utrecht and Amsterdam.

Tramways, also during the 70s, saw their renaissance period after years of neglect and dismantlement of their networks in all major cities around the world (Boquet, 2017). The tram reappeared with a renovated image: fewer lines, fewer stops, right-of-way routes. This was particularly evident in France, where tramways have been the tool used by cities to transform and redevelop their historic centres (Boquet, 2017). To this renovated concept of tramway, in the 1972, the U.S. Urban Mass Transportation Administration gave the name Light Rail, later developed into Light Rail Transit (LRT).

Nowadays, Bus Rapid Transit (BRT) and Light Rail Transit (LRT) are the two types of rapid transit modes that are often proposed one against the other for their similar characteristics in terms of capacity, travel time, level of priority and separation from the external road traffic. It is because of their similarities that it is not clear to what extent public transport users would prefer one or the other and according to which characteristics these two systems are perceived differently. And it is also because of those similarities that policymakers often do not really know which system should be implemented, creating the ground for strong political debates between the supporters of one system or the other.

In the following paragraphs, the problem definition, the research objective, the approach, the research relevance and the thesis outline will be presented.

1.2. Problem definition

BRT and LRT share similar characteristics and serve similar purposes. They are, in fact, very similar in terms of average speed and service capacity (not to be confused with vehicle capacity) that they can offer, and they can both be considered as valid solutions to satisfy the transport needs of medium demand corridors (Vougioukas, et al., 2008). Because of these similarities, it is difficult for policymakers to decide which of the two is best worth the investment, especially because it is not clear which of the two modes is mostly preferred by the public transport users, why and according to which vehicle/system characteristics. Understanding what people prefer can guide the decision-making and might improve the chances of obtaining high ridership and therefore a successful investment. For policymakers it is a real dilemma, that often gives rise to strong political arguments.

Several studies have confirmed that there exists the so-called “tram or rail bonus”, meaning that people have a slight preference for tram/rail-based systems over the bus [(Scherer & Dziekan, Bus or Rail: An Approach to Explain the Psychological Rail Factor, 2012), (Fell, Axhausen, Heidl, & Haupt, 2001), (Bunschoten, Molin, & van Nes, 2013)]. It is very well possible that this bonus also exists for LRT over BRT, but to this day it is not known to what extent and for which reasons. The tram bonus studied in literature is usually found for traditional bus and tram, however, due to the different system characteristics of BRT and LRT (they use different type of vehicles running on different type of infrastructure with different speeds and different stop spacing compared to traditional bus and tram) it is possible that this bonus exists to a different extent. If a rail bonus for LRT is confirmed and if the technical/system motives behind it are revealed, these insights could be used to understand how bus-based systems might be improved in such a way that their system/vehicle quality and ride experience is aligned to the ones perceived for trams, or to decide which system fits a particular situation according to the available budget.

To gain information about the reasons behind the “LRT bonus”, if its existence is confirmed, there is the need to study more in detail which characteristics influence the difference in mode preference. To do so, perceptions play a key role [(Klein, 2017), (dell’Olio, Ibeas, & Cecin, 2011)]. Knowing how BRT and LRT are differently perceived in terms of vehicle and system characteristics, and how these perceptions influence each other, might be the key to understanding what is inside the rail bonus black box.

Although the understanding of people’s preferences and perceptions could give some clarity on what the public prefers and what their tread-offs are for their daily commute, it would not solve the political debate behind the system choice. Other than users ‘preferences, there are other variables that have to be considered when deciding for a new transport system: budget available, urban renovation, new housing developments, economy. However, the political arena often do not consider these mobility-related aspects when deciding for a new transport mode. It is often an ideological choice (van Der Bijl, Bukman, & van Oort, 2018). Because of this, heated political arguments generally arise during the planning process and system choice for a new transport infrastructure: in North America and Australia, the debates about BRT and LRT projects are often key topics of the political election campaigns (Hamilton LRT plan represents the most recent example). From the BRT supporters, it is claimed that LRT is too expensive and that a BRT offers a better value for money. On the other hand, LRT advocates claim that BRT is not able to achieve the same performance level of a light rail and that BRT does not attract as many users as the LRT does. As stated in Hensher & Waters II (1994) and in Hensher (2007a), the political choice between BRT and LRT is often transformed into a blind commitment for one technology, rather than rational and reasoned arguments. For this reason, it is interesting to explore what lies behind policymakers commitment and perceptions for BRT and LRT, since the image that they have about a certain mode might influence the final decision.

1.3. Research objective

Given the problem defined in the previous section 1.2, the aim of this research in threefold: first, it tries to verify if and to what extent the rail bonus applies to LRT compared to BRT; second, it aims at understanding the factors which might be responsible for the rail bonus by analysing people’s perceptions and how these influence each other; and third, it aims at exploring how policy makers perceive BRT and LRT and how they would make a choice between one system or the other. More in general, this study wants to give a contribution to the scientific literature on understanding how preferences and perceptions between BRT and LRT differ. The target group of this research is composed by public transport users and policymakers. Public transport users because they are mostly affected by new public transport infrastructure and services and mostly affected by policymakers decision. Policymakers because they are responsible for making the final decision between BRT and LRT. For these reasons, the following main research question is addressed:

In what way do preferences and perceptions between BRT and LRT differ for public transport users and policymakers?

To answer the main research question, the following sub-questions are addressed:

a) To what extent do public transport users' preferences between BRT and LRT differ and for which mode-related characteristics?
b) In what way do public transport users' perceptions between BRT and LRT differ?
c) How do public transport users' perceptions influence each other?
d) How do policymakers differently perceive BRT and LRT and how would they make a choice?

1.4. Research approach

The objective of this research is to understand the differences in preferences and perceptions between BRT and LRT for public transport users and policymakers. From literature, there is some indication that there exists a bonus for rail-based modes compared to bus. This study wants to verify the existence of this bonus for LRT compared to BRT and to give insights into the factors that might be causing it. To do so, this research follows an eclectic approach by applying three different methodologies: users' preferences (research sub-question a) are captured by a stated preference experiment, whose results are used to estimate a discrete choice model, which gives information about the possible existence of a rail bonus and about the trade-offs that respondents make when making choices; users' perceptions (research sub-question b) are modelled using the results of likert-type questions, which are used to estimate psychological network models, a recently developed statistical tool which allows to visualize the interrelation existing between variables representing perceptions (research sub-question c): the structure of the networks and the possible presence of clusters can give an indication about the perceptions construct and might explain certain behavioural characteristics not captured by the discrete choice model. The data required to answer these first three questions is collected via a single survey. Question d is answered in a qualitative way by one-to-one interviews with policymakers, with the aim of not only understand how they perceive BRT and LRT but also how the decision-making process should take place. Interviews also provide valid inputs used for the survey design. Figure 1 schematizes the general approach followed in this study.

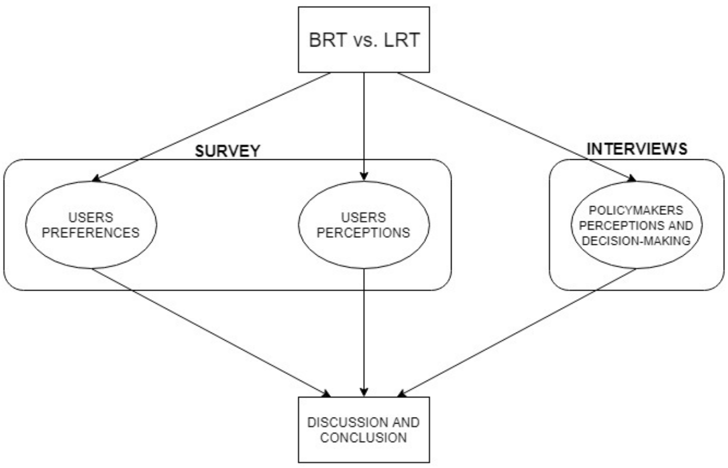

Figure 1: scheme of the threefold approach applied

1.5. Scientific, societal and company relevance

Scientific relevance: as mentioned in 1.2, the existence of the rail bonus has been verified in different studies. However, it has never been tested for BRT and LRT and therefore it is not known if and to what extent this bonus exists for LRT compared to BRT. Moreover, it is not clear what lies behind the existence of this bonus and if it is related to particular system or vehicle characteristics. This research wants to put some light into this black box by verifying the existence of the LRT bonus, to what extent it impacts the users preferences, and by analysing differences in perceptions about system and vehicle characteristics for BRT and LRT that could explain the bonus. The study of the interactions between perceptions using a new methodology (network psychometrics) also contributes to the scientific literature by testing how new statistical tools could help understanding the transport phenomena.

Societal relevance: the political arena is often divided when deciding between a rail or bus-based system. It appears that policymakers have a certain perception and a very well defined preference for BRT or LRT. With this research the aim is to understand why policymakers are so strongly attached to one of these two modes and what they consider important during the planning phases of a new transport infrastructure such as a BRT or LRT. The results of this research will also provide additional information about which characteristics should be improved to make BRT and/or LRT more attractive. Furthermore, the information acquired in this work can be used by policymakers to provide better information to the public, other than supporting the political debate.

Company relevance: this research is conducted on behalf of Royal HaskoningDHV. The company is mostly interested in the commercialization of research results and techniques. In this particular case, Royal HaskoningDHV is interested in knowing what lies behind the existence of the rail bonus (if verified). Knowledge about users' preferences would allow for better advices to the policymakers, other than providing more accurate ridership estimations. The information acquired by the perception analysis, might be used to advice the clients on how to improve the system or which system is better suited for a particular situation. Information about users' perceptions would also grant the possibility to cooperate with vehicle manufacturers by providing advices about how to improve the user experience on board of the vehicles. Moreover, the company is interested in knowing why policymakers are so strongly attached to the idea of implementing a BRT or an LRT and to investigate whether a "blind commitment" towards one of these two modes bias the final political decision. This knowledge would allow the company to better advice its clients and to better address the arguments in favour of BRT or LRT, according to the circumstances, and to support the clients in the choice for the most optimal system, given the available budget.

1.6. Report structure and thesis outline

The report is structured as displayed in Figure 2: chapter 2 will present the literature review available about the BRT/LRT debate, the rail bonus and BRT/LRT preferences and perceptions; chapter 3 will give some indications about the data collection methods; chapter 4 will introduce the case study, will discuss the questionnaire and choice experiment design and will show how data is collected; chapter 5 will focus on the data and perceptions analysis; chapter 6 will present the modelling methodologies, providing theoretical background information on discrete choice modelling and network psychometrics; chapter 7 will present the discrete choice model estimations and will discuss the key findings about the rail bonus and the public transport users preferences; chapter 8 will show the results of the network modelling and the interpretations of the perception structures; chapter 9 will report the key points unveiled during the one-to-one interviews with policymakers; chapter 10 brings together all the findings from the three different approaches; finally, chapter 11 close the report with conclusions and recommendations.

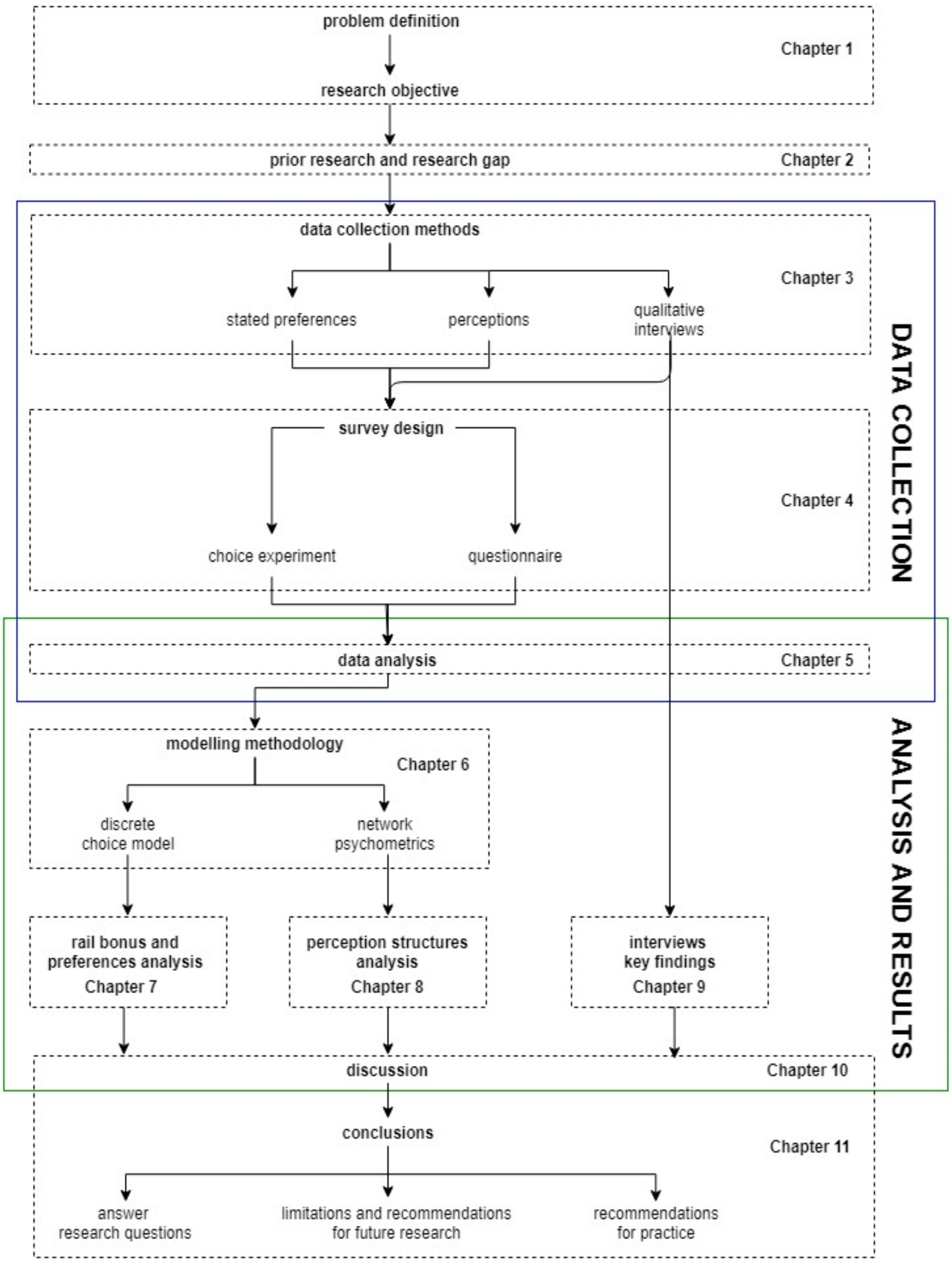

Figure 2: research outline and report structure

1.7. Conclusion introduction

In this chapter, the problem and the aim of the research have been defined. It has been explained that there is a dilemma when policy makers have to choose between BRT and LRT because of their strict similarities, and it is not known what are the preferences and perceptions that users have for these modes. It has also been highlighted the existence of the rail bonus, for which it is not known to what extent applies to LRT systems compared to BRT and according to which vehicle or system characteristics. As defined by the research question and sub-questions, the aim is to determine how BRT and LRT differ in terms of preferences and perceptions and to define which perception factors might determine this difference and their mutual interactions. Moreover, the political arena is often filled with debates when deciding between BRT and LRT because of personal commitment of policymakers towards one system or the other. The aim of this research is also to investigate how policymakers perceive BRT and LRT and how they make decisions during the planning phase of a new transport project. Finally, it has been highlighted the scientific, societal and company relevance for this research and the structure of the report.

2. PRIOR RESEARCH AND RESEARCH GAP

The aim of the literature review is to construct the theoretical framing of this research, in particular to identify the scientific gaps which justify the reasons behind this work. More in particular, it describes how this work relates to prior research and it highlights the relevance and originality compared to the existing literature.

The main goal of this work is to verify to what extent the rail bonus applies to LRT compared to BRT, to identify to what extent preferences and perceptions of public transport users differ between BRT and LRT and how perceptions relate to each other. Moreover, it aims at understanding how policymakers perceive BRT and LRT and how they would make a decision for new infrastructures. This chapter does not include the literature related to the methodologies applied in this study, which is more thoroughly discussed in chapter 6.

To find relevant literature, the following websites are consulted: sciencedirect, scopus, google scholar, TU Delft repository. Key words most often used are: BRT, bus rapid transit, LRT, light rail transit, BRT/LRT preferences/perceptions, BRT/LRT decision making, BRT/LRT cba/cost-benefit analysis, public transport perceptions, mode preferences. Once relevant publications are found, the method of snowballing is used to acquire additional literature.

In the following paragraphs, the literature review is organized as follows: 2.1 looks into papers addressing the BRT/LRT debate and the so called "blind commitment"; follows in 2.2 a brief list of studies that proved the existence of the "rail bonus" and literature that looked into BRT and LRT preferences; 2.3 gives an overview of studies that tried to look into users and policymakers' perceptions of BRT and LRT; finally, 2.4 concludes the chapter with a summary of the main research gaps that are found in literature and that are addressed in this research. Table 1 summarizes the reviewed literature with the main findings.

2.1. The BRT/LRT debate

The BRT versus LRT debate commenced as soon as these two systems started to increase in popularity. Already in the 80's, the academic world started wondering if policymakers were making decisions rationally or only due to personal preferences. John Kain (1988) was the first one introducing the expression "blind commitment", referring to the fact that a decision between a light rail or bus was only taken according to the policymakers personal preference. Kain states that there exists an "emotional and psychological attachment to rail" making it difficult to address the discussion for the system choice.

The concept of "blind commitment" was few years later recalled by Hensher & Waters II (1994), in which it is said that "*the enthusiasm (almost blind commitment) for LRT has caused many to overlook the potential for more cost-effective bus systems*". More than 10 years later, in 2007, Hensher recalled once again the concept of "blind commitment" pointing out the underestimated benefits for cheaper options such as those offered by the at-the-time so-called bus-based transitways [(Hensher, 2007a) & (Hensher, 2007b)]. More recently, Hensher argues again that the debate on choice versus blind commitment is resurfacing, in particular in Australian cities (Hensher, 2016): "*part of the problem may appear to be a perception that any PT option associated with the word 'bus'* […] *conjures up images of noisy polluting buses in mixed traffic congestion*". It is interesting to notice that Hensher refers to "perceptions" as the main cause of prejudices towards the bus. Van der Bijl et al. (2018), when introducing the arguments in favour of light rail, agree that "*deciding whether or not light rail is an effective or at least suitable mode for a certain public transport task is often subject to ideological debate*".

In some cases, the LRT supporters have accused the BRT counterparts of "*excessively sponsoring systems like BRT only with the purpose to facilitate road transport and oil industry lobbying*" (Lopez Lambas, Giuffrida, Ignaccolo, & Inturri, 2017). The debate is recurrently centered around the costs required to build, operate and maintain vehicles and infrastructure. It is often claimed that BRT is more flexible and cheaper to realize compared to LRT because of the infrastructure. However, those who make such a claim, often compare a fully separated LRT with a "BRT-lite" (cheaper and with less separation) (Levine, Singer, Merlin, & Grengs, 2018). In Levine et al. (2018) it is stated that by comparing a fully separated LRT with a bus service which does not meet the requirements of a real BRT, is misleading not only in terms of system performance, but also in terms of costs. Hodgson et al. (2013) states that the cost differences between BRT and LRT are less than is often claimed, however it is pointed out the major advantage given by bus-based systems in terms of flexibility.

The research of relevant literature on the BRT/LRT debate, reveals that part of the academic world points out the existence of a so-called "blind commitment" for rail-based systems from a large share of policymakers, while another part of scientists reveals that the support of BRT systems hides underneath a silent support of certain lobbies, or that the comparison between BRT and LRT systems in terms of costs and performances is not done fairly. This first brief part of the literature review confirms that there exists a debate over the choice between BRT and LRT, and that this debate not only involves policymakers, but also the academic world.

2.2. Rail bonus and BRT/LRT preferences

The rail bonus reflects the idea that travellers have a higher preference for rail-based transport systems compared to bus. Axhausen et al. (2001) defines the "rail bonus" as "*the inherent superiority of rail-based public transport options over bus-based alternatives, all other things being equal*".

The existence of this bonus has been verified in several studies. Fell et al. (2001) conducted a study in Dresden showing that there is a consistent (but weak) preference for rail option in terms of value of time and overall evaluation of vehicles, but that this preference is counterbalanced by a higher transfer penalty. Scherer & Dziekan (2012) in their article present the results of two studies conducted in Germany and Switzerland: it is concluded that there exists a so-called "psychological rail factor" of 63% for regional train and 75% for tram compared to bus. The studies also highlight that this rail factor is profoundly charged with "emotional and social attributions", which account for 20-50% in the different share preferences for bus, rail and tram (Scherer & Dziekan, 2012). More recently, a study conducted in the Netherlands confirmed that the tram was preferred over the bus in Amsterdam, Rotterdam and The Hague, but that the extent of these preferences is highly dependent on how people living in certain cities are familiar with the tram (Bunschoten, Molin, & van Nes, 2013). Currie (2005), on the other hand, did not find any added value for rail systems: he studied the relative passenger attractiveness of BRT systems compared to other transit modes. The research found that passengers "*value trip attributes for BRT and rail modes in a similar manner*" concluding that BRT systems should be as effective as rail systems in generating patronage.

Overall, studies focusing on the preference between BRT and LRT are limited, especially in Europe. Among the literature available, a study conducted by Balbontin et al. (2006), which included five developed countries, has shown the impact of familiarity and positive/negative experiences on riding a certain mode on mode support, revealing also that a poor experience on an LRT "*has helped the support for BRT even where BRT has not been experienced*". More recently, Chinnok et al. (2013) conducted a study in Nantes where both BRT and LRT were in operation, trying to capture people preferences. Nantes was an appropriate case study since users were familiar with both modes. The results showed that the overall preference was for LRT, but it is argued that this larger preference might be caused by the larger LRT network. Mulley et al. (2014) investigated if the preference for BRT and LRT varied across geographical jurisdictions. They concluded that the differences are present and that they are mainly caused by the familiarity that a city has towards BRT or LRT (Mulley, Hensher, & Rose, 2014).

This literature review on rail bonus and BRT/LRT preferences shows that the rail bonus was found in several studies, but it is also found to be highly dependent on mode familiarity and ride experience. However, the review also shows that literature about the added value of LRT compared to BRT is limited and that the extent and reasons behind the LRT preferences over BRT are not clearly addressed yet.

2.3. Users and policymakers perceptions

In the introduction it has been mentioned the importance of perceptions in public transport. Perceptions may be the key for identifying the reasons behind certain preferences and support for BRT or LRT and might explain the rail bonus. Perceptions are strongly related to the image that people have towards a certain mode (Cain, Flynn, McCourt, & Reyes, 2009). Travellers perceptions, in particular, profoundly impact the public transport usage and travel behaviour in general (Klein, 2017), and they might have a strong influence on ridership values (Guiver, 2007) (Stradling, Carreno, Rye, & Noble, 2007).

Hensher (2016) referred to “perceptions” as the main cause of negative prejudices towards the bus (as pointed out in section 2.1). In Mulley et al. (2014) it is given to perceptions the main cause affecting mode preferences for all stakeholders, in particular users and policymakers. Moreover, as stated by Hensher (2016): “*although the predominant focus of traveller behaviour research has been on studying the choice of mode for specific trips, a growing challenge is to understand why stakeholders (i.e. the community at large) in specific geographical jurisdictions, when asked, overwhelmingly support one PT mode over another, regardless of whether they use specific modes*”.

It appears that perceptions play an important role on mode preferences and contribute to the image users and stakeholders have towards specific modes. Several studies tried to investigate which factors might contribute at forming certain perceptions towards transport modes. Ride experience seems to be one of the most significant ones. Stradling et al. (2007) conducted a survey in Edinburgh to investigate which underlying factors mostly influence the bus ride experience. The results varied mostly with age and frequency of bus use, and safety emerged to be the most concerning aspect for bus users. Moreover, “*harsh braking, jerky driving and rude drivers; smoking upstairs; cramped, crowded and overheated buses; mobile phones and noisy passengers*” all loaded on the same factor, “*suggesting a common psychological mechanism*”.

The perceived quality of public transport was also evaluated in the study conducted by dell’Olio et al. (2011) and it was found that “*waiting time, cleanliness and comfort are shown to be the public transport variables that users most valued, but the degree to which they are valued varies according to the category of user*” and “*for potential users the more important variables when defining expected quality from public transport are waiting time, journey time and above all, level of occupancy*”.

Some work on perceptions relative to BRT and LRT was done by Hensher & Mulley (2015), who collected data from six Australian cities where individuals were asked to rate two BRT and two LRT designs presented as physical images from which a full rank mixed logit model was developed to “*identify candidate sources of influence on image preferences*”. The results suggest that the BRT has a general bad image compared to LRT, mostly because of its direct association to traditional bus and a very high preference for non-bus images has been observed. Income was found to play an important role. Another important study on perceptions for BRT compared to other rail systems was conducted by Cain et al. (2009) which tried to assess to what extent BRT can capture the image of rail-based transit, and to understand which factors might impact the different perceived quality between them. The research concluded that there exists a difference in perceived quality of transit systems, and this difference is highly related to the level of investment required to provide the service.

Rather limited literature is found on the underlying relations between mode perceptions. Determining how perceptions interact and influence each other gives an important insight into people’s behaviour and might give information on how to intervene on the system. Wu and Yang (2016) tried to explore the relationship between service attributes using Bayesian Networks to assess their influence on passenger overall satisfaction. De Oña et al. (2012) and Garrido (2014) proposed data mining techniques to capture the relationship between service attributes. However, these studies do not give information about the strength of the relation between the perceived mode characteristics, and none focused on studying the perception construct difference existing between BRT and LRT.

Finding relevant literature about the perceptions that policymakers have on public transport, and in particular for BRT and LRT, seems more challenging. Chowdhury et al. (2018) states that “*there is a certain alignment in perception between the policymakers and frequent users*” and that both value perceived network integration the most, followed by fare and ticketing attributes. The main difference between users and policymakers involved the integrated timed-transfer, which was ranked as key attribute by users but, although acknowledging its importance, policymakers did not select this as key perceived attribute, stating that financial and resourcing requirements of implementing this feature was the main concern. Finally, Brispat (2017), in his thesis, developed a new decision making tool by studying how perceptions influence the decision making between bus and rail-based systems. The study found that costs and patronage were the main indicators used by policymakers for their decision.

This section of the literature review revealed the importance of perceptions on mode preference. Numerous studies have been conducted trying to identify which aspects are mostly important for the evaluation of the ride experience and perceived quality of public transport in general. However, the literature review also shows that there is rather limited literature on perceptions for BRT and LRT, in particular to understand how these perceptions vary and relate to each other for these two modes. No literature was found about policymakers' perceptions for BRT and LRT.

Subject	*Literature*	*Main findings*
Blind commitment	(Kain, 1988), (Hensher & Waters II, 1994), (Hensher, 2007b), (Hensher, 2007a), (Hensher, 2016)	Existence among policymakers of a blind commitment for rail-based systems
BRT/LRT debate	(Lopez Lambas, Giuffrida, Ignaccolo, & Inturri, 2017), (Levine, Singer, Merlin, & Grengs, 2018), (Hodgson, Potter, Warren, & Gillingwater, 2013)	Influence of certain industries and lobby in the decision making, and debate about cost differences, a financial comparison that is often not done fairly
Rail bonus	(Fell, Axhausen, Heidl, & Haupt, 2001), (Scherer & Dziekan, 2012), (Bunschoten, Molin, & van Nes, 2013), (Currie, 2005)	Overall, slightly higher preference for rail-based systems, but is often dependent on how familiar people are with the vehicles
BRT vs. LRT preferences	(Balbontin, Hensher, Ho, & Mulley, 2006), (Chinnock, Routaboul, Swanson, & Gleave, 2013), (Mulley, Hensher, & Rose, 2014)	Overall, LRT receives higher appreciation compared to BRT, but that is again dependent on familiarity and the specific factors behind the higher appreciation are not completely clear
Users perceptions	(Cain, Flynn, McCourt, & Reyes, 2009), (Klein, 2017), (Guiver, 2007), (Stradling, Carreno, Rye, & Noble, 2007), (Mulley, Hensher, & Rose, 2014), (Hensher, 2016), (Stradling, Carreno, Rye, & Noble, 2007), (dell'Olio, Ibeas, & Cecin, 2011), (Hensher & Mulley, 2015), (Cain, Flynn, McCourt, & Reyes, 2009)	Definition and importance of perceptions, in particular for public transport usage and travel behaviour; high impact determined by perceived safety, comfort and ride experience; image of the vehicles rather relevant as well
Policymakers perceptions	(Chowdhury, Hadas, Gonzalez, & Schot, 2018), (Brispat, 2017)	Similarities between policymakers and frequent public transport users; design of a decision-making tool based on policymakers perceptions

Table 1: relevant literature per subject and main findings

2.4. Conclusion prior research and research gap

The literature review listed in this chapter shows that there is indeed a debate between BRT and LRT supporters, both within policymaking and academic world. From literature, it is also clear that the rail bonus existence is verified, although with exceptions and with high context-dependency, in particular relative to mode familiarity. However, the extent to which this rail bonus relates to LRT compared to BRT is still unknown, together with the factors that might be responsible for its existence. Literature has also shown the importance of perceptions in public transport, in particular in terms of ride experience and perceived quality of the service. No dedicated research has been found on studying to what extent perceptions between BRT and LRT differ and how they relate and influence each other. And finally, it is not known how BRT and LRT are differently perceived by policymakers.

A. DATA COLLECTION

3. DATA COLLECTION METHODS

This study follows an approach that includes three different methodologies, as mentioned in the research approach in section 1.4: user preferences and the existence of the rail bonus are explored using discrete choice modelling; user perceptions are analysed via likert statements and psychological network models; policymakers perceptions are qualitatively assessed via one-to-one interviews. The data required for these analyses is acquired in two ways: a survey (discussed in section 3.1) and interviews (discussed in section 3.2).

3.1. Survey

Different data collection methods exist and they typically include focus groups, observations and interviews, among which there are telephone, face-to-face and online interviews (Figgou & Pavlopoulos, 2015). For this research, an online survey form is used, since the length of the survey would not allow a face-to-face approach, also considering the high amount of respondents required.

Respondents are recruited by distributing, at strategic locations, flyers containing the link and QR-code addressing to the online form. The survey contains two main sections: the stated choice experiment, aimed at capturing and quantifying the preferences that people have for BRT and LRT, and the section with the statements aimed at evaluating their perceptions. In the following sections, these two data collection methods are described and the way respondents are recruited is shown.

3.1.1. Stated vs Revealed preferences

To elicit preferences, two main methods exist: revealed and stated preferences. Revealed preference (RP) experiments allow observing real choices made by the respondents, while stated preferences (SP) are able to capture the behaviour of the respondents in non-existing choice situations (dell'Olio, Ibras, & de Oña, 2018).

According to Sanko (2001), RP can only give information about the actual behaviour on existing alternatives, although the observation of real choices results in high validity of the estimated models. Moreover, RP only provides one observation per respondent, thus it requires a high amount of participants to obtain significant results. On the other hand, SP can also include hypothetical situations with non-existing alternatives and multiple responses per respondent are possible, limiting the total amount of participants required. Additional advantages of the SP method includes the possibility to have a wide range in the attribute levels, clear choice sets and control over the multicollinearity among the attributes (Sanko, 2001). The major drawback of SP is the hypothetical bias, that is the difference between the stated and the observed behaviour or, simply put, a difference between what people say and what people actually do (Loomis, 2014).

Since the case study used to collect the data includes an hypothetical situation in which an existing BRT line is replaced by a light rail (see case study in 4.1) it is only possible to collect stated preferences, and therefore this data collecting method will be used for capturing users' preferences.

In this method, respondents are presented with a number of choice scenarios in which attribute values are varied in each set. The respondents are asked to select their favourite alternative within the choice set (Train, 2002). As shown in the coming section 4.2.2, the choice sets are designed in a way that minimize the correlations between attributes. The data collected in the stated preference experiment, is used to estimate discrete choice models, as will be explained in section 6.1.

3.1.2. Perceptions

According to The SAGE Encyclopaedia of Qualitative Research Methods, "*perception is a mode of apprehending reality and experience through the senses, thus enabling discernment of figure, form, language, behaviour, and action. Individual perception influences opinion, judgment, understanding of a situation or person, meaning of an experience, and how one responds to a situation. A common way of defining perception is "how we see things"*" (Given, 2008).

McDonald (2011) states that a perception is composed of three essential attributes:

a) sensory awareness or cognition of the experience;
b) personal experiences that create a lens for interpreting and understanding a phenomenon;
c) comprehension that can lead to a response.

The task of capturing perceptions consists of inferring the above-mentioned effects and, although perceptions are highly peculiar for each individual, it is possible to find commonalities within certain groups of people (Ho, 2016).

In experimental psychology research, various approaches exist to capture perceptions: self-report measures, magnitude estimation, magnitude production, method of adjustment, forced-choice, and Likert-scale reporting (Lavrakas, 2008).

For this research, a likert-scale approach is adopted, given that it is the most typical method used for perception analysis (Ho, 2016). Most commonly, likert-scale procedure consists of five ordinal response categories: mostly agree, agree, neutral, disagree, and mostly disagree, but variations are possible (7, 9 or 10 scale points are commonly seen in literature).

Various advantages can be assigned to this type of methodology: first, respondents are generally familiar with this format, if written in an easy and appropriate language; secondly, it is a quantitative method, meaning that the findings can be analysed in a numerical way and allows to compare the final scores of one individual in respect to the others, although a scale score should be interpreted for what it is, a mere number that tries to approximate how a respondent feels about a certain aspect, which can be highly influenced by the context during which the respondent is completing the survey.

There are, however, also disadvantages related to this methodology: first, the study is completely controlled by the researcher, meaning that the general outcome of the study is only the result of what the researcher decided to include in it, and it is often a critical task the decision of which aspects should be considered and which are thought not to have an impact on the general question that needs to be answered with the study. The consequence of this approach, is that other relevant aspects might be excluded from the study. For this reason, an intense literature review, focus groups and/or preliminary interviews are important practices to be considered before designing the final questionnaire. The other disadvantage is that to obtain meaningful results, large samples are required.

The results of this part of the survey provides the input required to estimate network models, which enable to analyse the relations between perceptions and the perception structures, as it will be shown in chapter 8.

3.1.3. Respondents recruitment

The final survey has been designed on a Google Form and respondents have been recruited mainly by handing out flyers containing a link and QR-code to the online form, and via personal network of people. An example of flyer handed out can be found in Appendix 10.

Given that the main target group of this research are public transport users, it has been decided to hand out flyers and recruit respondents at public transport stops, with the particular objective to capture bus line 28 and tram users, which are the main examples of BRT and LRT lines used for the case study. The locations selected for the recruitment are the following:

- Tram stop at Utrecht Centraal (Jaarbeursplein)
- Bus stop at Utrecht Centraal (city centre side)
- Bus stop Rijnsweerd Noord
- Bus stops at the Utrecht Science Park

The flyers have been distributed during 5 working days between the 17th and 28th of June 2019, alternating peak and off-peak hours. The days were average, with mixed weather conditions of sunny warm days and colder rainy days.

About 4000 flyers have been handed out and a total of 370 individuals completed the survey, with a response rate varying between 10% and 12%, according to the location and time of the distribution. About 92% of the respondents that completed the survey have been recruited from the flyers, while the residual 8% of the responses come from personal social networks.

3.2. Interviews

Interviews play an important role in this research, since they provide inputs for the survey design and for the qualitative assessment of policymakers perceptions of BRT and LRT. Some of the interviewees also cover the role of public transport consultant or professors at university. These people, therefore, can be considered to be public transport experts.

The main objective of talking with public transport experts is to get insights into the BRT and LRT technical aspects and their differences. Moreover, they provide information about aspects usually taken into account from the user perspective when deciding to design a rapid transit system. Thus, these interviews give valid inputs for the survey design, in particular for the selection of the attributes to be included in the stated choice experiment and for the formulation of the perception statements (see chapter 4).

Interviews with policymakers are required to answer the research questions relative to how they perceive BRT and LRT and if it is true that there exist a “blind commitment” for rail-based systems as discussed in 2.1. The goal is also to understand how the decision-making process takes place when deciding between BRT and LRT and if in their opinion the public should be involved into the process.

In total, 6 contacts of policy makers are acquired via the university and Royal HaskoningDHV. To some interviewee it has been promised that no name would be added to their statements, therefore, to protect their anonymity, the name of none of the policymakers/experts interviewed is presented. The people interviewed include two consultants working on public transport projects, one university professor (who is also often involved in the design and decision-making of some public transport infrastructures and services), one politician, who is also involved in the CROW foundation (a non-profit organization working on infrastructures, traffic, transport and safety projects), and two civil servants working in the mobility/infrastructure departments of the province of Utrecht and municipality of Rotterdam respectively.

The interview protocol consisted of a semi-structured conversation, favouring a more natural flow of ideas exchange rather than a more impassive Q&A that would create a colder environment. The only structure relates to the main themes presented to the interviewee: different perceptions between BRT and LRT, existence of a “blind commitment” among policymakers, the decision making approach that they would follow to decide between BRT and LRT, and finally the importance of involving the citizens in the decision making process.

3.3. Conclusion data collection methods

This chapter presented the data collection methods available in literature and those selected for this study. The threefold approach presented in 1.4 requires the construction of a survey to be distributed among public transport users with the aim of collecting their preferences and perceptions of BRT and LRT. It has also been shown that the data is collected at strategic locations, namely bus and tram stops and that a total of 370 individuals compiled the survey. Moreover, the approach also includes one-to-one interviews aimed at getting inputs for the survey design and to understand policymakers perceptions for BRT and LRT and their approach for the decision-making.

4. SURVEY DESIGN FOR THE UTRECHT CASE STUDY

This study aims at mapping people's preferences and perceptions by collecting data via a survey. To do so, a case study is necessary to provide context to the respondents, which gives more realism and it increases the validity of the responses. Being familiar with a location and the transport modes object of the study, in fact, respondents might be more willing to provide truthful answers. This chapter introduces the case study and describes the steps taken to design the final survey. The case study is given in 4.1 with the reasons for selecting Utrecht and a short description of the BRT and LRT lines used as reference. 4.2 gives the steps for the survey design, in particular the selection of the socio-demographic questions (4.2.1), selection of attributes and attribute levels for the choice experiment (4.2.2) and statements for the perception analysis (4.2.3). 4.3 concludes the chapter.

4.1. Case study

Research on peoples' preferences and perceptions requires a case study to be used as background for the data collection. Ideally, a valid case study for this research would include a city in which public transport users are familiar with both BRT and LRT. In the Netherlands, all major municipalities are served by busses, some have regular trams, but only few provide a BRT or LRT service. Even more difficult is to find a location with both. For this reason, Utrecht was chosen as city for the case study, since BRT and LRT systems are currently in operation.

Tram lines 60 (between the central station and Nieuwegein Zuid) and 61 (between central station and Ijsselstein Zuid) are considered light rail systems, although they still use the old high-floor vehicles. They are known to the users as "Sneltram" and the line number is not displayed on the vehicle. The route of these two lines is shown in Figure 3. Along their shared route between Utrecht Centraal and Nieuwegein Stadscentrum, the two tram lines operate during peaks with a headway of 7.5 minutes (8 runs per hour), and during off-peak they provide a headway of 15 minutes (4 runs per hour).

The tram service will be soon extended with the opening of the Uithoflijn between the central station and the USP, replacing current bus line 12. It will start the operations in the coming months introducing into service modern low floor vehicles. According to the official webpage of the Uithoflijn (Provincie Utrecht, Gemeente Utrecht), the line will operate 16 runs per hour during peaks and 4 runs per hour during off-peak and late evenings.

Figure 3: route of tram lines 60 and 61

Bus line 28, running between Vleuten, the central station and the Utrecht Science Park (USP) via the city centre, is considered a BRT system (Anahid & Leurent, 2011), although with some considerable limitations since it has no priority at the intersections and the dedicated infrastructure is available only on one section of its route. During rush hours, between Utrecht Centraal and the USP, main focus of the case study, line 28 is supported by the bus line 18, which operates on the same route and with the same type of vehicles. These two lines combined, during the morning and evening peaks, offer a frequency up to 18 runs per hour (about one every three minutes).

Figure 4 displays in violet the route of bus line 28 in its section between the central station and the USP, and in dashed blue line the route of the Uithoflijn. It can be observed that the upcoming Uithoflijn circumnavigates the historic centre, while bus line 28 runs right through it from west to east.

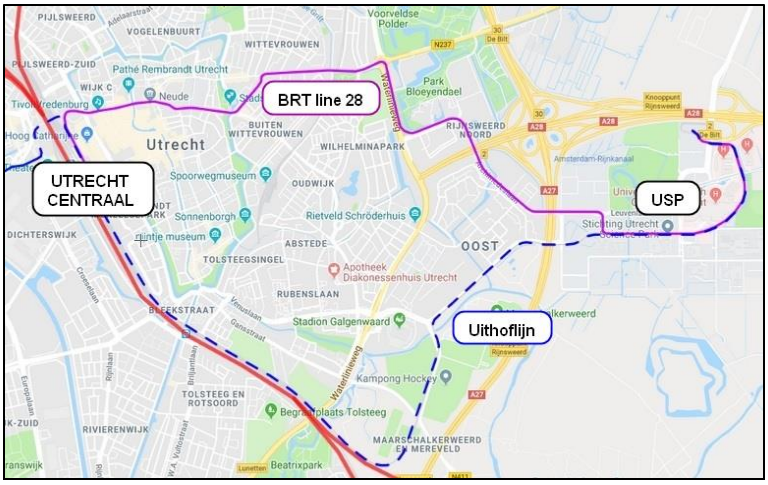

Figure 4: routes of bus line 28 via the city centre (in purple) and the Uithoflijn (dashed blue)

Additional data about the bus and tram systems in Utrecht can be found in Appendix 4.

Since the 80s, discussions about introducing a tramway in the city centre of Utrecht are regularly feeding the local political debate. During the adjustment works aimed at improving the road infrastructure for the introduction of the BRT service and during the recent construction of the Uithoflijn section that connects the existing tram to the central station, preparations have been made in the eventuality that a tramway line will be realized in the near future.

This is another reason to choose Utrecht as a case study to explore people's preference and perceptions for BRT and LRT: in the stated preference section of the survey (as it will be discussed in 4.2.2), the respondents are asked to imagine the hypothetical scenario in which bus line 28 is replaced by a light rail. Due to the numerous discussions and rumours about this possibility, the case study becomes more realistic for the respondents, who might be more willing to give a truthful answer following their personal needs and preferences.

4.2. Survey design

Following the definition of the research questions that need to be answered and the selection of the case study, it is possible to design the survey required for the data collection. The main goal is to gather sufficient responses that allow to analyse preferences and perceptions, and to estimate the two main statistical models that will be outlined in chapter 6: discrete choice model and network psychometric model. For the estimation of choice models, a stated preference approach needs to be used, as outlined in 3.1.1, while for perception analysis and estimation of the network models, likert scale statements are introduced, as mentioned in 3.1.2.

For this reason, the survey is divided into three sections: general socio-demographic questions, stated preferences choice experiment and likert scale statements for perception analysis. In the following sub-sections, more detail is given regarding these three survey components.

4.2.1. Socio-demographics

Numerous studies have shown the importance of socio-demographic variables on travel behaviour, finding a significant relationship between travel behaviour and income, age, gender, education, ethnicity (Syam, Khan, & Reeves, 2012).

Age is found to have an important relation with travel behaviour, which varies among children, young people, adults and older people, and is strictly related to the type of activities these groups perform: "*children are mainly engaged in educational and playing activities, young people mainly in educational and social activities, adults or parents in work-related activities and the elderly mainly in leisure and social activities*" (Syam, Khan, & Reeves, 2012).

Level of education is shown to have an impact on mode choice. For example, Limtanakoolet al. (2006) found that highly educated commuters in the Netherlands are more likely to travel by train. CBS statistics from the

Netherlands confirms that higher educated people travel longer distances (CBS, 2016). An indirect relation of education with car ownership is also often found significant. For example, Flamm (2009) found that higher educated people have higher environmental awareness which is indirectly linked to lower car ownership.

Gender is another socio-economic factor strictly related to travel behaviour: it has been shown that women are likely to travel more often than men but that their total travel distance is lower (Rosenbloom, 2006). This is confirmed by the CBS statistics for the Netherlands, showing that men travel 1.5 longer distances than women (CBS, 2016).

More relevant for this research, it is interesting to see how socio-demographics play a role in the preference for rail and bus-based systems. Regarding gender, in a recent study conducted in Lisbon, It has been found that women are 2.2 times more likely to choose bus or tram then men (Ng & Acker, 2018), but no difference was highlighted for the different preference for bus versus tram. In his research on the tram bonus, Bunschoten (2012) has shown that there are different values for the tram bonus within different segments of the population. In particular, he found a linear relationship between the tram preference and the level of income, age and level of education.

In another study conducted in Switzerland and Germany (Scherer & Dziekan, 2012) to explore the preference for train over the bus, it was found that younger people have a higher preference for train than older people and that older women are more likely to prefer the bus than older men. The same study confirmed that higher education level is highly correlated with a higher preference for train over the bus.

Balbontin et al. in their study about cross-cultural contrasts of preferences for Bus Rapid Transit and Light Rail Transit in the US, France, Portugal, the UK, and Australia (Balbontin, Hensher, Ho, & Mulley, 2006), found that gender was the only significant variable having an effect on preference for BRT or LRT (it was found that females have a higher preference for BRT in Portugal and France).

Following the findings of this short literature review on the impact of socio-demographic variables on travel behaviour and mode preference, and considering the total length of the survey, it is decided to include in the final survey the socio-economic variables displayed in Table 2.

For the purpose of this research, three questions are added to better understand the travel behaviour of the respondents in the city of Utrecht. The first aims at capturing which transport mode is most frequently used by the respondents during an average day, and the other asks how often people use bus line 28 and tram lines 60/61, main examples of BRT and LRT services operating in Utrecht.

QUESTION	OPTIONS
GENDER	Female Male Prefer not to say
AGE	Number
HIGHEST LEVEL OF EDUCATION COMPLETED	Primary school Lower vocational/secondary education Higher/intermediate/pre-university education Higher vocational education University / postgraduate
WHICH TRANSPORT MODE DO YOU MOSTLY USE ON AN AVERAGE DAY?	Walk Bike Car Train Bus Tram Other
HOW OFTEN DO YOU USE BUS LINE 28? **HOW OFTEN DO YOU USE TRAM LINES 60/61?**	4 or more days per week 1-3 days per week 1-3 days per month 1-11 days per year Never

Table 2: socio-demographic questions

4.2.2.Choice experiment

Choice experiments aim at collecting the necessary data to be used to estimate discrete choice models (methodology that will be explained in chapter 6). To construct these experiments, precise steps need to be followed to obtain a valid survey design, as explain with large detail in ChoiceMetrics (2018). The main steps consist of: (step 1) model specification, (step 2) generation of experimental design and (step 3) construction of questionnaire. These steps are described in detail in the following sections.

Experimental conditions

Before start specifying the model, it is important to define the context and the choice situation that the respondents have to consider when making their choices. The objective of the stated preference choice experiment is to gain insights into the trade-offs that respondents make to choose between BRT and LRT. In the description of the case study, it has been shown that currently bus line 28 (which is considered a BRT-type of service) connects the Utrecht central station to the Utrecht Science Park (USP) via the city centre. It has also been mentioned that discussions about introducing a light rail system on this corridor is being debated for a long time. Therefore, the respondents are asked to imagine the following scenario:

Imagine the hypothetical situation where the fast bus line 28 connecting the central station with the Science Park (university) via the city centre is replaced by a fast tram.
You will be presented with 9 scenarios and for each of them you are requested to make a choice between "fast bus" and "fast tram".

To notice the wording “fast bus” and “fast tram” used to describe the choice alternatives. The wording is important in survey design since it determines what the respondents imagine and keep into account while making their choices. It is decided not to use technical words such as BRT or LRT (not even Bus Rapid Transit and Light Rail Transit) since many people would not know what they mean. It is necessary to make the respondents understand that the alternatives are not the normal bus or tram, but something slightly different, with a different type of service.

Step 1: model specification

In this step, two important aspects need to be addressed: which alternatives to be included and which attributes need to varied in the experiments (ChoiceMetrics, 2018).

The decision about the alternative to be included in the choice experiment is straightforward: two alternatives need to be put next to each other, namely BRT and LRT. Respondents have to choose one or the other according to their preference and their trade-offs on the presented attributes. It is decided not to include a third option “none” to keep the structure of the survey easy, compact and to understand how respondents would make a choice even if they do not have a preference for any of the two modes.

The definition of the attributes to include in the experiment and their levels depend on what the research is trying to achieve. The definition of the right attributes implies a first literature review on similar studies to check what was included and what was found to have an impact on people’s preferences.

Ten relevant studies about mode choice that used stated preference surveys are analysed, and the most relevant attributes used are summarized in Table 3. Merely looking at the frequency of occurrence, it can be seen that travel cost, in-vehicle travel time and waiting time are the most recurrent attributes explored in mode choice studies. These three attributes are therefore retained in the choice experiment of this study. Transfers are ignored since in the context of the Utrecht corridor through the city centre they are not relevant. Access and egress times are also excluded from the experiment to focus only on the most important aspects that are directly related to BRT and LRT. Comfort is a more complicated one and it requires additional explanation.

	(Bunschoten, Molin, & van Nes, 2013)	(Chinnock, Routaboul, Swanson, & Gleave, 2013)	(Axhausen, Haupt, Fell, & Heidl, 2001)	(González, Marrero, & Cherchi, 2017)	(Currie, 2005)	(Hensher, Rose, & Collins, 2011)	(Hensher & Rose, 2007)	(Baidoo, Nyarko, & Mettle, 2015)	(Richter & Keuchel, 2012)	(Mulley, Ho, Ho, Hensher, & Rose, 2018)	SUMMATION
Travel cost (individual or grouped)		X	X	X	X	X	X	X	X		**8**
In-vehicle travel time	X		X	X	X	X	X		X	X	**8**
Waiting time/frequency	X			X	X	X	X	X	X	X	**8**
Transfer waiting time	X						X				**2**
Access time (individual or grouped per access mode)	X		X	X	X	X	X			X	**7**
Egress time (individual or grouped per egress mode)	X				X	X	X				**4**
Number of transfers			X		X	X			X		**4**
Comfort (expressed in different ways)		X				X		X	X	X	**5**

Table 3: studies that included the listed attributes

Various studies included comfort as attribute by expressing it in different ways. Sometimes in terms of seat availability, other times in terms of security, or crowding. Comfort might be one of the factors that determine the so-called “rail bonus” discussed in 1.2 and 2.2. A key role is played by the interviews with policymakers/experts (the main points are addressed in chapter 9 and the full content of the interviews can be found in Appendix 9), who listed a series of possible variables that might impact the rail bonus. What emerged from the interviews, is that two factors seem to be crucial in people preferences: how smoothly a vehicle rides and the crowding levels.

Thus, it has been decided to include these two additional attributes to explore if they indeed play a role in the final preference for BRT and LRT. The attribute “smoothness of the ride” was already used in Hensher (2015) and was found to be strongly significant. Regarding crowding effects, it has been decided to include an attribute called “crowdedness” in a way that in the different levels it would describe different situations in which seats are available, or not available in a crowded or non-crowded vehicle.

Selected the attributes, the next step consists of selecting the number of attribute levels and their ranges. For this research, it is decided to vary the attributes in three levels, so that the central level of travel cost, travel time and waiting time coincides with the current values observed for bus line 28. The lower and upper levels of these three attributes are determined in a way that equidistance between levels is preserved, while remaining within a realistic range, which increases the validity of the choice task. The current time and cost are observed on the website 9292.nl, which is a reference platform to derive current travel information in the Netherlands. Since the choice context refers to a trip between Utrecht central station and the USP, fare and times are observed for current trips made by bus 28 between Utrecht Centraal and Utrecht Heidelberglaan (which is located in the heart of the USP).

The current fare required to travel between the central station and the USP is observed to be €1.85. The upper and lower levels are varied by ± €0.50 (€1.35 and €2.35), which keeps the price within a realistic range. The current time required to run on the section under consideration is on average 19 minutes and the upper and lower levels are varied from the central level by ±5 minutes (14 and 24 minutes), which are also rather realistic. The average waiting time during peak hours is about 3 minutes, with lower and upper values varied by 2 minutes (1 and 5 minutes).

To verify whether the levels of these three attributes are indeed realistic, it is possible to calculate the a-priori value of time savings for travel time (VoTTS) and waiting time(VoWTS) by dividing the values of the travel cost (between levels) by the waiting and travel time ranges (again, between levels). The three levels for travel cost are €1.35, €1.85 and €2.35, therefore the two possible ranges are €0.50 and €1.00. The three levels for waiting time are 1, 3 and 5 minutes, therefore the two possible ranges are 2 and 4 minutes. In total, four combinations can be determined. Same is valid for travel time.

The general formula to calculate the value of time savings (for both VoWTS and VoTTS) is the following:

$$VoTS = \left(\frac{cost\ range}{time\ range}\right) \cdot 60$$

For example, combining the waiting time range of 4 minutes with the travel cost range of €0.50, it is possible to determine the first VoWTS as follows:

$$VoWTS = \left(\frac{€0.50}{4\ minutes}\right) \cdot 60 = 7.5\ €/hour$$

The time saving values are summarized in Table 4 and Table 5.

Travel cost savings	Waiting time saving	Value of waiting time savings (VoWTS)
€0.50	4 minutes	**7.5 €/hour**
€1.00	4 minutes	**15 €/hour**
€0.50	2 minutes	**15 €/hour**
€1.00	2 minutes	**30 €/hour**

Table 4: design values of the waiting time savings

Travel cost savings	Travel time savings	Value of travel time savings (VoTTS)
€0.50	10 minutes	**3 €/hour**
€1.00	10 minutes	**6 €/hour**
€0.50	5 minutes	**6 €/hour**
€1.00	5 minutes	**12 €/hour**

Table 5: design values of the travel time savings

According to the values of waiting time savings and travel time savings previously determined, the final ranges are the following:

$$7.5 \leq VoWTS \leq 30\ €/hour$$

$$3 \leq VoTTS \leq 12\ €/hour$$

To notice that the range for the VoTTS contains the average value measured in the Netherlands (which is €7.42 per person per hour, (Kennisinstituut voor Mobiliteitsbeleid, 2017)), confirming that these ranges are realistic. The range for the VoWTS is 2.5 times higher. This is in line with research (such as in Jara-Díaz & Tirachini (2013)) that confirms that travellers have a higher penalty for waiting rather than for riding on the vehicle, resulting in higher values of waiting time savings.

The definition of the attribute levels for smoothness of the ride and crowdedness requires more attention, because these two are categorical variables and wording is extremely important to make the respondents understand the context. The three levels assigned to crowdedness are the following: seats available, only standing (not crowded), and only standing (crowded). For smoothness of the ride, the three levels included in the choice tasks are: very smooth, generally smooth, and jerky. For this last one, an additional explanation is added in the description of the choice context to clarify the meaning of the three levels:

The fifth attribute "smoothness of the ride" can assume these values:

- very smooth: no sudden braking
- generally smooth: rare sudden braking
- jerky: sudden braking occurs often

Table 6 summarizes the attributes and their levels included in the final survey.

waiting time	1 min	3 min	5 min
travel time	14 min	19 min	24 min
travel cost	€1.35	€1.85	€2.35
crowdedness	seats available	only standing (not crowded)	only standing (crowded)
smoothness of the ride	very smooth	generally smooth	jerky

Table 6: final attributes and attribute levels included in the choice experiments

Having the attributes selected and their levels defined, everything is ready to generate the experimental design.

Step 2: generation of experimental design

As stated in ChoiceMetrics (2018), the generation of the final experimental design requires to make some important decisions.

First, it needs to be decided whether the design should be "labelled" or "unlabelled". An alternative is defined as unlabelled if the only scope of the name is to distinguish the alternative from the others (e.g. alternative 1, alternative 2, …), while it is defined as labelled if the name of the alternative carries characteristics that makes that alternative peculiar from the others (e.g. bus, tram, …). Experiments with unlabelled alternatives estimate generic parameters, i.e. a single parameter for every attribute, which is the same for all the alternatives that include that attribute. Labelled alternatives, on the other hand, allow estimating a different parameter for different alternatives for the same attribute. This allows verifying how differently an attribute is weighted among different alternatives (it allows, for example, to explore if travel time is perceived differently for bus and tram).

In the particular case of this research, it is decided to use labelled alternatives, namely BRT and LRT (to the respondents these are shown as "fast bus" and "fast tram"), allowing to determine if the five attributes included in the experiment are weighted differently between these two modes. It also allows determining if there is a difference in the monetary value of time savings.

Secondly, the design is attribute level balanced. The attribute level balance implies that each attribute level appears an equal amount of times for each attribute for all the alternatives (ChoiceMetrics, 2018). This ensures that parameters for each level have the same standard error and have an equal probability of becoming statistically significant.

Third, it needs to be decided which type of design to be used. There are multiple types of designs available. A *full factorial design* consists of all possible different choice situations. Although conceptually simple and allowing to estimate all main interaction effects, it produces too many choice situations (in this case it would produce 3^5=243 choice scenarios). To avoid this issue, *fractional-factorial* designs are often considered. Within this class of designs, there are two main sub-classes of designs to choose from: orthogonal and efficient designs. The main characteristic of orthogonal designs is that they guarantee zero correlations between alternatives and low standard errors (resulting in more reliable parameters); moreover, orthogonal designs are attribute level balanced.

The main issue with orthogonal designs is related to dominant alternatives: they do not reveal any information about trade-offs and should be avoided. However, by removing dominant alternatives correlations are introduced. To solve this issue *efficient designs* may be used. Efficient designs aim at balancing the utilities of the alternatives to avoid dominance, maximising the information about trade-offs and minimizing the standard errors of the parameters (Molin, 2017). The main drawback of efficient designs is that they require prior values for the parameters, that can be retrieved from previous research or from a pilot study.

For this study there are no reliable priors available, therefore it is decided to adopt an orthogonal fractional-factorial design. Given that the two alternatives are labelled and different parameters for every alternative are estimated, a simultaneous construction is used.

Finally, it has to be decided the amount of choice sets to be included in the experiment. For this research, the orthogonal fractional-factorial design results in 27 choice sets. Considering that this is a high number of choice situations to be presented to a respondent, it is decided to introduce blocking. Blocking allows reducing the number of choice sets by dividing the total number of choice situations in smaller blocks. Each block is not orthogonal anymore, but is attribute level balanced. For this research, the 27 generated choice scenarios are divided into three blocks, therefore each respondent is faced with 9 choice situations.

The final experimental design is generated using the software Ngene (ChoiceMetrics, 2018). The syntax used to generate the design is reported in Appendix 2.

Regarding the minimum amount of respondents required to get significant results, the following rule of thumb can be used (de Bekker-Grob, Donkers, Jonker, & Stolk, 2015):

$$N > 500 \cdot \frac{C}{T \cdot A}$$

where C is the number of attribute levels, T the number of choice sets and A the number of alternatives. According to this formula, 28 is the minimum number of respondents required for this research for each block (84 in total).

Step 3: Construction of the questionnaire

The software Ngene automatically produces the experimental design and the final choice situations to be included in the survey. The generated choice scenarios can be found in Appendix 3. An example of the choice task layout is displayed in Figure 5. The icons used to distinguish the two alternatives are as simple and schematic as possible, to avoid flaws in the choice behaviour of the respondents based on vehicles' characteristics instead of the attribute levels. Preferences which are not captured by the attributes will end up in the constant (this will be discussed in 7.2).

SCENARIO 5	**FAST BUS**	**FAST TRAM**
Waiting time	1 min	3 min
Travel time	24 min	19 min
Travel cost	€1.85	€2.35
Crowdedness	only standing (crowded)	seats available
Smoothness of the ride	very smooth	very smooth

Figure 5: example of choice task included in the final survey

4.2.3. Perceptions

The objective of analysing perceptions in this research is to gain more detailed insights into how people perceive BRT and LRT in terms of ride experience, service, and vehicle characteristics, and to visualize them in a network model to determine the perception construct and the relations existing between them. If the existence of the rail bonus is found, perceptions might explain it in a way that the stated choice experiment is not able to capture.

In this study, perceptions are captured with likert type statements, as discussed in section 3.1.2. The selection of the statements to be included in the survey involved mainly three steps: literature review, inputs from the interviews with policymakers/experts and brainstorming.
Most of the literature that offers valid inputs for studying public transport perceptions come from studies that aim to assess how people evaluate public transport services. The list of some indicators most frequently used in these studies are summarized in Table 7.

	(Cain, Flynn, McCourt, & Reyes, 2009)	**(Scherer & Dziekan, 2012)**	**(Mulley, Hensher, & Rose, 2014)**	**(Currie & Delbosc, 2013)**	**(Scherer, 2011)**	**(Stradling, Carreno, Rye, & Noble, 2007)**	**(Redman, Friman, Garling, & Hartig, 2013)**	**SUMMATION**
Frequency	X		X		X	X	X	**5**
Reliability	X	X	X	X	X	X	X	**7**
Comfort of the ride	X		X				X	**3**
Crowdedness		X	X		X	X		**4**
Internal space		X			X	X		**3**
Seats availability	X	X						**2**
Vehicle design		X	X		X	X	X	**5**
Ease of boarding		X	X	X	X	X	X	**6**
Speed/travel time			X	X		X	X	**4**
Environmental friendliness			X		X			**2**
Noise			X		X	X		**3**

Table 7: indicators most frequently observed in literature about public transport quality assessment

According to the interviews with public transport experts/policymakers, it emerges that BRT and LRT are perceived differently by the users in particular for characteristics such as smoothness of accelerations and brakings, smoothness of the vehicles riding on curves and level of ride bumpiness due to the conditions of the rolling surface (asphalt or rails). Additional aspects are acquired through brainstorming sessions aimed at understanding which characteristics might determine a different level of perceptions for bus- and rail-based vehicles.

Combining these three input sources, it is decided to include in the final survey a total of 21 statements. The selection of this number of statements is such that the questionnaire in the online form only includes seven statements per page for maximum three pages. This choice is made not to overload the respondent with a long list of sentences that would be perceived as overwhelming and tiring. The aim is also to combine the aspects that are believed to be the most relevant for perception analysis.

The statements are phrased in a neutral way to fit both BRT and LRT, and for this reason BRT and LRT are often referred to as “the vehicle” or “the service”. The respondents are asked, for each statement, to indicate to what extent they agree or disagree on a scale from one (totally disagree) to five (totally agree) for both BRT and LRT (again, as in the choice experiment, these are indicated as “fast bus” and “fast tram”).

The 21 selected statements are presented in Table 8 (in the same randomized order as presented in the final survey).

1	The vehicle has easy and fast boarding
2	The vehicle provides enough capacity for passengers transferring from train
3	The service feels reliable (every time almost equal travel time and is punctual)
4	During peak hours the vehicle feels uncomfortably crowded
5	The vehicle has enough seats
6	The route has many bumps making the ride not enjoyable
7	The vehicle rides smoothly on curves
8	The vehicle is often delayed
9	The vehicle looks modern and appealing
10	The vehicle is fast
11	The vehicle has a sufficient number of doors
12	The vehicle waits too long at stops
13	If this vehicle is driverless (automated), I would be willing to use it
14	The vehicle is comfortable
15	The vehicle accelerates and brakes smoothly
16	The vehicle is environmentally friendly
17	The vehicle rides without making noise
18	The vehicle has enough leg space to sit comfortably
19	The vehicle has enough standing space
20	From the inside the vehicle feels spacious and has a pleasant design
21	It is a frequent service

Table 8: the 21 perception statements investigated in the research

As can be seen, four of the 21 statements (4, 6, 8 and 12) are phrased in a "negative" manner: this is done as control strategy to verify if the respondent is sincerely paying attention while filling the survey or if it is just trying to reach the end as quickly as possible. Responses which show the same repetitive scores both for positive and negative statements would need to be carefully evaluated.

4.3. Conclusion survey design

In this chapter, the case study has been presented. In particular, it has been explained that the choice of Utrecht was motivated by the presence of both a BRT and LRT systems. This chapter also explained the steps taken for the design of the survey, in particular for its three main components: socio-demographics, choice experiment and perceptions. For the choice experiment, in particular, it has been shown how the attributes have been selected and their levels determined. For the perceptions, it has been briefly exposed how the 21 statements included in the final survey have been formulated.

5. DATA ANALYSIS

The data gathered is carefully analysed to exclude responses which are believed not to be reliable due to the repetitive response pattern or because the age of the respondents is below 16: in total, 19 respondents are removed and excluded from the analysis. 351 is the number of observations used for all the analysis.

In this chapter, a description of the main figures observed from the data is given. In particular, section 5.1 gives an overview of the socio-demographics; 5.2 provides an overview of the distribution of the responses from the choice experiment between BRT and LRT for all respondents in all nine choice tasks; section 5.3 illustrates the results of the perception scores, first in terms of absolute values for BRT and LRT, then in terms of score differences. The interpretation and justification of the perception scores is given as well. 5.4 concludes the chapter by summarizing the main findings.

5.1. Socio-demographics

Table 9 gives an overview of the descriptive statistics of the socio-demographic questions, which covered the first section of the survey.

Variable	Category	Sample	
Language	English	10%	
	Dutch	90%	
Gender	Female	46%	51%*
	Male	53%	49%*
	Prefer not to say	1%	
Age	<18	5%	20%**
	18-24	37%	13%**
	25-34	28%	21%**
	35-54	19%	27%**
	>54	11%	19%**
Highest level of education completed	Primary school	0%	
	Lower vocational / secondary education	5%	
	Higher / intermediate / pre-university education (MBO)	17%	
	Higher vocational education (HBO)	25%	
	University / postgraduate (WO and post HBO)	52%	
Transport mode used on an average day	Walk	3%	
	Bike	28%	
	Car	5%	
	Train	26%	
	Bus	21%	
	Tram	16%	
	Other	1%	
Frequency of use bus line 28	4 or more days per week	8%	
	1-3 days per week	16%	
	1-3 days per month	11%	
	1-11 days per year	20%	
	Never	45%	
Frequency of use tram lines 60/61	4 or more days per week	25%	
	1-3 days per week	16%	
	1-3 days per month	7%	
	1-11 days per year	16%	
	Never	36%	

*Table 9: descriptive statistics of the socio-demographics (*CBS Utrecht, **wistudata.nl)*

The survey has been mainly compiled by Dutch-speaking respondents (about 90%), while only 34 people completed the survey in English. Gender is almost equally distributed between males and females. 4 respondents preferred not to reveal their gender. The age of the respondents varies between 16 and 75, with an average value of 32 years old (standard deviation of 14.5). The majority of the respondents belong to the age groups between 18 and 34 years old (about 65%). This high representation of young people can be explained by the large number of respondents recruited at the two bus stops placed in the heart of the USP where universities and educational institutes are located. Gender and age groups can be visualized in Figure 6 and Figure 8.

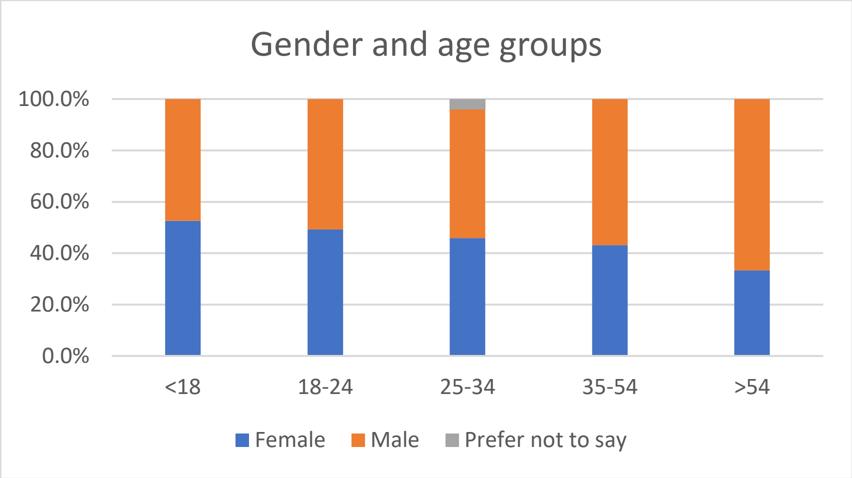

Figure 6: gender and age groups

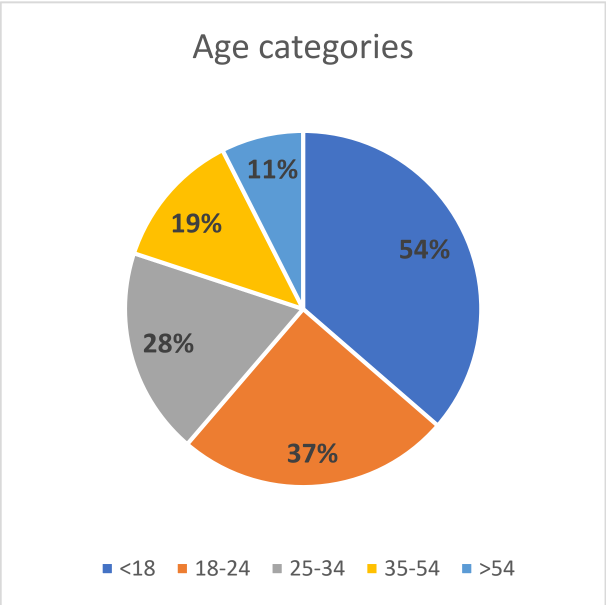

Figure 8: age categories

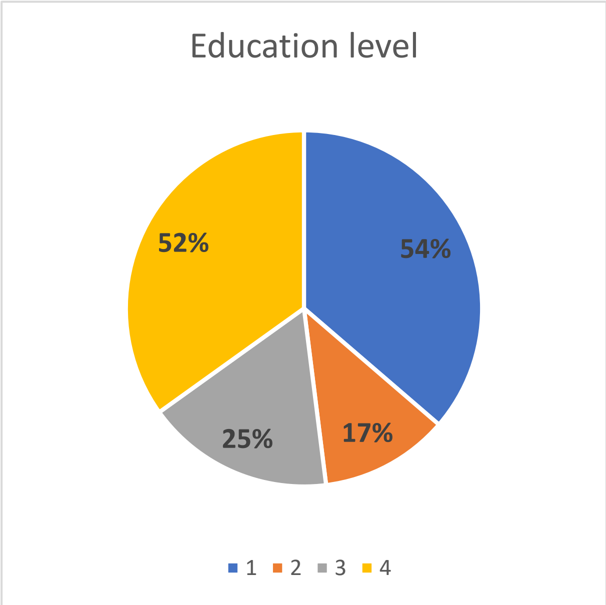

Figure 7: education levels

Legend figure 7: *1: Lower vocational / secondary education;*
2: Higher / intermediate / pre-university education (MBO);
3:Higher vocational education (HBO);
4: University / postgraduate (WO)

To verify the representativeness of the sample, in Table 9 are also reported for gender and age the values currently available for the municipality of Utrecht [(CBS StatLine, 2018) for gender and (Gemeente Utrecht, 2018) for age groups]. It can be seen that while gender in the sample is nearly similar to the statistical data available, the age groups seem not to represent the 2018 data for the Utrecht population. As explained, the higher number of students who took part to the survey is the main reason for this misrepresentation.

For the same reason as for having high representativeness of young people, slightly more than half of the respondents in the sample are highly educated, having completed a university or postgraduate program, while 25% have completed an HBO (Figure 7).

At the question "Which transport mode do you mostly use on an average day?" the responses vary substantially (Figure 9). The larger group (about 28%) state that they mostly use the bike, followed by the frequent train users (26%). Bus users are in the third position with figures around 21%, followed by frequent tram users, who are 16% of the respondents. Car users and walkers are the least represented, clearly due to the locations chosen for recruiting respondents aimed at capturing frequent public transport users.

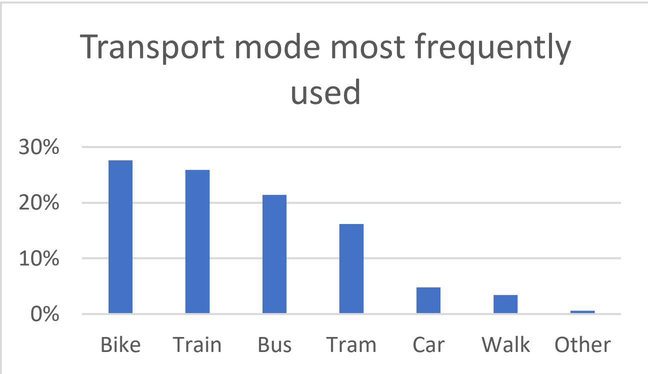

Figure 9: transport mode most frequently used

Regarding the frequency of using bus line 28 and tram lines 60/61 (which were considered as base examples of BRT and LRT systems available in Utrecht) the participants responded as follow (Figure 10): bus line 28 is used daily by 8% of the sample and during most days of the week by 16%, while about 45% claimed to never ride on it. A higher share of respondents (about a quarter) uses tram lines 60/61 daily during the week, and another 16% makes use of the tram most days of the week, while 36% of the sample declared to never travel by tram. It can be noticed the higher amount of frequent tram users (at least one trip per month) compared to those who use bus line 28 (50% vs. 35%). The reason lies in the ease of recruiting respondents at the tram stop in Jaarbeursplein, which has a single access/exit point and it is, therefore, easier to catch a larger number of tram users.

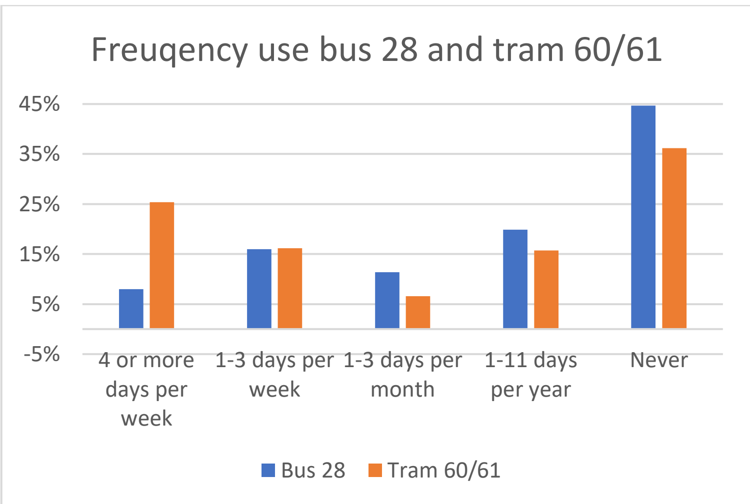

Figure 10: frequency of use for bus line 28 and tram lines 60/61

5.2. Stated preferences

The choice experiment was divided into three blocks. Respondents were asked to select a number of their choice between 1,2 and 3, method used to "randomly" assign participants to one of the three blocks. Respondents were asked to select their preferred alternative between BRT and LRT for 9 different scenarios in which 5 attributes were varied according to the orthogonal design used for the survey construction (4.2.2).

Concerning the distribution of respondents among the three blocks, 24.2% chose block 1, 45.3% block 2 and 30.5% block 3. Although there is a large uneven distribution between block 2 and the others, the number of respondents used for the stated preferences analysis is larger than the minimum required (28 responses per block according to the empirical formula proposed in 4.2.2), therefore no issues for the model estimations are expected.

351 respondents are included in the analysis and for each respondent 9 choices are observed, therefore 3159 observations are available. The total distribution of choices among the two alternatives is shown in Table 10.

	BRT	LRT
Count	1304	1855
Percentage	41%	59%

Table 10: distribution of the observed choices between BRT and LRT

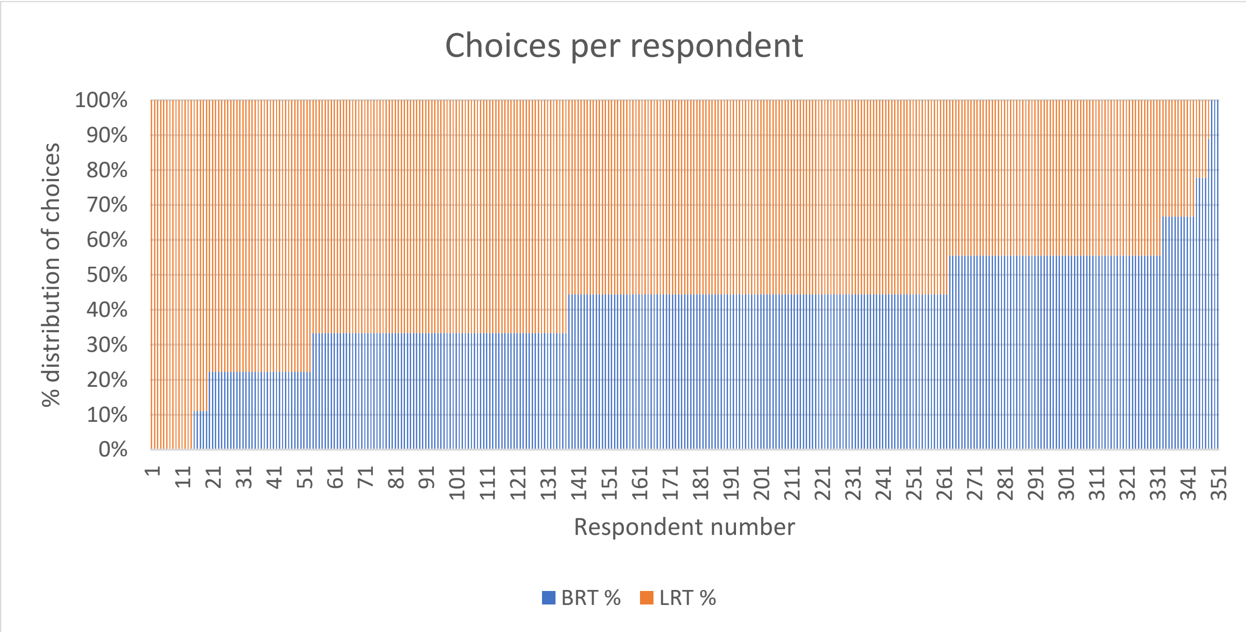

Figure 11: share of the choices for the nine choice tasks for each respondent

LRT has received a higher amount of preferences compared to BRT: 59% for LRT and 41% for BRT. Although these choices are highly dependent on the attribute levels presented for each choice situation, this first result seems to confirm the existence of a "tram bonus", but this will further discussed in 7.2.

Figure 11 displays the share of preferences between BRT and LRT in the nine choice tasks for each respondent. 14 respondents (about 4% of the respondents) always choose LRT, irrespective of the attribute levels, while only three respondents (less than 1%) selected BRT as their preferred mode for all nine scenarios.

The choices are used to estimate multinomial logit models, which theoretical background will be given in section 6.1 of the modelling methodology. The modelling results are shown in chapter 7.

5.3. Perceptions

Perceptions are captured by presenting to the respondents 21 statements asking to indicate the extent to which they agree or disagree on a scale from one to five, both for BRT and LRT. The average scores of the 21 statements are reported in Table 11 (on the left for BRT and on the right for LRT). The statements highlighted in red colour are those expressed in negative terms and their result should thus be interpreted accordingly.

Statements BRT	Avg.	Statement LRT	Avg.
During peak hours the vehicle feels uncomfortably crowded	3.98	The vehicle has easy and fast boarding	4.03
It is a frequent service	3.53	The vehicle has a sufficient number of doors	3.89
The vehicle has easy and fast boarding	3.40	The service feels reliable (every time almost equal travel time and is punctual)	3.70
The vehicle has a sufficient number of doors	3.21	The vehicle is fast	3.69
The vehicle looks modern and appealing	3.18	The vehicle rides smoothly on curves	3.68
The vehicle is fast	3.11	The vehicle has enough standing space	3.60
The vehicle is often delayed	3.01	It is a frequent service	3.60
The vehicle is comfortable	3.01	The vehicle provides enough capacity for passengers transferring from train	3.58
The service feels reliable (every time almost equal travel time and is punctual)	2.95	The vehicle is comfortable	3.58
From the inside the vehicle feels spacious and has a pleasant design	2.94	If this vehicle is driverless (automated), I would be willing to use it	3.56
The vehicle has enough leg space to sit comfortably	2.93	The vehicle looks modern and appealing	3.53
The vehicle has enough standing space	2.90	The vehicle is environmentally friendly	3.52
The vehicle rides smoothly on curves	2.87	The vehicle has enough leg space to sit comfortably	3.45
The route has many bumps making the ride not enjoyable	2.82	From the inside the vehicle feels spacious and has a pleasant design	3.42
If this vehicle is driverless (automated), I would be willing to use it	2.79	The vehicle accelerates and brakes smoothly	3.40
The vehicle rides without making noise	2.77	The vehicle has enough seats	3.32
The vehicle provides enough capacity for passengers transferring from train	2.73	During peak hours the vehicle feels uncomfortably crowded	3.21
The vehicle accelerates and brakes smoothly	2.70	The vehicle rides without making noise	3.16
The vehicle is environmentally friendly	2.68	The vehicle is often delayed	2.43
The vehicle has enough seats	2.59	The vehicle waits too long at stops	2.15
The vehicle waits too long at stops	2.24	The route has many bumps making the ride not enjoyable	1.84

Table 11: average perception scores received by BRT and LRT on a scale from 1 to 5

BRT scores highest (3.98 on a five points scale) on the statements "*during peak hours the vehicle feels uncomfortably crowded*", meaning that on average people highly agree that on rush hours bus vehicles are too crowded. This same statement scores much lower (and is down in the list) for LRT. The first item in the LRT list with the highest score (4.03 average points) relates to "*the vehicle has easy and fast boarding*", which obtains relatively high score also for BRT. After all, bus line 28 uses low floor vehicles and the tram, although still operating the old rolling stock with high floor, also offers planar accessibility due to the high platforms. Considering the high score obtained on this statement for LRT, and considering that the second-highest score is related to the number of doors, it appears that respondents appreciate also the longer vehicles, which allow a faster boarding and alighting process.

On the second place for BRT, there is "*It is a frequent service*", a statement that received a higher score on LRT but, because other items obtained even higher scores, it is lower in the list. However, as it will be shown later on in this section, the difference is so low that it can be neglected. This result is rather surprising considering that bus 28 has a much higher frequency than the tram. However, respondents perceive almost no difference between these two services. For LRT, as mentioned, the second-highest score goes to the item "*the vehicle has a sufficient number of doors*", which is relatively high in the list for BRT as well, although the score difference is not negligible.

To notice that for LRT all statements expressed with negative phrasing are at the bottom of the list, meaning that, compared to all the others, respondents do not agree as much for those. The statement "*the vehicle waits too long at stops*" scores low for both BRT and LRT and the score difference is quite minimal. This means that not only the respondents do not agree with this statement, but they also do not see high differences between the two modes.

These results assume a more meaningful connotation if the average score differences between BRT and LRT are examined. It is also interesting to have an average score of appreciation for BRT and LRT, to verify to what extent the total average score for BRT differs from the one of LRT. To do so, some adjustments are needed: four of the 21 statements, in fact, are presented with a negative phrasing, thus, in order to analyse the average appreciation for the two modes, the scores of these statements are reversed (1→5, 2→4, 3→3, 4→2, 5→1). The average score is calculated and the results are displayed in Table 12. In green are indicated the statements for which the score is reversed. The statements are ordered based on the percentage difference between the average scores for LRT and BRT, according to the following formula:

$$\Delta_{\%} = \frac{|LRT - BRT|}{\left(\frac{\overline{LRT} + \overline{BRT}}{2}\right)} \cdot 100$$

Where LRT and BRT are the average score for the single statements, while $\overline{LRT}$ and $\overline{BRT}$ are the total average of all scores.

Statement	Avg. BRT	Avg. LRT	Δ	$\Delta_{\%}$
The route has many bumps making the ride not enjoyable	3.18	4.16	0.98	30.1%
The vehicle provides enough capacity for passengers transferring from train	2.73	3.58	0.85	26.1%
The vehicle is environmentally friendly	2.68	3.52	0.84	25.6%
The vehicle rides smoothly on curves	2.87	3.68	0.81	24.9%
During peak hours the vehicle feels uncomfortably crowded	2.02	2.79	0.77	23.5%
If this vehicle is driverless (automated), I would be willing to use it	2.79	3.56	0.77	23.4%
The service feels reliable (every time almost equal travel time and is punctual)	2.95	3.70	0.76	23.2%
The vehicle has enough seats	2.59	3.32	0.73	22.3%
The vehicle accelerates and brakes smoothly	2.70	3.40	0.71	21.6%
The vehicle has enough standing space	2.90	3.60	0.70	21.4%
The vehicle has a sufficient number of doors	3.21	3.89	0.68	20.8%
The vehicle has easy and fast boarding	3.40	4.03	0.64	19.5%
The vehicle is fast	3.11	3.69	0.59	17.9%
The vehicle is often delayed	2.99	3.57	0.58	17.9%
The vehicle is comfortable	3.01	3.58	0.57	17.5%
The vehicle has enough leg space to sit comfortably	2.93	3.45	0.52	16.0%
From the inside the vehicle feels spacious and has a pleasant design	2.94	3.42	0.48	14.6%
The vehicle rides without making noise	2.77	3.16	0.40	12.1%
The vehicle looks modern and appealing	3.18	3.53	0.35	10.7%
The vehicle waits too long at stops	3.76	3.85	0.09	2.6%
It is a frequent service	3.53	3.60	0.06	1.9%
Tot. Average	**2.96**	**3.58**	**0.61**	**18.75%**

Table 12: difference in average perception scores for BRT and LRT

It is important to remind that the statements highlighted in green have their score reversed, so that it is possible to have an indication of how that particular mode is evaluated. According to the results, LRT scores higher than BRT on all statements, and on total average it scores about 19% higher than BRT (3.58 versus 2.96 on a one to five likert scale). This result seems in line with the higher number of preferences obtained by LRT in the choice experiment, suggesting that it is reasonable to claim the existence of a "tram bonus".

The Mann-Whitney U-test (specifically used for likert type ordinal data, the results are shown in Appendix 5) is performed to have a statistical confirmation that the difference between two scores is indeed different from zero. The test confirms that for all statements but two, the differences are statistically different from zero. The BRT and LRT scores for the statements "*the vehicle waits too long at stops*" and "*it is a frequent service*" are not statistically different. Therefore, it can be concluded that in the Utrecht population BRT and LRT do not differ in terms of perceptions for stop waiting time and service frequency.

The other items present a noticeable difference in scores. In the following, to keep the analysis compact and to include only the main aspects, a description and possible explanations of the results are given for the first 11 statements, whose score differences are higher than 20%.

The route has many bumps making the ride not enjoyable

This statement is the one that shows the highest percentage difference between BRT and LRT. This means that compared to LRT, the ride of a BRT is perceived as much more bumpy. This result is not surprising, since rail vehicles are known to have a smoother ride due to the more regular surface of the rails. The perceived high difference between the two modes might also be influenced by the experience of riding busses operating on particular roads with irregular surface.

The vehicle provides enough capacity for passengers transferring from train

The second item in the list indicates that LRT is perceived to be much more suitable as a transport mode able to accommodate the passengers transferring from train. This might be due to the high capacity of trains: when the train arrives at the station, passengers leave the train at the same time and many of them transfer from train to the local public transport. These transfer passengers, direct themselves towards the stop all at the same time and, even though the bus has a higher frequency than the tram, all passengers expect to board on the first bus available. Since the capacity of a bus vehicle is much lower than the capacity of a tram, the users perceive that all these passengers cannot be accommodated on a bus. This item suggests that passengers transferring from train have a much stronger perception for the "vehicle capacity" rather than for the "service capacity" and it might have implications for the service design.

The vehicle is environmentally friendly

It is interesting to notice that at the third position on the list there is the perception for environmental friendliness. According to the observed responses, LRT is perceived to be 27% more environmentally friendly than BRT. In the specific case of Utrecht, this might be determined by the different power source of bus and tram vehicles: bus line 28 is operated with diesel vehicles, while the trams are electrically powered.

The vehicle rides smoothly on curves

One spot lower on the list, another item related to the route: LRT is perceived to ride more smoothly on curves than BRT. This is indeed another inherent characteristic of the rail-based vehicles which are more stable and are equipped with more rigid dampers, limiting the swinging of the vehicle body when riding at speed on narrow curves.

During peak hours the vehicle feels uncomfortably crowded

The results of this statement indicates that compared to LRT, BRT is perceived much more uncomfortable and crowded during the rush hours. In the specific case of Utrecht, the tram vehicles have a much higher number of seats than the bus, and this aspect might contribute to the different perceived level of crowding between the two services. Although this difference, the LRT score for crowdedness is not among the highest compared to the other statements, meaning that crowdedness is perceived rather high on trams as well.

If this vehicle is driverless (automated), I would be willing to use it

This statement was introduced to explore the different willingness to ride on a driverless vehicle. As expected, respondents would be more willing to ride on an automated tram rather than on an automated bus. This might be related to the presence of the tracks, which might be considered as an assurance of higher safety levels that is perceived cannot be reached with trackless vehicles. It can also be related to the particular situation when busses ride in mixed traffic together with private vehicles (as already mentioned, the route of bus 28 is only partially operated on dedicated lanes), which does not happen for the tram.

<u>The service feels reliable (every time almost equal travel time and is punctual)</u>

This statement is more related to the different type of service rather than to the different type of vehicle. It is difficult to claim whether the motivation behind the higher perceived reliability of LRT is related to the familiarity with the current service in Utrecht or because rail-based services might be perceived as more reliable due to their technical characteristics.

<u>The vehicle has enough seats</u>

As mentioned for the first statement in the list, in Utrecht trams have a much higher seating capacity than the busses (even considering the double articulated ones) and this probably has an influence on the observed score difference.

<u>The vehicle accelerates and brakes smoothly</u>

The different technology is once again visible in the different score of this statement. The LRT is perceived to accelerate and brake more smoothly. Multiple reasons could lie behind this different perception: vehicles with electric engines are generally smoother, while with combustion engines it is easier to have sudden brakings (EV do not have transmission and therefore no gear shift causing jerky rides). The driving style of the driver might also play a role.

<u>The vehicle has enough standing space</u>

According to the respondents, it appears that busses, compared to tram vehicles, not only have lower seating capacity, but also lower perceived space to stand comfortably. This might have implications on the service design (e.g. increasing the bus frequency) and on the vehicle design (in the situation when new busses are planned to be acquired).

<u>The vehicle has a sufficient number of doors</u>

Tram vehicles are longer and therefore are able to accommodate a higher number of doors. However, the fact that the amount of doors for busses is perceived lower, might be related to the statement presented earlier regarding passengers transferring from train. In transfer nodes, the passengers that need to board a bus vehicle perceive that they need to queue longer than when boarding on a tram, creating this feeling that more doors would make the process faster.

The same type of list is realized using sub-sets of the data for different group segments, in particular for frequent bus line 28 users (which are called BRT users), frequent tram users (LRT users), (general) public transport users (PT users) and non-public transport users (non-PT users). These results are reported in Appendix 6.

5.4. Conclusion data analysis

In this chapter, the main results from the data analysis for socio-demographics, choice experiment and perceptions has been given. From the socio-demographics, it emerges that respondents are about equally distributed between males and females and that the younger age categories are overrepresented due to the locations selected for handing out flyers near the university. The majority of the respondents are highly educated and the modes of transport most frequently used by respondents are bike, train and bus.

From the analysis of the responses of the choice experiment it emerges that LRT has higher number of preferences and that it might be a first signal for the existence of the rail bonus.

Looking at the results of the perception scores, more in particular the score differences, it emerges that overall LRT receives higher score than BRT in all statements, and that on average LRT is evaluated about 19% higher than BRT. Bumpy route, capacity for passenger transferring from train and environmental friendliness are the three main factors which mostly determine a difference in perception between BRT and LRT. The time spent by the vehicle at the stops and the service frequency are the only two statements that do not differ between the two modes.

B. ANALYSIS AND RESULTS

6. MODELLING METHODOLOGY

The objective of this research is to verify the existence of the rail bonus for LRT compared to BRT and to identify the causes that determine the difference in preferences and perceptions for the two modes among public transport users. The rail bonus is defined as the higher preference for rail-based modes over bus-based alternatives. The literature analysed in section 2.2 has shown that previous studies determined the existence of this bonus by analysing stated preference data and by estimating a discrete choice model. To determine the factors that are causing a difference in preferences between BRT and LRT, perceptions are analysed, more in particular how perceptions relate to each other and how the perception constructs vary between BRT and LRT. To do so, psychological network models are applied. In this chapter, the theoretical background of discrete choice modelling (section 6.1) and network psychometrics (section 6.2) is given.

6.1. Discrete choice modelling

Discrete choice models are statistical tools that enable the researcher to analyse certain behavioural aspects, giving insights into how people make choices and why. Developed in the '70s, they rapidly grew in popularity among economists and psychology/behavioural researchers (Manski, 2001), and they now form the base for transport modelling regarding route and mode choice, other than being valid tools for transport appraisal (Tjiong, 2015).

DCMs base their theory on the concept of rational decision making, meaning that it is assumed people make choices in a rational way by choosing the option which maximises their benefit (or minimises their loss). For this reason, the theoretical construct of DCM associates to each alternative within the choice set (that is the set of available alternatives to choose from) a so-called "utility function" which, in random utility theory, represents the associated utility that the decision-makers want to maximise by choosing a particular alternative (or the associated disutility that they want to minimize) (Cascetta, 2009). This particular theory is called Random Utility Maximisation (RUM), which assumes that the total utility U associated to an alternative i is composed by two components: the so-called "observed" (or "systematic") utility V of the alternative i, which includes all observable factors that the researcher believes play a role in the decision-makers' final choice, and an error component ε which represents the incomplete preference information from the side of the analyst caused by unobserved attributes, measurement errors and by randomness in choice behaviour from the side of the decision-makers (Cascetta, 2009). The mathematical formulation of the total utility is expressed as follows:

$$U_i = V_i + \epsilon_i$$

The observed utility V of the alternative i is a linear in parameters function, therefore the total utility of an alternative i with m observed attributes and m parameters β is expressed as follows (Cascetta, 2009):

$$U_i = \sum\nolimits_m \beta_m x_{im} + \varepsilon_i$$

The decision-maker chooses the alternative with the highest utility, which can be expressed with the following mathematical decision rule (Chorus, 2018):

$$i \text{ chosen if:} \qquad \sum\nolimits_m \beta_m x_{im} + \varepsilon_i > \sum\nolimits_m \beta_m x_{jm} + \varepsilon_j \,, \forall i \neq j$$

Often, to one or more utility functions is added a constant, estimated as well together with the other parameters. This constant represents the higher preferences for that alternative cause by factors not captured by the attributes included in the model.

The choice probabilities are determined in various ways, here are presented the most common ones.

- *Multinomial Logit Model:* it has been mentioned that the total utility includes the error component ε: as long as there is an error term in the model formulation, it is not possible to predict choices, but only choice probabilities. With the assumption that the error term is i.i.d. (independent and identically distributed) extreme value (EV) type 1 distributed across the alternatives, the choice situations and the individuals, with a variance $\pi^2/6$, the probability that an individual chooses alternative i over a set of j alternatives is given by the canonical linear-additive multinomial logit model (also known as MNL), which represents the most popular and simplest form to calculate choice probabilities (McFadden, 1973):

$$P(i) = P\left(V_i + \epsilon_i > V_j + \epsilon_j, \forall i \neq j\right) = \frac{e^{V_i}}{\sum_j e^{V_j}} = \frac{e^{\sum_m \beta_m x_{im}}}{\sum_j e^{\sum_m \beta_m x_{jm}}}$$

- *Nested logit models*: these models assume that there exist multiple levels within the choice alternatives in a way that the so-called IIA property (Independence from Irrelevant Alternatives) holds within each nest, but it does not between different nests of alternatives (Cascetta, 2009). An example is the choice between car, bus and tram: bus and tram are clearly part of the same nest, being both public transport modes sharing a number of characteristics which are not peculiar of the car mode;
- *Mixed logit models*: these type of models try to overcome the issues carried by the i.i.d. property of the MNL models (Chorus, 2018). This property assumes that the error terms of the alternatives are not correlated, which is not true for alternatives which are similar in attributes (or nested within the same nest). In the example presented before with the car, bus and tram alternatives, the i.i.d. property implies that all these three modes have an independent and uncorrelated error term, which is not true for bus and tram since they belong to the same nest and their error terms are somehow correlated. Mixed logit models overcome this issue by estimating an extra error term that captures the similar characteristics shared by similar alternatives and it allows to capture taste heterogeneity and panel effects. Although more realistic, these models do not assume a closed-form and need to be estimated by simulation (Chorus, 2018);
- *Latent class models*: these models assume that the choice behaviour of the individuals "*depends on the observable attributes and on latent heterogeneity that varies with the unobserved factors*" (Greene & Hensher, 2003). Therefore, a different set of parameters are estimated for each class allowing the analyst to explore in which ways choice behaviour changes among the different classes of people.

For the purpose of this research, the MNL model is used, since only two modes are included in the choice set (BRT and LRT) and they both belong to the same mode category (public transport) and there is no need to test for taste heterogeneity. Moreover, the main focus is on public transport users in general, therefore there is no need to estimate a latent class model.

MNL models are estimated using the data collected in choice experiments and the estimation is done according to the maximum likelihood principle, which implies that the parameters are estimated from the data in a way that they make the data most likely. The mathematical formulation of the likelihood function L for the parameter β is the following (Cascetta, 2009):

$$L(\beta) = \prod_n \prod_i P_n(i|\beta)^{y_n(i)}$$

where y(i) = 1 if alternative i is chosen, 0 otherwise. This is because in maximum likelihood estimation only the likelihood of chosen alternatives matters.

Usually, the likelihood assumes small values, close to zero. Therefore, MNL are estimated by maximising the log-likelihood function:

$$LL(\beta) = \sum_n \sum_i y_n(i) \cdot \ln(P_n(i|\beta))$$

Hence, this function becomes large and negative and reaches the maximum at the same β.

The final value of this function can be used to determine the model fit using the rho-squared formulation (McFadden, 1973):

$$\rho^2 = 1 - \frac{LL_\beta}{LL_0}$$

where LL_β is the final loglikelihood of the estimated model, and LL_0 is the loglikelihood of the null-model (the model in which all parameters are zero).

The ρ^2 value gives the percentage of initial uncertainty explained by the model. The higher the value, the better the model fits the data, but it is not possible to determine which value can be considered to be a good fit. It is, however, a valuable tool to compare models.

Another tool used to compare models (in particular when one model is nested in another with q degrees of freedom) is the Likelihood Ratio Statistics (LRS), formulated by the following (Chorus, 2018):

$$LRS = -2(LL_A - LL_B)$$

where model A is nested in B with q additional parameters. LRS is χ^2 distributed across the samples with q degrees of freedom. If LRS is higher than the threshold associated with the significance level, the null-hypothesis that the models A and B are the same is rejected, meaning that the two models are actually different in the population.

6.2. Network psychometrics

This research wants to verify the existence of the rail bonus for LRT compared to BRT and the causes behind it. The previous methodology (discrete choice model) is used to test the existence of the bonus and the trade-offs respondents make. To have more insights into the rail bonus "black-box", perceptions are analysed, more in particular the differences in perceptions between BRT and LRT. As defined by one of the research sub-questions formulated in 1.3, the aim is to determining how perceptions for mode specific characteristics influence each other and if the perception constructs differ between BRT and LRT. One way to approach this question, is to analyse perceptions in a form of a network. For this reason, psychological network modelling is the approach selected in this research to analyse how the perception constructs differ between BRT and LRT.

Psychological network models are a recently developed tool that allow visualizing the psychological behaviour in a form of a network in which the nodes represent the observed variables and the edges represent the statistical relationships between them (Epskamp, Borsboom, & Fried, 2018). This methodology has been applied to a variety of different fields, such as psychology, psychiatry, personality research and health sciences (Epskamp & Fried, 2018).

The main difference between psychological networks and other network models lies in the fact that edges are the estimated parameters, while in other network models (such as power grids, social networks or road/rail/transit networks) edges are known entities (Epskamp & Fried, 2018).

To this date, according to literature review, there have been found no studies applying this methodology to transport/travel behaviour research, excluding few examples that use Bayesian networks (such as in Wu, Yang, Rasouli., & Xu (2016)) which are probabilistic in nature. The reason for this is that network psychometrics is a new methodology and is slowly being applied to a variety of fields.

Psychological networks are estimated from the data and are analysed and evaluated by observing the network structure and the network centrality indicators, which are derived from graph theory. The parameters estimated in network models are the partial correlations between the observed variables. Their value ranges between -1 and 1 and they represent the "*remaining association between two nodes after controlling for all other information possible, also known as conditional independence associations*" (Epskamp & Fried, 2018).

The estimation of these partial correlations is only the first step; the second step consists of visualizing them in a weighted network structure. If between two variables the partial correlations are zero, no edges are displayed, meaning that the two variables, after controlling for all the others, are independent. Using the most common software packages, negative partial correlations are displayed in red, while green (or blue) edges represent positive relations. Wider edges are associated with larger partial correlations. Figure 12 shows an example of an estimated network model with 20 nodes and 111 non-zero edges.

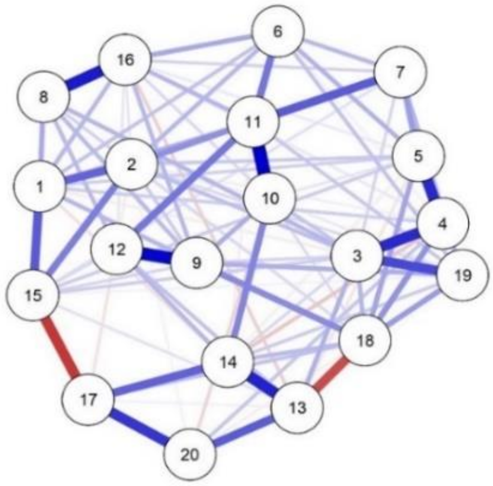

Figure 12: example of estimated network model

Typically, the partial correlations are obtained from the inverse of the variance-covariance matrix. Obtaining the partial correlations from the variance-covariance matrix is done as follows (Epskamp & Fried, 2018): assuming that y is a set of item responses, ∑ is the variance-covariance matrix, and assuming that y have a multivariate normal distribution. Then it is possible to write the following:

$$y \sim N(0, \Sigma)$$

If K represents the inverse of ∑ ($K = \Sigma^{-1}$), then the element k_{ij} of K "*can be standardized to obtain the partial correlation coefficient between variable y_i and variable y_j, after conditioning on all other variables in y, $y_{-(i;\, j)}$*" (Epskamp & Fried, 2018):

$$Cor(y_i, y_j | y_{-(i,j)}) = -\frac{k_{ij}}{\sqrt{k_{ii}}\sqrt{k_{jj}}}$$

The additional step of the network estimation consists of limiting the number of spurious edges, those that connect two conditionally independent variables and that are always present in network models estimated from data (Epskamp & Fried, 2018). The elimination of these spurious edges is important in order to avoid network misinterpretations and false conclusions. This is done with the so-called LASSO methodology (Least Absolute Shrinkage and Selection Operator), a particular statistical regularization technique that "*limits the sum of absolute partial correlation coefficients; as a result, all estimates shrink, and some become exactly zero*" (Epskamp & Fried, 2018). To do so, a penalty parameter λ (called tuning parameter) is introduced, as explained by (Friedman, Hastie , & Tibshirani, 2007): if S represents the variance-covariance matrix, the LASSO regularization "*aims to estimate K by maximizing the penalized likelihood function*":

$$\log\det(K) - trace(SK) - \lambda \sum_{<i,j>} |k_{ij}|$$

This parameter λ controls the level of network sparsity: when λ is low, more edges are retained, with a higher likelihood of retaining spurious ones; when λ is high more edges are removed, with a higher likelihood of removing true edges (Epskamp & Fried, 2018).

The choice of the right tuning parameter is done by minimizing the Extended Bayesian Information Criterion (EBIC). EBIC uses an additional (hyper)parameter γ which needs to be manually set by the analyst (and usually varies between 0 and 1):

$$EBIC = -2L + E\ log(N) + 4\gamma E \log(P)$$

where L represents the loglikelihood, N the sample size, E the number of non-zero edges and P the number of nodes (Epskamp & Fried, 2018).

Setting γ to higher values results in a more parsimonious model with fewer edges. It is usually suggested to set the hyperparameter γ to 0.5 (Foygel & Drton, 2010). However, this particular aspect of network models requires further research.

The estimated networks are analysed and compared by looking at centrality measures of graph theory. The main measures typically observed in network models are (JASP):

- *Node strength (or degree)*: is calculated by taking the sum of all edge weights a node is directly connected to. It quantifies the extent to which a node influences other nodes in the network;

- *Closeness centrality*: it is calculated as the inverse of the sum of the distance from one node to all other nodes in the network. It quantifies how well a node is indirectly connected to the other nodes. It measures to what extent a specific node is able to predict other nodes;

- *Betweenness centrality*: is the number of shortest paths that pass through that specific node. It quantifies how important a node is in the average path between two other nodes.

6.3. Conclusion modelling methodology

This section presented the basic theoretical background of discrete choice modelling and network psychometrics. The first, is used to verify the existence of the rail bonus for LRT compared to BRT and to verify how the attributes are differently traded-off. The second, allows to analyse the different perception structure of the two alternatives and to understand how perceptions relate to each other, possibly giving insights into the psychological factors that might be behind the rail bonus.

7. RAIL BONUS AND PREFERENCES ANALYSIS

This chapter presents the results of the discrete choice model estimation and the interpretation of the main results. More in particular, 7.1 provides the model specifications, 7.2 gives the results of the estimation with parameter values and their interpretation; section 7.37.27.3 describes the monetized results, in particular for what concerns the value of time and the value of the rail bonus; 7.47.3 focuses on the non-monetary trade-offs; 7.57.47.5 provides the application of the results with scenario analyses; 7.6 concludes the chapter by summarizing the main findings.

7.1. Model specifications

The data obtained in the stated preference experiment is prepared and adjusted to be properly used for the model estimation. The alternatives included in the estimation are BRT and LRT. The attributes varied in the experiment and used for the model estimation are: waiting time (WT), travel time (TT), travel cost (TC), crowdedness (CR) and smoothness of the ride (SR). The last two attributes are categorical variables and need to be dummy coded. They both vary into three levels, therefore two parameters are introduced both for crowdedness (CR1 and CR2) and for smoothness of the ride (SR1 and SR2). The variables are coded as indicated in Table 13.

	CROWDEDNESS (CR)	CR1	CR2		SMOOTHNESS OF THE RIDE (SR)	SR1	SR2
0	Seats available	0	0	0	Very smooth	0	0
1	Only standing (not crowded)	1	0	1	Generally smooth	1	0
2	Only standing (crowded)	0	1	2	Jerky	0	1

Table 13: dummy coding for crowdedness and smoothness of the ride

"Seats available" and "Very smooth" are the two reference levels, therefore the estimated parameters express the penalty for moving from the reference to the first or second attribute level. The utility contributions of these two attributes are given by the following:

$$V_{CR} = \beta_{CR1} \cdot CR1 + \beta_{CR2} \cdot CR2$$

$$V_{SR} = \beta_{SR1} \cdot SR1 + \beta_{SR2} \cdot SR2$$

The complete (systematic) utility specification for the two alternatives is given in the following:

$$V_{BRT} = \beta_{WT\_BRT} \cdot WT_{BRT} + \beta_{TT_{BRT}} \cdot TT_{BRT} + \beta_{TC_{BRT}} \cdot TC_{BRT} + \beta_{CR1_{BRT}} \cdot CR1_{BRT} + \beta_{CR2_{BRT}} \cdot CR2_{BRT} + \beta_{SR1_{BRT}} \cdot SR1_{BRT} + \beta_{SR2_{BRT}} \cdot SR2_{BRT}$$

$$V_{LRT} = \beta_{WT\_LRT} \cdot WT_{LRT} + \beta_{TT_{LRT}} \cdot TT_{LRT} + \beta_{TC_{LRT}} \cdot TC_{LRT} + \beta_{CR1_{LRT}} \cdot CR1_{LRT} + \beta_{CR2_{LRT}} \cdot CR2_{LRT} + \beta_{SR1_{LRT}} \cdot SR1_{LRT} + \beta_{SR2_{LRT}} \cdot SR2_{LRT} + ASC$$

Where:

$V_{BRT} \quad = \; systematic\ utility\ for\ BRT$

$V_{LRT} \quad = \; systematic\ utility\ for\ LRT$

$\beta_{WT_{BRT}} \; = \; waiting\ time\ for\ BRT$

$\beta_{WT_{LRT}} \; = \; waiting\ time\ for\ LRT$

$\beta_{TT_{BRT}} \; = \; travel\ time\ for\ BRT$

$\beta_{TT_{LRT}} \; = \; travel\ time\ for\ LRT$

$\beta_{TC_{BRT}} \; = \; travel\ cost\ for\ BRT$

$\beta_{TC_{LRT}} \; = \; travel\ cost\ for\ LRT$

$\beta_{CR1_{BRT}} = \; first\ level\ of\ crowdedness\ for\ BRT$

$\beta_{CR1_{LRT}} = \; first\ level\ of\ crowdedness\ for\ LRT$

$\beta_{CR2_{BRT}} = \; second\ level\ of\ crowdedness\ for\ BRT$

$\beta_{CR2_{LRT}} = \; second\ level\ of\ crowdedness\ for\ LRT$

$\beta_{SR1_{BRT}} = \; first\ level\ of\ smoothness\ of\ the\ ride\ for\ BRT$

$\beta_{SR1_{LRT}} = \; first\ level\ of\ smoothness\ of\ the\ ride\ for\ LRT$

$\beta_{SR2_{BRT}} = second\ level\ of\ smoothness\ of\ the\ ride\ for\ BRT$

$\beta_{SR2_{LRT}} =$ $second\ level\ of\ smoothness\ of\ the\ ride\ for\ LRT$

$ASC \quad = \quad alternative\ specific\ constant\ for\ LRT$

As shown in the equations, both utilities include mode-specific parameters for all attributes. This is necessary to analyse to what extent the attributes vary among the two modes, thus verifying how the attributes are differently traded-off. It is possible, for example, that travel time is weighted differently for BRT compared to LRT. With mode-specific parameters can then be tested if the difference in preferences for the two modes is related to one (or more) of the attributes.

An alternative specific constant is also included in the utility specification for the LRT mode: this parameter represents the unobserved utility (attribute-related preferences which are not included in the utility function) which determines the underline preference (or penalty) for LRT compared to BRT (for which the constant is set to zero). A positive significant constant would confirm the existence of a rail bonus, and that this bonus is not captured by the parameters specified in the utility function. In this way, it is possible to both verify if the attributes alone can explain the different preference for one mode or the other and/or if something else is also playing a role.

7.2. Model estimation, results and interpretations

The model is estimated using the freely available software package Python Biogeme (Bierlaire, 2016). The coding file used for the estimation is reported in Appendix 7. Table 14 and Table 15 summarize the results.

Name	Full parameter name	Value	Robust Std err	Robust t-test	p-value
ASC	Alternative Specific Constant LRT	1.8	0.54	3.34	0
$\beta_{CR1_{BRT}}$	Crowdedness 1 BRT	-0.523	0.126	-4.16	0
$\beta_{CR1_{LRT}}$	Crowdedness 1 LRT	-1.25	0.159	-7.89	0
$\beta_{CR2_{BRT}}$	Crowdedness 2 BRT	-0.69	0.153	-4.5	0
$\beta_{CR2_{LRT}}$	Crowdedness 2 LRT	-2.31	0.14	-16.47	0
$\beta_{SR1_{BRT}}$	Smoothness of the ride 1 BRT	-0.551	0.15	-3.68	0
$\beta_{SR1_{LRT}}$	Smoothness of the ride 1 LRT	0.249	0.136	1.83	0.07*
$\beta_{SR2_{BRT}}$	Smoothness of the ride 2 BRT	-1.27	0.136	-9.37	0
$\beta_{SR2_{LRT}}$	Smoothness of the ride 2 LRT	-0.746	0.127	-5.86	0
$\beta_{TC_{BRT}}$	Travel Cost BRT	-1.44	0.145	-9.95	0
$\beta_{TC_{LRT}}$	Travel Cost LRT	-1.56	0.161	-9.71	0
$\beta_{TT_{BRT}}$	Travel Time BRT	-0.263	0.0143	-18.35	0
$\beta_{TT_{LRT}}$	Travel Time LRT	-0.271	0.0154	-17.58	0
$\beta_{WT_{BRT}}$	Waiting Time BRT	-0.189	0.0368	-5.15	0
$\beta_{WT_{LRT}}$	Waiting Time LRT	-0.322	0.0348	-9.24	0

Table 14: parameter estimates

Estimation report	
Number of estimated parameters:	15
Sample size:	3159
Excluded observations:	0
Init log likelihood:	-2189.652
Final log likelihood:	-1266.177
Likelihood ratio test for the init. model:	1846.95
Rho-square for the init. model:	0.422
Rho-square-bar for the init. model:	0.415

Table 15: Biogeme report file

In total, 15 parameters are estimated, which are, all but one, of the expected sign and highly significant. The only parameter with a non-expected sign is the one related to the first level of smoothness of the ride, which is found to be non-significant. The adjusted rho-square, which measures the explanatory power of the model by taking into account the number of parameters estimated, is 0.415, meaning that more than 41% of the initial uncertainty is explained away by the model. According to McFadden, this value represents an extremely good model fit, proving that the estimated model fits the data rather well (McFadden, 1977).

Looking at the parameters estimates, the first important result that can be noticed is that the alternative specific constant for LRT (ASC) is large, positive and significant. This means that excluding travel time, travel cost, waiting time, smoothness of the ride and crowdedness, people prefer the LRT, and it confirms the existence of the rail (or tram) bonus, supporting what was found in 5.2 and 5.3 by analysing the stated preference results and the perceptions. This also means that the attributes included in the utility functions do not explain the rail bonus, but that there is something else causing it. Perceptions might partially explain this inherent rail preference, in particular their structure and how they relate to each other. This type of analysis is explained in chapter 8.

To better visualize the difference in the parameter estimates between BRT and LRT, these are reported next to each other in Table 16. In in Figure 13 the 100% stacked columns help visualize the differences between the parameter estimates for each attribute for the two modes. This visualization method is chosen because the parameters measure (in general) different quantities with different units and cannot be directly compared with each other.

Parameter	BRT	LRT
Waiting time	-0.189	-0.322
Travel time	-0.263	-0.271
Travel cost	-1.44	-1.56
Crowdedness 1	-0.523	-1.25
Crowdedness 2	-0.69	-2.31
Smoothness of the ride 1	-0.551	0.249*
Smoothness of the ride 2	-1.27	-0.746

Table 16: parameter estimates divided between BRT and LRT

Overall, it can be observed that mode-specific parameters for LRT are negatively larger compared to their respective BRT ones for waiting time and crowdedness, while smoothness of the ride estimates are larger for BRT. Travel time and travel cost are about the same for both modes. The estimated parameters are explained with higher detail in the following paragraphs.

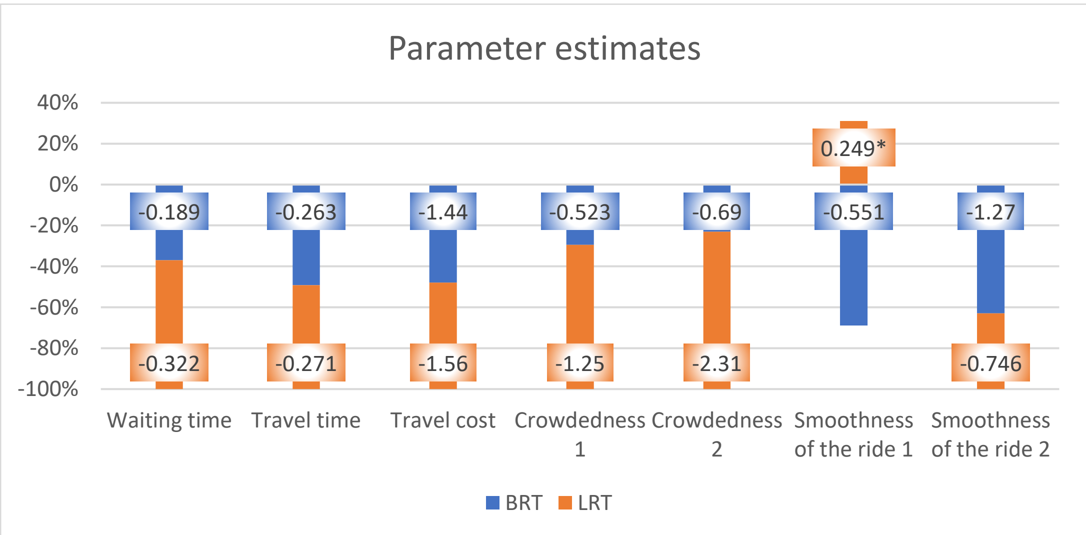

Figure 13: graphical visualization of the parameter estimates for BRT and LRT

Waiting time

Waiting time is weighted more negatively for LRT than for BRT, meaning that the disutility for waiting an LRT is higher than the one for waiting a BRT. Although in the perception analysis (5.3) it has been shown that the respondents, asking them directly (*"It is a frequent service"),* they perceive the frequency of the two modes of an equal extent, the MNL model, on the contrary, is able to show that there is indeed in the sample (and in the Utrecht population) a difference in how frequency (and therefore waiting time) is weighted. This difference might be related to the current situation in which LRT waiting times are higher than those for bus line 28 (which is additionally supported by bus line 18 as well, contributing at reducing further the waiting times along the section through the city). This results suggests that, although the frequency of the two modes is perceived equally, put in the condition to make a choice between alternatives having a different waiting time (which is dependent on the frequency), waiting time becomes one of those factors that influences people's preferences.

Travel time

The parameters for travel time do not differ between BRT and LRT. In the perceptions, the statement "*this vehicle is fast*", the difference in the average liker scale was only about 17% in favour of LRT. Combining these two results, it appears that respondents do not mind much if the same travel time is achieved via an LRT or a BRT, which are perceived to have almost equal speed. It is important to mention that in the description of the case study, there was no mention about possible improvements on the public transport circulation in the city centre corridor, such as the implementation of priority at intersections for public transport vehicles. Therefore, the respondents might have assumed that the travel time would not change by only substituting a BRT with an LRT. Although the difference in parameter values is negligible, travel time still plays an important role in the total utility, as it will be shown later on in this section. To notice also that travel time for BRT is weighted more negatively than waiting time, suggesting that travellers have a higher penalty for travelling on a bus vehicle than for waiting its arrival (this will be further explained in section 7.3).

Travel cost

Travel cost also does not change substantially between BRT and LRT. Therefore, although cost still plays a role in the total value of the utility, it is not one of the attributes which cause a different preference for BRT and LRT.

Crowdedness

Both dummy parameters for crowdedness (CR1 and CR2) are much more negative for LRT, with a large difference compared to the values for BRT. This means that respondents weight crowdedness much more negatively for LRT than for BRT. The reason might be due to the larger seating availability on the current tram vehicles. People expect to find a seat on a tram and would have a large penalty for standing (in particular if they have to stand on a crowded vehicle, as confirmed by the higher value of the second dummy for crowding). On the bus, on the other hand, the number of seats available is lower, therefore respondents do expect that by taking the bus, they might have to stand. It appears that mode familiarity plays a role: people know that during peak hours, on the tram a seat is almost always guaranteed, and they also know that travelling on a bus they almost always have to stand, resulting in a much different penalty for crowding between the two modes. These expectations are confirmed by the scores of the perception statements analysed in 5.3: crowdedness, during rush hours, is perceived less negatively on an LRT than on a BRT (about 24% difference on a five points scale) and seat availability on the LRT scores 22% higher than the BRT. Scenarios with no seats available and standing in a crowded vehicle are therefore highly penalized for LRT.

Smoothness of the ride

The two dummies SR1 and SR2 for smoothness of the ride are negatively larger for BRT. The dummy SR1 for LRT is interestingly positive, but not significant at 5% level. Thus, the parameter for SR1 can be considered equal to zero for LRT, meaning that respondents do not perceive any difference between a very smooth ride and a generally smooth with sudden brakings ride on an LRT. Only the difference between a very smooth and a jerky ride plays a role. For BRT, on the other hand, both levels are large, negative and significant, meaning that users perceive the bus ride as not comfortably smooth. This result is confirmed also from the perception statements (section 5.3): LRT is perceived 30% less bumpy, 25% smoother on curves and 22% smoother during acceleration and braking phases.

Since the attributes have different units, it is difficult to compare the parameter estimates only by looking at their values. A measure that seems more appropriate for comparing parameters, is the relative importance of attributes derived by their utility ranges. The relative importance of an attribute is calculated with the following equation (Halbrendt, Wang, Fraiz, & O'Dierno, 1995):

$$RI_i = 100 \cdot \frac{UR_i}{\sum_{j=1}^{n} UR_j}$$

where:

RI_i = Relative Importance of attribute i
UR_i= Utility Range of attribute i

The relative importance of the attributes for BRT and LRT are reported, in decreasing order, in Table 17 and visualized in Figure 14. The numbers "1" and "2" next to the attributes relates to the first or second level of crowdedness and smoothness of the ride (they will be referred in the text as CR1, CR2, SR1 and SR2).

Attribute	BRT	Attribute	LRT
Travel time	33.5%	Travel time	22.7%
Travel cost	18.3%	Crowdedness 2	19.4%
Smoothness of the ride 2	16.2%	ASC	15.1%
Waiting time	9.6%	Travel cost	13.1%
Crowdedness 2	8.8%	Waiting time	10.8%
Smoothness of the ride 1	7.0%	Crowdedness 1	10.5%
Crowdedness 1	6.7%	Smoothness of the ride 2	6.3%
		Smoothness of the ride 1	2.1%

Table 17: attribute importances for BRT and LRT listed by value

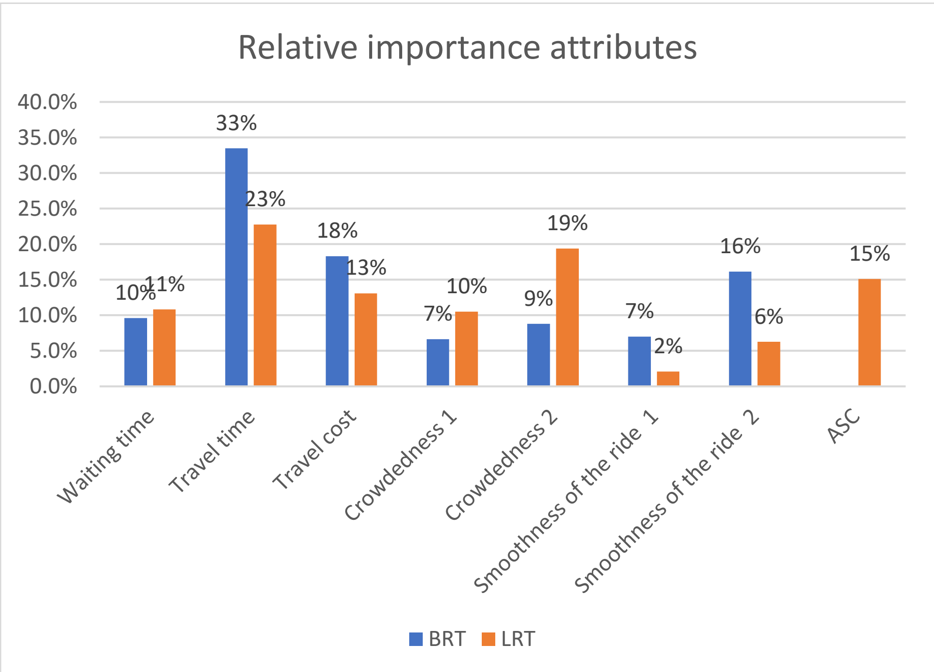

Figure 14: graphical visualization of the attribute importances for BRT and LRT

For both BRT and LRT travel time seems to be the most important attribute (relative to the others). Previously, it has been explained that the estimates for travel time do not vary between BRT and LRT, however, travel time still plays a fundamental role in the value of the total utility. For BRT, the other two attributes which are relatively important are travel cost and smoothness of the ride SR2. It appears that, for BRT, apart from travel time and travel cost, the disutility for going from a smooth to a jerky ride seems rather significant. The first dummy for smoothness of the ride SR1 and the first dummy for crowdedness CR1 are the least important. This means that the total disutility is not particularly influenced by changing from a very smooth to a generally smooth ride and for changing from a vehicle with seats available to standing in a non-crowded vehicle. It appears that for the respondents, the first levels of smooth ride and crowdedness is not much different than their respective base levels.

For LRT, the second most important attribute appears to be the second dummy of crowdedness CR2, confirming what was mentioned earlier in this section, that standing on a crowded tram vehicle is perceived rather negatively. Follows in the list the ASC, meaning that a combination of other factors plays a role in the total value of the utility. Finally, the two dummies for smoothness of the ride SR1 and SR2 are the least important for LRT, probably because respondents, when deciding for a rail-based transport mode, they automatically assume it rides smoothly and focus their attention on other aspects for their final choice.

7.3. Monetization of the results: willingness to pay

The estimated parameters allow performing different type of analysis. Among these, the most important one consists of determining the value of time (or the willingness to pay). In transport economics, the value of time is the cost of the time a passenger spends for the journey and is often used as a tool to determine how much a traveller is willing to spend to save time (Galetzka, et al., 2017). The monetization of time is often used on appraisal methods such as cost-benefit analysis (Meunier & Quinet, 2014), for example to quantify the monetary benefit of a new transport infrastructure in terms of reduced journey time.

Conceptually, the value of time (often referred to as VoT or VoTTS as for value of travel time savings), is calculated as the ratio of the impact of a (marginal) change in travel time on utility and the impact of a (marginal) change in travel cost on utility (Chorus, 2018) and is expressed by the following:

$$VoT = \frac{\frac{\partial V}{\partial TT}}{\frac{\partial V}{\partial TC}}$$

For linear utility functions, the ratio of partial derivatives becomes a ratio of the time and cost parameters (Cascetta, 2009):

$$VoT = \frac{\beta_{TT}}{\beta_{TC}} \qquad [€/hour]$$

Since travel time is generally expressed in minutes, the above formula gives the value of time in euros/minute. To obtain the value in euro/hour it is sufficient to multiply by 60.

The same approach can be used to estimate the value of waiting time which can be used, for example, to assess the economic benefit of increasing the service frequency. The values of travel (VoTT) and waiting time (VoWT) for BRT and LRT found with this research are reported in Table 18 (expressed in euro/hour).

		BRT	LRT
Value of Travel Time	VoTT [euro/hour]	10.96	10.42
Value of Waiting Time	VoWT [euro/hour]	7.88	12.38

Table 18: values of travel and waiting time for BRT and LRT

It can be seen that the values of travel time are similar for BRT and LRT (it was already mentioned that they were both at the first place in terms of attribute importance for utility contribution and that they had similar parameter estimates). These two VoTT are slightly higher than the average VoT of 7.42 euro/hour found for the Netherlands (Kennisinstituut voor Mobiliteitsbeleid, 2017).

The values for waiting time are particularly interesting and deserve further explanation. In 4.2.2, it was mentioned that, according to literature, waiting time is usually weighted more than travel time. People generally perceive the time spent waiting at the stop as much slower compared to the time spent on a vehicle. This seems true for LRT, but not for BRT, whose VoWT is lower than the VoTT. According to this result, respondents would rather spend time waiting at the stop than travelling on a bus. It is not possible to state why this is the case, only speculations can be made. Combining the results obtained in the perception analysis in 5.3 and those from the choice modelling in this chapter, it might be concluded that overall comfort on a bus vehicle is perceived as very low. The perception scores showed that the key differences between BRT and LRT included crowding during peaks, capacity for passengers transferring from train, bumpiness of the route and smoothness on curves. From the estimated MNL model, it appeared that a jerky ride is evaluated particularly negatively by the respondents. The combination of these results might explain why people prefer to wait at the stop rather than travelling on the vehicles.

This can have repercussions on service design: if it is true that passengers prefer to wait longer rather than travelling on a crowded vehicle, than it would be interesting to explore public transport solutions aimed at improving the service not by increasing the frequency, but using more spacious vehicles, with more seats, and possibly driving in a smoother way. The result of the values of time also more clearly shows what was already mentioned earlier in this section: that waiting for a bus weights less than waiting for a tram, probably due to its current higher frequency.

In the same way as for deriving the values of times, by dividing the estimate of the ASC with the (absolute value of the) parameter for cost, it can be calculated the monetary value of the LRT bonus:

$$VoLRT_{bonus} = \frac{ASC}{\beta_{TC_{LRT}}} = 1.15\ euro$$

The monetary value of the rail bonus is found to be 1.15 euro. This means that a traveller in the (Utrecht) population have an additional monetary utility of 1.15 euro when deciding for an LRT. In other words, €1.15 is the price a traveller is willing to pay additionally to the ticket fare to travel on an LRT instead of a BRT.

Other types of similar analysis can be performed by combining the estimated parameters in a particular way. Inspired by van Mil et al. (2018), it is possible to draw the pentagon illustrated in Figure 15.

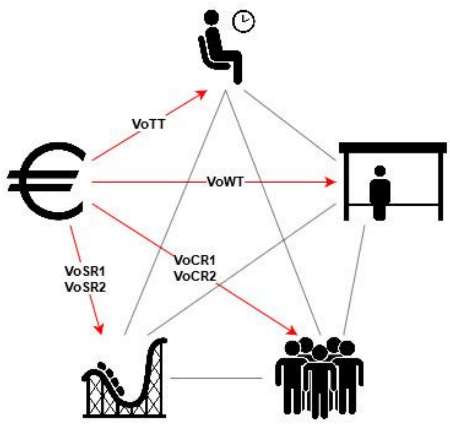

Figure 15: pentagon of the monetary trade-offs

This pentagon shows, with the red arrows, all possible analyses that can be performed by combining the parameter for cost with those for travel time, waiting time, crowdedness and smoothness of the ride. The first two have already been found and described few paragraphs earlier (VoTT and VoWT), while the monetary values for crowdedness and smoothness of the ride are reported in Table 19. They are reported in terms of euro/crowding level (VoCR1 and VoCR2) and euro/smoothness level (VoSR1 and VoSR2).

		BRT	LRT
Value of first level of crowdedness	VoCR1 [euro/level]	0.36	0.80
Value of second level of crowdedness	VoCR2 [euro/level]	0.48	1.48
Value of first level of smoothness of the ride	VoSR1 [euro/level]	0.38	n.a.
Value of second level of smoothness of the ride	VoSR2 [euro/level]	0.88	0.48

Table 19: monetary values of crowdedness and smoothness of the ride

These values represent the willingness to pay of an average traveller for changing from the first or second level of crowding or smoothness of the ride to the base level (seats available and smooth ride). It can be seen that for LRT the respondents are willing to pay a higher price compared to BRT for changing from standing in the vehicle to seating. Particularly high is the price they are willing to spend (€1.48) for changing from standing in a crowded vehicle to seating. Lower willingness to pay is observed for BRT, whose monetary values for the first and second crowding levels are more aligned.

For smoothness of the ride, on the other hand, respondents seem more willing to pay to travel on a smoother bus than on a smoother tram (the first smoothness level for LRT is zero since that parameter was not significant). According to these results, people would pay €0.38 to go from a generally smooth to a very smooth bus ride and €0.88 for changing from jerky to a very smooth bus ride.

7.4. Non-monetary trade-offs: willingness to wait and willingness to travel longer

In the previous section 7.3, the monetary values of travel and waiting time together with the monetary values of the two levels of crowdedness and smoothness of the ride have been shown. The same strategy can be applied to determine non-monetary trade-offs that people would be willing to make. In this section, the trade-offs involving travel time, waiting time, crowdedness and smoothness of the ride, as displayed by the green and purple arrows in the pentagon of Figure 16, are discussed.

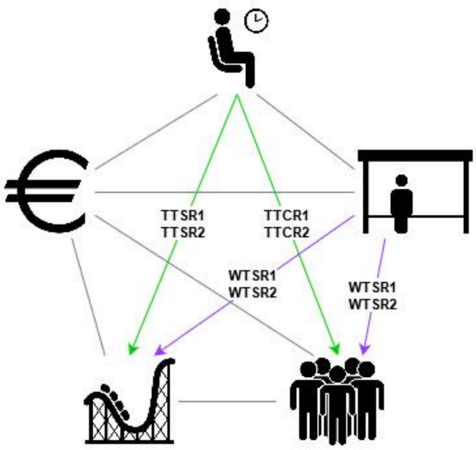

Figure 16: pentagon of the non-monetary trade-offs

In this case, the purpose is not to determine how much money people are willing to pay to ride on a smoother or less crowded vehicle, but rather how much longer they would be willing to ride on a vehicle and how much longer they would be willing to wait at the stop. These trade-offs are reported in Table 20.

		BRT	LRT
Additional travel time for the first level of crowdedness	TTCR1 [min/level]	1.99	4.61
Additional travel time for the second level of crowdedness	TTCR2 [min/level]	2.62	8.52
Additional travel time for the first level of smoothness of the ride	TTSR1 [min/level]	2.10	n.a.
Additional travel time for the second level of smoothness of the ride	TTSR2 [min/level]	4.83	2.75
Additional waiting time for the first level of crowdedness	WTCR1 [min/level]	2.77	3.88
Additional waiting time for the second level of crowdedness	WTCR2 [min/level]	3.65	7.17
Additional waiting time for the first level of smoothness of the ride	WTSR1 [min/level]	2.92	n.a.
Additional waiting time for the second level of smoothness of the ride	WTSR2 [min/level]	6.72	2.32

Table 20: non-monetary trade-offs

these values are expressed in terms of minutes per level. It can be seen that the highest value is observed for LRT in terms of willingness to travel longer for changing from standing in a crowded vehicle to a vehicle with seats available (for such a change the respondents would be willing to tolerate more than 8 minutes additional travel time, as shown by the TTCR2 value). For BRT, and for the same kind of service change, respondents would be willing to tolerate lower additional travel time (a bit more than two and a half minutes). For the same level of crowding on an LRT, people would also be willing to wait 7 minutes longer at the stop (WTCR2) to go from standing in a crowded vehicle to a vehicle with seats available. The other significant result concerns the willingness to wait almost 7 minutes longer (WTSR2) to change from a jerky ride on a BRT to a very smooth ride. The same service upgrade is also displayed by people's willingness to travel about 5 minutes longer on a BRT vehicle (TTSR2).

These results might have an implication on transport service design: if comfort is a highly weighted attribute and if users are willing to wait longer at the stops to have higher comfort levels, it would be ideal, for example, to design a less frequent service with higher vehicle capacity. Clearly, in order to decide how to improve the service, looking at these values alone is not sufficient, but combining the results of all the trade-offs and having a big picture about people's preferences and perceptions, it is possible to design a service which matches the minimum comfort and service needs expected by the travellers.

Finally, it can also be determined the non-monetary value of the tram bonus expressed in terms of waiting and travel time, which can simply be determined by dividing the ASC estimate by the parameters for waiting and travel time. The two values are reported in Table 21. It can be seen that people are willing to wait about six minutes longer or travel almost seven minutes longer if the journey is made on a tram vehicle instead of a bus.

Tram bonus in terms of waiting time [min]	5.59
Tram bonus in terms of travel time [min]	6.64

Table 21: time values for the tram bonus

7.5. Scenario analysis

The MNL model has one indisputable advantage: the formula to calculate the choice probabilities assume an elegantly closed form (McFadden, 2000):

$$P(i) = \frac{e^{V_i}}{\sum_j e^{V_j}}$$

This formula can then be used to calculate the probability that a randomly sampled individual would use a BRT or an LRT (which determines the so-called "modal share"). To do so, scenarios need to be created, in particular it needs to be decided which attributes to vary for the sensitivity analysis and to what extent. The purpose is twofold: on one hand the impact of the tram bonus on the modal share has to be verified, and on the other hand the impact of varying the attribute levels on choice probabilities has to be determined.

Since one of the primary reasons for using a discrete choice model in this study is to determine the role of crowdedness and smoothness of the ride, it is decided to analyse the sensitivity of choice probabilities of only these two attributes. This means that travel time, waiting time and travel cost are not varied in the scenarios. The scenarios consider the same situation proposed in the case study for the stated preference questionnaire, that is the replacement of bus line 28 operating via the city centre of Utrecht with a light rail. For this reason, in all scenarios the current travel time, waiting time and travel cost are used. These correspond to the intermediate attribute levels used for the MNL estimation (travel time: 19 minutes, waiting time: 3 minutes, travel cost: €1.85).

How to design the scenarios by including also crowdedness and smoothness of the ride requires more careful planning. There are two modes: BRT and LRT, and both include the two attributes for crowdedness and smoothness of the ride, which both vary in three levels. Wanting to consider all possible combinations, it would be required the analysis of 3^4=81 different scenarios. To reduce the number of scenarios, it is wise to make a reasoned selection. Previously, when analysing the importance of the attributes in 7.2, it emerged that travel time, travel cost and second level of smoothness of the ride (SR2) were the most relatively important attributes for BRT, while for LRT the most important ones were travel time, second level of crowdedness (CR2) and ASC. Since travel time and travel cost are kept constant in all scenarios, it seems reasonable to analyse the variation in choice probabilities by varying only smoothness of the ride for BRT and crowdedness for LRT. At the same time, to maintain the scenarios realistic and by combining what emerged from the perception analysis, it is decided to keep crowdedness for BRT on the first level and smoothness of the ride for LRT on the base level for all the scenarios, since it emerged that bus is generally perceived more crowded and tram is perceived smoother.

With these assumptions, a total of nine scenarios are produced, as summarized in Table 23. Two additional scenarios (numbered as A and B) are added to explore the impact of the ASC (highlighted in green). The three levels for crowdedness and smoothness of the ride are shown in Table 22.

Crowdedness	0: seats available 1: only standing - not crowded 2: only standing - crowded
Smoothness of the ride	0: very smooth 1: generally smooth 2: jerky

Table 22: coding used to represent the three attribute levels

	BRT					LRT				
scenario	**travel time**	**waiting time**	**travel cost**	**crowdedness**	**smoothness of the ride**	**travel time**	**waiting time**	**travel cost**	**crowdedness**	**smoothness of the ride**
A	19	3	1.85	0	0	19	3	1.85	0	0
B	19	3	1.85	2	2	19	3	1.85	2	2
1	19	3	1.85	1	0	19	3	1.85	0	0
2	19	3	1.85	1	0	19	3	1.85	1	0
3	19	3	1.85	1	0	19	3	1.85	2	0
4	19	3	1.85	1	1	19	3	1.85	0	0
5	19	3	1.85	1	1	19	3	1.85	1	0
6	19	3	1.85	1	1	19	3	1.85	2	0
7	19	3	1.85	1	2	19	3	1.85	0	0
8	19	3	1.85	1	2	19	3	1.85	1	0
9	19	3	1.85	1	2	19	3	1.85	2	0

Table 23: scenarios and their attribute values

SCENARIO	BRT	LRT
A	26%	74%
B	52%	48%
1	18%	82%
2	43%	57%
3	68%	32%
4	11%	89%
5	30%	70%
6	55%	45%
7	6%	94%
8	17%	83%
9	38%	62%

Table 24: choice probabilities of the scenarios

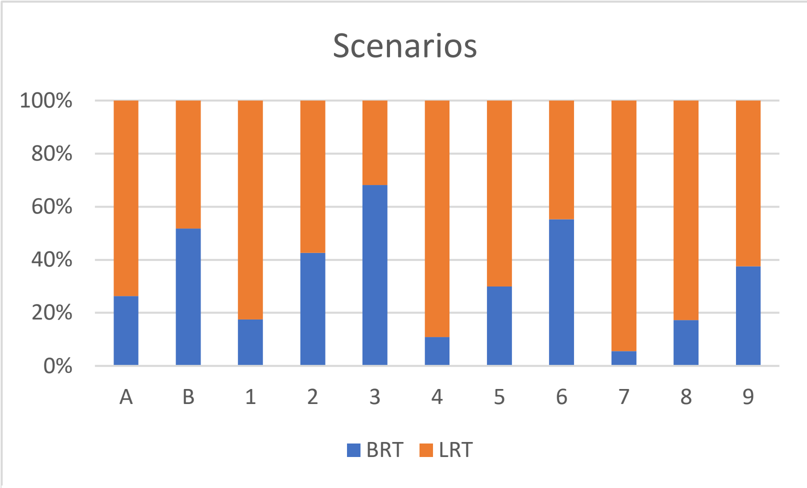

Figure 17: graphical visualization of the choice probabilities of the scenarios

The results are displayed in Table 24 and Figure 17. It can be seen that overall LRT obtains the largest mode share probabilities in 8 over 11 scenarios

To explain to what extent the ASC impacts choice probabilities (and therefore the modal share between BRT and LRT), it is decided to analyse scenarios A and B. The reason for using these scenario is that both modes have the same attribute levels. More precisely, they both include the most favourable and most disadvantageous scenarios in regards to crowding and smoothness of the ride (which are in both modes set to the favourable base level in A and set to disadvantageous level in B).

According to scenario A, 26% choice probabilities are for BRT and 74% for LRT. This result can be compared to the one from scenario number 5, which also has the same attribute levels (the intermediate level) for both alternatives (excluding the first dummy for smoothness of the ride for LRT, which is zero because found not significant). The choice probabilities are not much different: 30% for BRT and 70% for LRT. It appears that the ASC, controlling for the other attributes which are kept at the same values, gives the LRT a 40% higher share. Comparing with scenario B, however, things change. By including for both modes the worst situation in terms of crowding and smoothness of the ride, BRT prevails slightly with 52% share. This is because the attribute for crowding for LRT is negatively large, such that even with the ASC, this mode cannot get the highest share.

The attributes, therefore, play an important role. It can be observed in scenario 3, for example, that choice probability is highly in favour of BRT (68% versus 32%). This is the scenario in which the attribute smoothness of the ride is most in favour for BRT (very smooth ride) and crowdedness is very much in disfavour for LRT (standing in a crowded vehicle). It means that between a very smooth and partially crowded BRT and a very smooth and very crowded LRT, despite the rail bonus, people still prefer the BRT. BRT also obtains higher probabilities in scenario 6, where the BRT is generally smooth (with rare sudden brakings) and LRT is again very crowded (55% versus 45%). Therefore, in the scenarios where LRT requires to stand in a crowded vehicle, put next to a BRT which does not have a jerky ride, the rail bonus fails to give LRT the primate as preferred mode over BRT. In all other scenarios, the combination of rail bonus and attribute estimates, gives to LRT the higher mode share.

The previous paragraph showed the impact that the alternative specific constant (which represents the rail bonus) has on the choice probabilities. Keeping into account its existence is therefore important not to have flaws and wrong conclusions when forecasting mode usage. It is thus interesting to see what would happen if, for some reason, a policymaker ignores the existence of the rail bonus and proceeds at evaluating mode preferences in the population by considering only the main five attributes. This is done by looking at what would happen to the choice probabilities when the ASC is removed. The results are reported in Table 25 and Figure 18.

SCENARIO	BRT	LRT
A	68%	32%
B	87%	13%
1	56%	44%
2	82%	18%
3	93%	7%
4	43%	57%
5	72%	28%
6	88%	12%
7	27%	73%
8	56%	44%
9	78%	22%

Table 25: choice probabilities without the ASC

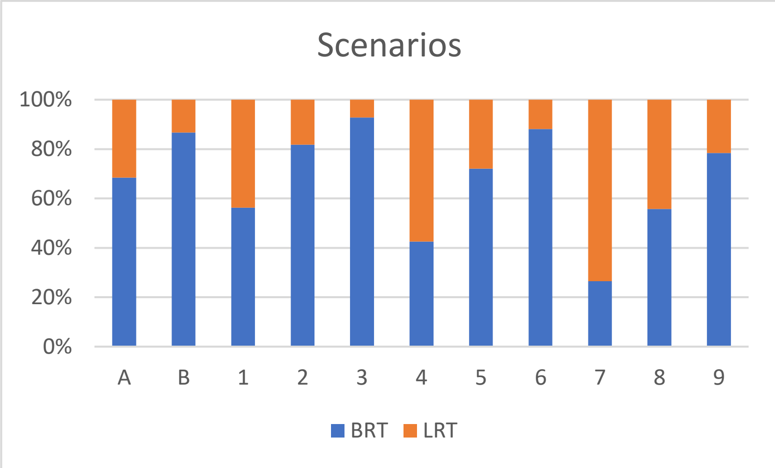

Figure 18: graphical visualization of the choice probabilities of the scenarios without the ASC

It can be seen, that, by neglecting the existence of the rail bonus, all choice probabilities go in favour of BRT. The only exceptions are for scenarios 4 and 7, in which the crowding levels for LRT are set to 0 (base level, seats available). This reveals two aspects: first, that without considering the rail bonus it is hard for LRT to be the preferred mode, and completely different mode shares are obtained, and second, it confirms that crowding on LRT hugely impacts the modal share. The wrong mode share estimation can lead to dramatic modelling mistake as well, with wrong estimation of the flows on the network.

7.6. Conclusion rail bonus and preferences analysis

This chapter provides the main results of the discrete choice modelling. The most important finding is the confirmation of the existence of the rail bonus, in a form of alternative specific constant for the LRT, which is positive and highly significant. The existence of the rail bonus, also confirms that the attributes included in the estimation do not explain the bonus, but rather that other factors play a role in the inherent preference for LRT over BRT. Moreover, it is found that for BRT the smoothness of the ride play an important role, in particular if the bus has a jerky ride, while it is not as important for LRT. On the other hand, for LRT crowdedness is found to have a rather negative impact on the total utility, especially if people have to stand in a crowded vehicle. Crowding for BRT is not perceived as much negatively.

The values of the willingness to pay (value of time) are in line with literature. The main surprising result refers to the lower value of waiting time for BRT compared to its value of travel time, meaning that people perceive travelling on a bus vehicle more negatively than waiting at the stop, contradicting the general scientific finding that waiting time is weighted more negatively than spending time on a moving vehicle. The non-monetary trade-offs confirm this finding, that people are willing to wait longer at the stop if they have more comfort on the vehicle. The estimate for the constant combined with the parameter for cost gives the monetary value of the rail bonus and it reveals that people are willing to spend about one additional euro to travel on a LRT compared to BRT. Moreover, the non-monetary value of the ASC shows that people are willing to wait or travel about 6-7 minutes longer if the ride is made on a tram vehicle. The application of the results obtained in the MNL model are used in different scenarios, confirming once again that crowdedness for LRT and smoothness of the ride for BRT are rather determinant for the computation of the modal share probabilities. Moreover, the two scenarios A and B showed that the rail bonus influences the final modal share values only to the extent that the attributes for smoothness of the ride (for BRT) and crowdedness (for LRT) are not set to the worst levels (jerky ride and standing in a crowded vehicle).

8. PERCEPTION STRUCTURES ANALYSIS

The aim of network modelling in this research is to determine the relationship existing between perception variables and how the network construct for BRT and LRT differ. A substantial difference in the network structures, in particular the presence of clusters, might give an indication about which perceptions mostly determine the difference in how BRT and LRT are seen by the respondents. Moreover, it might explain the reasons behind the rail bonus black-box. In the following sections, the results and interpretations of the network modelling are given. In particular, 8.1 provides an analysis of the differences observed on the network constructs for BRT and LRT; 8.2 looks into more detail the edge differences between the two networks; 8.3 briefly dives into network stability and reliability; 8.4 explores the structure of the network estimated with the score differences; finally, 8.5 concludes the chapter by summarizing the main findings.

8.1. Network structures

The network models are estimated by importing the perception scores into the freely available statistical software Jasp (Department of Psychological Methods, University of Amsterdam, 2018). The software allows to select which variables to include into the modelling and it automatically computes the variance-covariance matrix from which the partial correlations between the variables are derived, as described in section 6.2. Moreover, the software automatically removes the spurious edges following the EBIC lasso procedure. After these computations, the networks are displayed, together with the partial correlation matrix and graphs of the centrality indicators.

For this modelling technique, only the original perception scores are included, none of the scores is reversed as done in 5.3 for the perception analysis. In this way, negative partial correlations are visualized. After few trial iterations, the statement "*if this vehicle is driverless (automated), I would be willing to use it*" is found to have little relations with all other variables, and is therefore excluded from the analysis. In total 20 statements are included in the network modelling. Keeping the tuning parameter at the value of 0.5 (as suggested by Foygel & Drton (2010)), two networks are estimated: one for BRT and one for LRT (Figure 19 and Figure 20). For BRT, 111 over 190 edges are found significant, while for LRT the significant edges are 105. In the figures, to ease the visualization, only edges with partial correlations higher than 0.05 are visualized. The letters A and B in the nodes are required to separate the score results for BRT from those for LRT, while the numbers are associated with the statements as indicated in Table 26, which also reports the clusters observed in each network.

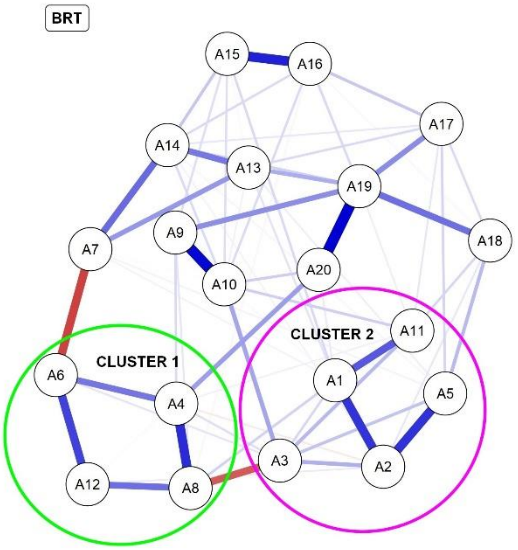

Figure 19: estimated network for BRT

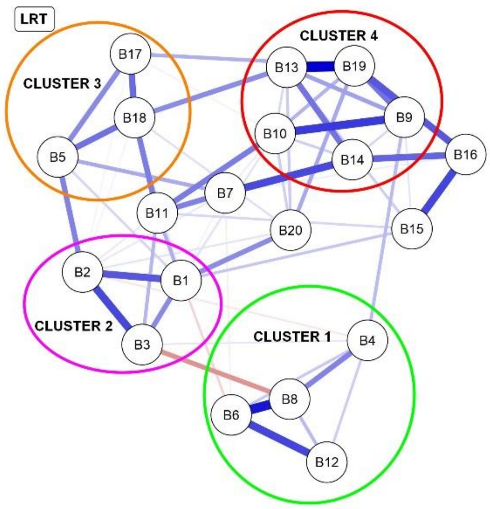

Figure 20: estimated network for LRT

Number	Statement	BRT		LRT			
		Cluster 1	Cluster 2	Cluster 1	Cluster 2	Cluster 3	Cluster 4
1	The vehicle has easy and fast boarding		X		X		
2	The vehicle provides enough capacity for passengers transferring from train		X		X		
3	The service feels reliable (every time almost equal travel time and is punctual)		X		X		
4	During peak hours the vehicle feels uncomfortably crowded	X		X			
5	The vehicle has enough seats		X			X	
6	The route has many bumps making the ride not enjoyable	X		X			
7	The vehicle rides smoothly on curves						
8	The vehicle is often delayed	X		X			
9	The vehicle looks modern and appealing						X
10	The vehicle is fast						X
11	The vehicle has a sufficient number of doors		X				
12	The vehicle waits too long at stops	X		X			
13	The vehicle is comfortable						X
14	The vehicle accelerates and brakes smoothly						X
15	The vehicle is environmentally friendly						
16	The vehicle rides without making noise						
17	The vehicle has enough leg space to sit comfortably					X	
18	The vehicle has enough standing space					X	
19	From the inside the vehicle feels spacious and has a pleasant design						X
20	It is a frequent service						

Table 26: statements included in the network modelling and clusters

Looking at the network structures, it appears that the BRT network is more sparse than LRT one. While the strength of the relation between single nodes is displayed by the strength of their edges, the level of sparsity reveals the strength of relation between the nodes as a group: the higher the relations (i.e. the partial correlations) between a certain group of nodes, the closer these nodes are to each other.

In the case of LRT, four clusters are observed. The largest and most evident one is cluster 4 (in red) composed by the nodes 9, 10, 13, 14 and 19 related to characteristics such as the look of the vehicle (from the inside and outside), speed, smoothness of the ride, comfort and internal space. These perceptions seem highly related to each other. More in particular, it seems that node 9 (The vehicle looks modern and appealing) is very much related to 10 (The vehicle is fast) and 19 (From the inside the vehicle feels spacious and has a pleasant design), while node 13 (The vehicle is comfortable) seems more related also with 19 and 14 (The vehicle accelerates and brakes smoothly). It is not possible from these networks to determine what is causing what, but only the extent to which items are related to each other. However, it can be speculated that an LRT that is perceived as modern, is also perceived fast and spacious, and an LRT perceived as comfortable is also perceived as spacious and riding smoothly.

For BRT, this cluster disappears and these same relations are weaker, except the partial correlation between 9 and 10, meaning that a modern bus can also be perceived as fast (and vice versa). The existence of this large cluster for LRT and its complete disappearance in the network for BRT seems rather relevant and it suggests that this strong difference in network construct might partially explain the difference in perceptions between these two types of vehicles.

Cluster 1 (in green) is present in both networks (although for LRT this cluster seems quite separated from the rest of the network) involves the nodes 4, 6, 8 and 12, related to crowding during peaks, route with many bumps, often delayed and waiting too long at stops. It is possible that a too crowded vehicle is a cause of perceived delays and prolonged waiting at the stops for boarding and alighting passengers. It is also possible that a bumpy route is perceived as one of the causes for the delays, and this perception might be further strengthened by being in a crowded vehicle.

Cluster 2 present in the BRT network, is composed by nodes 1, 2, 3, 5 and 11, related to easy fast boarding, enough capacity for passengers transferring from train, reliability, enough seats and sufficient number of doors. This cluster seems related to boarding and internal capacity. Node 1 in particular (ease of boarding) appears to be strongly related with 11 (number of doors) and 2 (capacity for passengers coming from train). This means that making the bus vehicle easier to access (by also increasing the number of doors) it might increase the perception of more capacity available for those transferring from train. It could be that this perception structure is related to the queues that are usually formed for boarding a vehicle at major transfer nodes: seeing a queue of people entering the bus gives the perception that there is not enough space for everyone, while more doors would make the access faster, there would be no queues and even if the provided space is the same, passengers would perceive that the capacity provided is enough. To notice that node 3 (reliability) is directly related to all the other nodes belonging to the cluster, probably because there exists a perceived relation between vehicle capacity, ease of boarding and reliability. This cluster is only partially present for LRT (nodes 1, 2 and 3) probably because tram vehicles have more doors and more seats available, therefore this type of perception structure is much weaker.

Finally, in the LRT network is observed a triangle cluster, completely missing for BRT, composed by nodes 5, 17 and 18, related to number of seats, leg space and standing space. It seems that the perceived internal space of tram vehicles are strictly related to the combination of these three perceived factors. The proximity of this cluster to node 13 (comfort) seems to suggest that a vehicle is perceived comfortable if there is an optimal combination of seats, leg space and standing space.

These networks are evaluated with centrality measures derived from graph theory, as explained in 6.2. Degree, closeness and betweenness are plotted for BRT and LRT in Figure 21. On a high level, it can be observed that the centrality measures follow a similar pattern both for BRT and LRT networks, meaning that overall, there are some similarities in terms of nodes centrality. Some important differences, however, can be explained.

It can be observed that the statements 11 (The vehicle has a sufficient number of doors), 19 (From the inside the vehicle feels spacious and has a pleasant design) and 13 (The vehicle is comfortable) are the most central for the LRT network. It appears that number of doors, internal environment and comfort are the three items that mostly relate with most of the other perceptions. Thus, by intervening on one of these aspects, it is possible that perceptions about other vehicle/system-related aspects would change as well.

The perceptions with the lowest centrality for LRT appear to be 12 (The vehicle waits too long at stops), 17 (The vehicle has enough standing space) and 4 (During peak hours the vehicle feels uncomfortably crowded). This does not mean that these perceptions are not relevant, but only that they do not influence all other items to the same extent as the three previous ones.

For BRT, 19 (From the inside the vehicle feels spacious and has a pleasant design), 4 (During peak hours the vehicle feels uncomfortably crowded) and 10 (The vehicle is fast) appear to be the most central nodes in the network. 19 is found to be central both for LRT and BRT, meaning that in both cases the internal space and atmosphere might have an impact on multiple other aspects. Item number 4, however, which is found to be quite central for BRT, was found to be the least central for LRT. This tells that, while for LRT the perception of travelling on a crowded vehicle during peaks do not influence other perceptions, for BRT crowding during peaks seems to have an impact on the general perceptions people have for BRT.

Items 12 and 17 seem to have low centrality score for BRT as well, together with statement number 15 (The vehicle is environmentally friendly). It seems that the perception for waiting too long at the stop, the availability of enough standing space and the environmental friendliness are perceptions by their own and do not impact substantially the others.

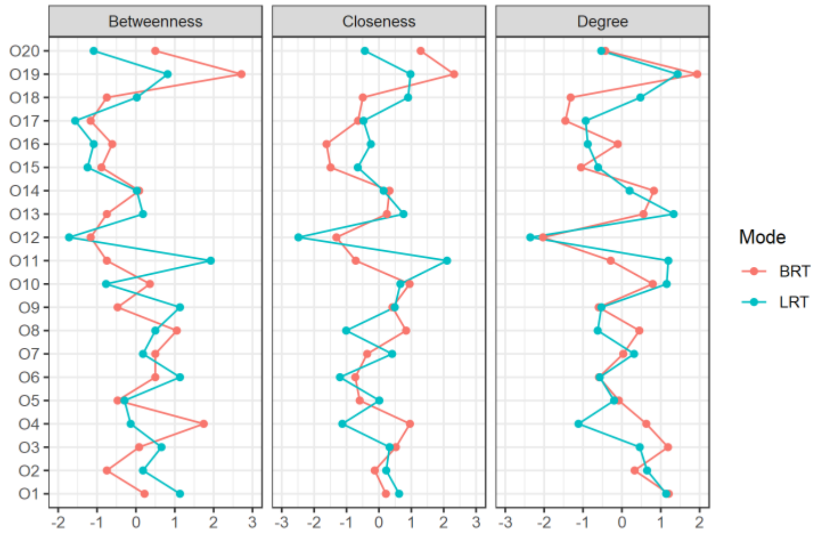

Figure 21: centralities plottings

8.2. Main edge differences

The networks displayed in Figure 19 and Figure 20 have the advantage of showing the different structures and the different clusters that are formed for BRT and LRT. They are, however, difficult to compare with each other, especially to verify edge differences. To ease the visualization of the differences, a new estimation is performed, which preserves the original edge strengths but displays the two networks with the same shape. The original structure peculiar of each mode is lost, but the visualization of the differences in terms of edge strength is improved. The new networks are displayed in Figure 23 and Figure 22.

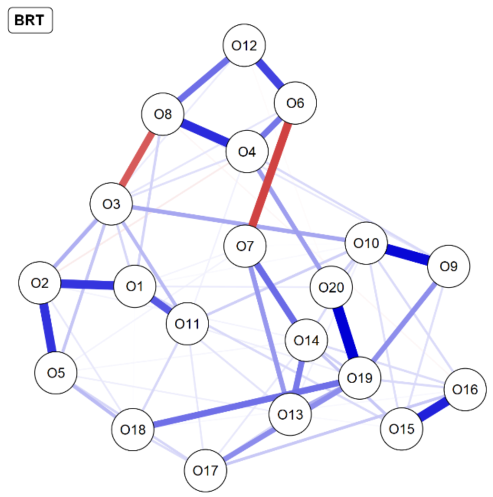

Figure 23: re-estimated network for BRT

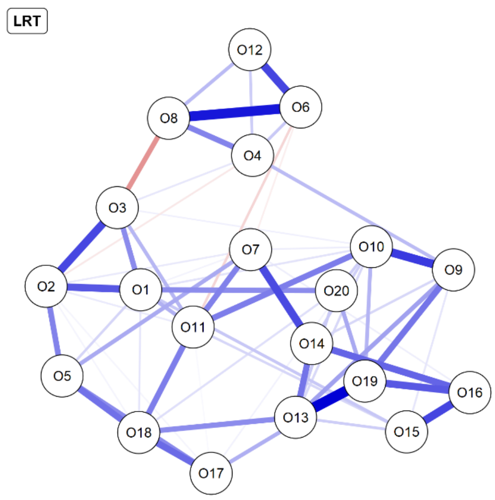

Figure 22: re-estimated network for LRT

<u>Negative relations</u>

The first difference that results by comparing the two networks relates to the negative relations 3-8 (The service feels reliable (every time almost equal travel time and is punctual) - The vehicle is often delayed) and 6-7 (The vehicle rides smoothly on curves - The route has many bumps making the ride not enjoyable). For BRT, the first is much stronger than for LRT, but the existence of this edge is expected for both modes since both statements are a measure of the reliability of the service and are expressed one with a positive and the other with a negative phrasing. The second negative edge is considerably strong for BRT, while is almost non-existent for LRT. It appears that a vehicle riding on a bumpy route is also perceived as less smooth on curves. It is possible that when riding at speed on curves, the swinging of the bus vehicle is also perceived as bumpy, causing this high relation between route bumpiness and smoothness of the ride. The absence of this strong relation for LRT is presumably due to the smoother ride perceived on rail vehicles, which generally have a lower swinging rate at curves.

Delay

The presence of a strong link between 8 and 6 (The vehicle is often delayed - The route has many bumps making the ride not enjoyable) seems rather curious for LRT (a link that is absent in the case of BRT). This relation for LRT might relate to the low average score that both items have produced for LRT (in general LRT is perceived as not bumpy and not often delayed). There is, on the other hand, a strong relation between delays and item number 4 (During peak hours the vehicle feels uncomfortably crowded) for BRT, while is less pronounced for LRT. It appears that crowding during peak hours on bus vehicles are perceived as one of the causes for the delays, but it can also be the other way around, that due to delays more people are waiting at the stops and the vehicle would become more crowded. This seems confirmed by the high relation between delay and waiting too long at the stop (statement 12): presumably, due to crowding and delays, people perceive that the vehicles have to wait longer at the stop to board and alight the numerous amount of passengers.

Capacity and ease of boarding

For both networks there is a strong edge between nodes 2 and 1 (The vehicle provides enough capacity for passengers transferring from train - The vehicle has easy and fast boarding), meaning that for both modes an easy and fast boarding process is related to a perceived higher capacity for passengers transferring from train. The presence of a relatively large edge between the ease of boarding and the number of doors (node 11), and considering the low scores obtained by these items for BRT compared to LRT, it seems that people perceive bus vehicles as not suitable for transfer points, probably also due to the queue that are usually formed at the front door for boarding as already mentioned in 5.3: even if the vehicle can actually contain all the passengers, the fact that before boarding they have to queue, makes the process being perceived as slow and not suitable for the situation. However, this relation does not seem confirmed for LRT, for which the number of doors and ease of boarding both received high scores, but do not seem much correlated by controlling for the other variables.

Environment, noise and appearance

For both modes it is observed a strong relation between nodes 15 and 16 (The vehicle is environmentally friendly - The vehicle rides without making noise): in both cases, a more silent vehicle is perceived as more environmentally friendly, and the other way around, a greener vehicle is also expected to be more silent. To notice the edge between 16 and 14 (The vehicle accelerates and brakes smoothly) for LRT which is almost absent for BRT, meaning that a silent tram vehicle is also perceived to ride smoother. It is also interesting the strong edge connecting 16 and 19 (From the inside the vehicle feels spacious and has a pleasant design): in reality, noise does not have anything to do with interior design and space, but for some reason people associate the produced level of noise with the dimension and design characteristics of the vehicle. Another example of apparently unrelated perceptions is given by the relation existing for both BRT and LRT between 9 (The vehicle looks modern and appealing) and 10 (The vehicle is fast): a vehicle can be fast but also ugly at the same time, however, it seems that if a vehicle is slow but nice looking, it can be perceived as faster.

8.3. A mention on network stability

The objective of investigating network stability is to determine to what extent the estimated networks are reliable and if their results can then be interpreted without incurring in wrong conclusions.

Investigating the stability of the estimated network implies gaining insights into network accuracy. Research on how to determine the accuracy of psychological networks is still ongoing, nonetheless, some results have been achieved and basic network stability analyses can be now performed. The analysis of the stability of the network is important because network models can easily run into serious problems caused by fundamentally two reasons: too many nodes, or too little responses. Outliers might also be a cause of network instability and false interpretations (Fried, 2018).

The key procedure for analysing network stability involves the methodology of bootstrapping (Epskamp, Borsboom, & Fried, 2018). Bootstrapping consists of estimating models using hundreds, or thousands of subsets of the data. Stability analysis is performed by inspecting the stability of two types of indices: edges and centralities. At each bootstrap, different respondents are included in the model, a network is estimated and edge and centrality indicators are confronted with the network originally estimated including the entire dataset, and finally a coefficient stability (CS) index is calculated, which represents the correlation between edges and centrality values in the bootstrap compared to the entire model. This is repeated hundreds, or thousands of times and results are plotted on graphs reporting the variation of the CS index as a function of the percentage of samples included in the model. If the functions representing the edge strengths or the network centrality indicators remain above correlation values of 0.5-0.7, even after removing more than 50% of the sample, the network can be considered stable and the results can be considered reliable and interpretable.

For this research, 1000 bootstraps are performed and the results are displayed in Figure 24 and Figure 25 for BRT, and Figure 26 and Figure 27 for LRT.

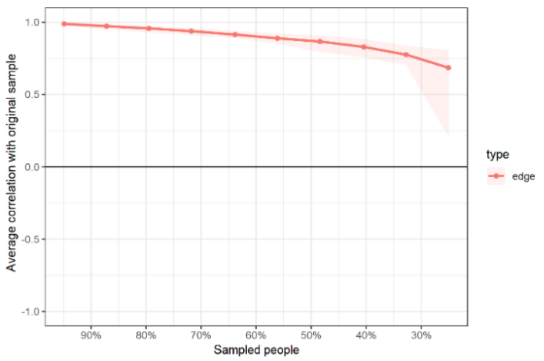

Figure 25: edge stability function for BRT

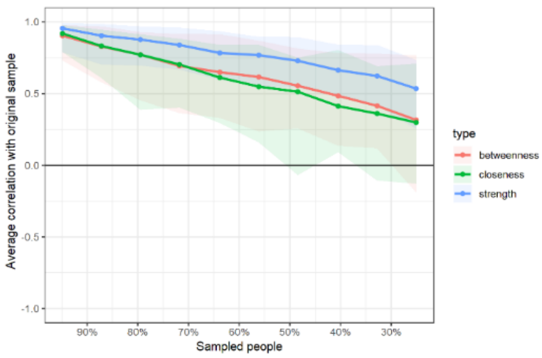

Figure 24: centrality stability functions for BRT

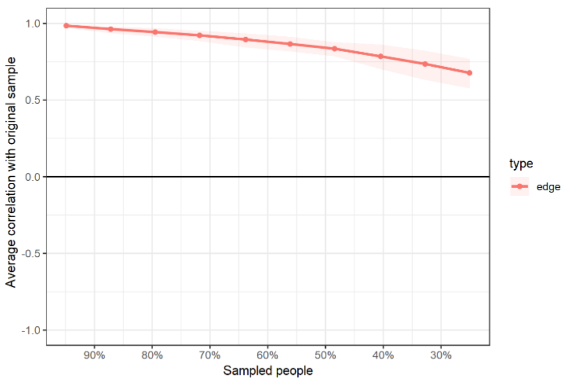

Figure 27: edge stability function for LRT

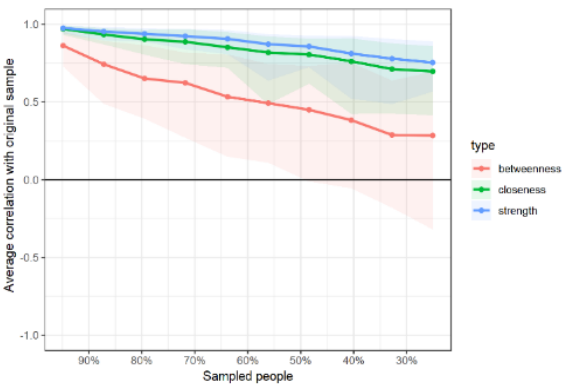

Figure 26: centrality stability functions for LRT

It can be observed that the edge stability function remains fairly stable for both BRT and LRT networks, starting to decline slightly after more than 50% of the sample is removed, but never reaching correlation values lower than 0.6.

The centrality indexes, on the other hand, seem to decrease more steeply. For BRT, betweenness and closeness are the indexes that decline more quickly, while strength always remains over 0.5 correlation values. Somewhat different is the situation for the network related to LRT, where closeness and strength perform very well, keeping their correlation values solidly above 0.6, while betweenness performs worse declining at under 0.5 already with 65% of the sample removed.

This basic stability analysis shows that edge strengths are reliable and can be interpreted, while the interpretation of centrality indicators requires more caution.

8.4. Network of the score differences

Throughout this research, the aim was to understand people's preferences and perceptions of BRT and LRT. But most importantly, the main goal of this study is to determine how preferences and perceptions for BRT and LRT differ between them. In the case of the discrete choice modelling, differences are assessed by verifying the existence of a constant (the rail bonus) and by analysing the variation of the estimated parameters. Differences in perceptions are also estimated, by simply measuring the average score difference obtained by each statement. Therefore, it seems reasonable to estimate a network of the score differences as well. In this network, the reversed scores of the statements formulated with negative phrasing are included. This is done because, as it was previously shown in the perception analysis performed in 5.3, all score differences between LRT and BRT are positive.

A network estimated with score differences needs careful interpretation. A link between two nodes (nodes that represent the perception statements) signals the existence of a direct relation between the perceived difference of those two statements between BRT and LRT. For example, the existence of a link between the node representing the statement "*The vehicle accelerates and brakes smoothly*" and the node relative to "*The vehicle is comfortable*", in the network of the differences does not indicate that smoothness of the ride is directly linked to comfort for either BRT or LRT, it indicates instead that the difference in perception between BRT and LRT for smoothness of the ride is directed linked to the difference in perception for comfort. In other words, if it is perceived that the LRT accelerates and brakes more smoothly than the BRT, than it is also considered that LRT is more comfortable than the BRT.

After several iterations, the final estimated network includes the 14 nodes reported in Table 27 and it can be visualized in Figure 28. The other seven nodes are excluded due to the low centrality indexes and low edge strengths with the other nodes. In total, 61 out of 91 edges result to be non-zero. To ease the visualization, only edges with a partial correlation higher than 0.05 are displayed.

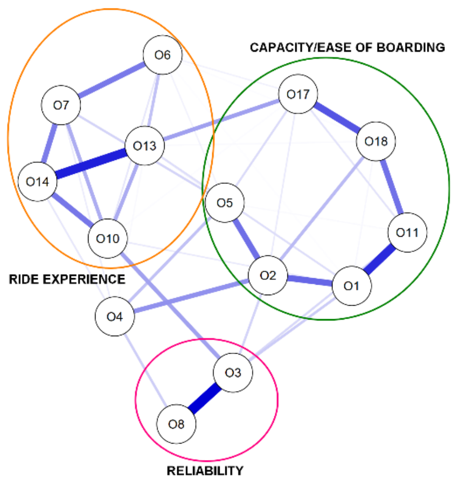

Figure 28: network of the score differences

Number	Statement
1	The vehicle has easy and fast boarding
2	The vehicle provides enough capacity for passengers transferring from train
3	The service feels reliable (every time almost equal travel time and is punctual)
4	During peak hours the vehicle feels uncomfortably crowded
5	The vehicle has enough seats
6	The route has many bumps making the ride not enjoyable
7	The vehicle rides smoothly on curves
8	The vehicle is often delayed
10	The vehicle is fast
11	The vehicle has a sufficient number of doors
13	The vehicle is comfortable
14	The vehicle accelerates and brakes smoothly
17	The vehicle has enough leg space to sit comfortably
18	The vehicle has enough standing space

Table 27: statements included in the network modelling

It can be seen that all edges are positive. This is due to the fact that the perception scores for LRT are always higher than those for BRT, therefore the differences are always positive. Three main groups of nodes can be identified and are highlighted in the figure with different colours. Groups are identified by looking at their position in the network, the structure of the edges construct, and by identifying similarities. It is then possible to give a name to each group as follows: purple (reliability), green (capacity/ease of boarding) and orange (ride experience).

Reliability

This group includes only two nodes, namely:

3) The service feels reliable (every time almost equal travel time and is punctual);
8) The vehicle is often delayed.

The strong partial correlation between these two items suggests that the difference in perception for delay and reliability are highly related. This means that if the LRT is perceived to be more punctual than BRT (because scores are reversed), than LRT is also considered more reliable. This is no surprise since these two statements measure similar perceptions.

To notice the edge between reliability and node 10 (The vehicle is fast), meaning that the difference in perception for reliability is linked to the difference in perception for speed. Interesting also the link between delay and node 4 (crowding during peaks) confirming what was found in the original score network, that delays and crowding are related and that the differences in perceptions are dependent as well.

Capacity/ease of boarding

Interestingly enough, in this group, there seems to exist a chain of relations running through all the six nodes. It appears that the relations between these items do not have a single factor causing them to be related, but rather they influence each other via an exchange of perceptions transmitted through intermediate nodes. The group is composed of the following nodes (in chain order):

5) The vehicle has enough seats;
2) The vehicle provides enough capacity for passengers transferring from train;
1) The vehicle has easy and fast boarding;
11) The vehicle has a sufficient number of doors;
18) The vehicle has enough standing space;
17) The vehicle has enough leg space to sit comfortably.

The commonality in this group relates to the difference in perceived capacity (seats, internal space) and ease of accessing the vehicles (which seems strongly related to the perceived difference in the number of doors). This strong interrelation between vehicle capacity and the ease of boarding confirms what was found in the networks of absolute scores, that a reduced queue and time required to board the vehicle seems to influence the perception of available internal space.

Ride experience

The remaining nodes form a group that is named “ride experience” since it includes factors related to smoothness of the ride, comfort and speed. The nodes included in this group are the following:

6) The route has many bumps making the ride not enjoyable;
7) The vehicle rides smoothly on curves;
10) The vehicle is fast;
13) The vehicle is comfortable;
14) The vehicle accelerates and brakes smoothly.

Although in this group more and stronger node intercorrelations are observed, it is still possible to recognize, as for the previous group, a chain of difference in perceptions running through nodes 6-7-14-10, which appears to be related mainly to smoothness of the ride and speed. The nodes belonging to this chain are then all linked to node 13 (comfort), indicating that a difference in perception on smoothness of the ride could determine the perceived difference in levels of comfort. Comfort is particularly strongly linked to smoothness of acceleration and brake, suggesting that that node is more than the others strongly related to the difference in perceived comfort.

To notice that node 4 (perceived crowding during rush hours) is not included in either group. Its location in the network and its links suggest that this perception is related to all three groups: crowding during peaks might have effects on delays and reliability, it might have effects on capacity and ease of boarding and it might also influence the perception of smoothness of the ride, causing its location to be "equidistant" to some extent to these three groups.

A look at the centrality indexes (Figure 29), combined with the analysis of the network structure, suggests that nodes 13, 10, 5 and 2 are overall the more central ones. It means that comfort, speed, number of seats and capacity for train transfers are the main cause of the difference in perceptions for BRT and LRT.

The stability functions displayed in Figure 30 and Figure 31 (1000 bootstrapping) indicate that edge strengths and centrality indicators are rather stable, correlations of bootstrapped networks with the original one are consistently above 0.5 and only after removing 70% of the dataset stability declines. This means that the estimated network and its interpretations are reliable.

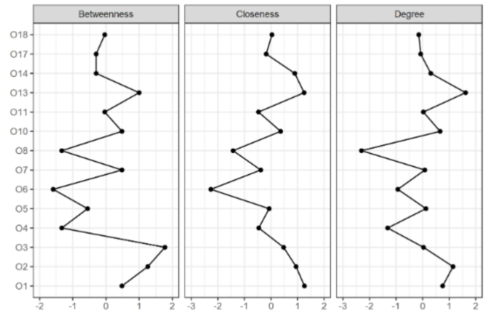

Figure 29: centralities plottings

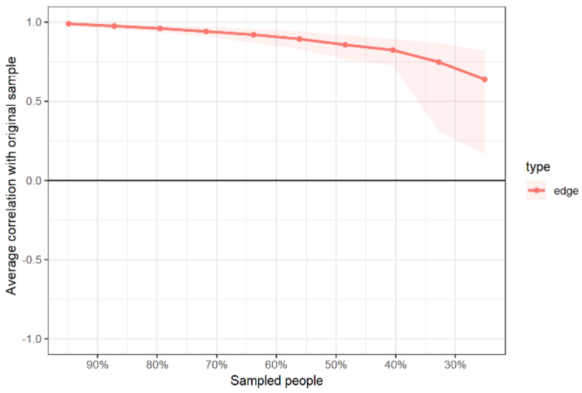

Figure 30: edge stability function

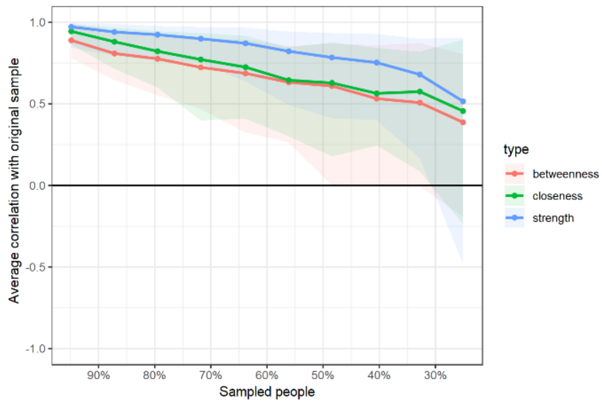

Figure 31: centrality indicators stability functions

8.5. Conclusion perception structures analysis

This chapter presented the results of the network modelling by analysing the network constructs, the difference in edge strengths and by analysing the network of the perception score differences. From the network structure analysis, it appears that the network for BRT is more sparse than the one for LRT. More in particular, in the LRT network it is observed a cluster composed by characteristics such as look of the vehicle, speed, smoothness of the ride, comfort and internal space, which all seem highly correlated to each other. This same cluster disappears in the BRT network. The analysis of the centrality measures shows that the number of doors, internal space and design, and comfort are the most central characteristics for LRT. On the other hand, internal space and design, crowding during peaks, and speed are the most central variables for BRT. The networks are then compared in terms of edge strengths focusing on the main differences observed, in particular for what concerns negative correlations, delays, capacity of the vehicle, ease of boarding, environment, noise and vehicle appearance. The networks are also briefly assessed for their reliability in terms of stability indicators for edge strengths and centrality indicators. It results that edges values are rather reliable, while centrality indicators have to be interpreted with more care. Finally, an additional network estimated with perception score differences have been analysed. Three main clusters are identified, namely for reliability, capacity and ease of boarding, and for ride experience. The reliability analyses shows that the network is considerably stable and reliable.

9. BRT AND LRT ACCORDING TO POLICYMAKERS

In this section, the main points raised during the interviews with six policymakers are discussed. The main goal of these interviews is to understand how BRT and LRT are perceived by policymakers and how the decision-making for their realization should take place. Table 28 summarizes the main outputs of the interviews with the six policymakers, while the complete content of the interviews is reported in Appendix 9. This chapter is structured into three main sections: 9.1 summarizes what emerged from the interviews in terms of policymakers' perceptions for BRT and LRT and discusses the evidence of the so called "blind commitment" (mentioned in 1.1 and 2.1); section 9.2 dives into what policymakers believe are good practices for BRT/LRT decision making; 9.3 discusses what policymakers think about public involvement into the decision making process; finally, 9.4 concludes the chapter summarising the main outputs.

	Policymaker 1	**Policymaker 2**	**Policymaker 3**	**Policymaker 4**	**Policymaker 5**	**Policymaker 6**
Blind commitment	- higher commitment for LRT; - politicians often too ambitious; - landmark in the city; - shows more quality; - attract businesses;	- higher commitment for BRT; - lobbies and industries pressure; - Eindhoven: automotive city; - Amsterdam: higher focus on rail; - often wrong political decisions; - policymakers committed not only to rail or bus, also to car, metros, etc… - commitment depends on mode familiarity	- higher commitment for tram; - it is a way to show improvement in the quality of PT; - Eindhoven: automotive city; - Amsterdam: higher focus on rail	- bus has lower image than tram; - electric busses are changing this negative vision; - rail connection seen as "sexier", bus not given enough chances in the academic comparison; - city with tram is perceived as of a higher social status	- higher commitment for rail; - higher societal status; - landmark in the city that will stay there for long time; - it is a way to show improvement in the quality of PT;	- rail connections higher social status; - bus does not show quality; - LRT to be preferred for new urban developments
Cost as decision making factor	LRT too expensive, valid only for high patronage	- BRT convenient if labour market is cheap; - true BRT is expensive: elevated sections, viaducts, tunnels, stations;	- cost will be more the main decision-making factor; - national government not willing to spend on local PT	- tram often proposed as more cost-efficient; - tram is very expensive as well; - less drivers, more ground crew; - need for more fair cost comparison between bus and rail	/	- cost will be more the main decision-making factor; - national government not willing to spend on local PT
Other non-cost related aspects for decision-making	future vision for the city/region more important	- future vision for the city/region more important - type of connections; - define important axes; - urban renovation/extensions; - economic improvement of an area; - social cohesion; - home-work connections; - environment;	- quality of PT comes first (frequencies, travel times, reliability); - technology selection comes later;	/	/	/

Smoothness of the ride	- rail vehicles ride smoother; - good for those who suffer from sickness from travelling	/	- rail vehicles ride smoother; - on a tram you feel "more guided"; - higher stability in the movements	/	/	/
Comfort/ capacity	- LRT more comfortable - rail vehicles have higher capacity	/	- comfort should be the same for bus and tram; - main issue for bus: it moves too much (vibrations, harsh driving style, curves at speed)	- tram higher capacity but less flexible	- rail vehicles have higher capacity; - better option for dense city areas; - BRT better suited for suburbs	/
Technical aspects	/	- true BRT is not flexible; - focus on reliability, not flexibility	- tram is safer for pedestrians, cyclists and cars; - tram movements more predictable and constrained by the rails; - old tram system very inefficient (slow, old vehicles, no priority, no dedicated lanes)	- problem with bus: often quality of system is reduced during design; - tram has more non-negotiable requirements; - a BRT can be as efficient as an LRT if there is the political will	- old tram system very inefficient (slow, dense, no dedicated lanes)	- old tram system very inefficient (no direct connections, slow, no priorities)
Involving public into decision-making	/	- only to a certain extent; - people do not always know what they need/want; - new transport solutions are not a translation of individual wishes; - collective interest prevails	- always, but only to certain extent; - public can influence political debate; - keep collective interests as priority; - keep good conversation with public	/	/	/

Table 28: main outputs of the interviews

9.1. Policymakers' perceptions for BRT and LRT and evidence of the "blind commitment"

Throughout this study, the aim was to have a better understanding about how people perceive BRT and LRT and according to which characteristics using mathematical tools. For policymakers, it is decided to use a qualitative approach, since finding an adequate number of policymakers willing to participate in such a study would be rather complicated. Therefore, during the interviews, policymakers are asked directly how they perceive differently bus-based systems from rail-based ones.

"It is smoother, it is more comfortable, it feels better" says one policymaker, who continues saying that the added comfort of a rail-based systems would also be beneficial for those who suffer from sickness from travelling, especially because the tram is less influenced by the drivers' driving style. In terms of quality of the comfort, some policymakers generally agree that there should be no difference between bus and tram, but that the feeling of "being guided" seems the key behind their preference for rail.

Another policymaker adds that the main difference between bus and tram lies on safety as well, in particular for cyclists and pedestrians, because guided vehicles, such as trams, being constrained by the rails, have more predictable movements, something quite challenging to achieve with a bus.

But there are two points over which almost all interviewed policymakers seem to agree: first, it appears that the rails represent an important landmark in the city and they give the impression that they are there to stay for a long time, while with the bus the perception is that it can be easily changed/rerouted/removed; second, it appears that policymakers view rail-based systems as a transport mode which is higher in the status hierarchy: the tram is perceived as “sexier”, while busses are seen as having a lower image and lower quality.

These comments might explain the reasons behind the “blind commitment” often recalled in literature. However, not all policymakers agree. One of them, tells that it is not true that all policymakers are blindly committed to rail, there are also those committed to bus, others to cars, others to metros, and so on, and that this commitment in general depends on how they are familiar with a particular system. The interviewed policymaker gives the example of Australia, where politicians and academic people often oppose any light rail solution because they are familiar with what they see in Melbourne, where the “light rail” system is a “total failure”. Moreover, he adds that some policymakers and politicians are committed to one type of technology or the other according to the commercial interests of various industries and lobbies. It appears, according to him, that the lobby is well organized in BRT services. The example he gives is in Eindhoven, where there is a strong pressure on BRT systems because the city wants to be an example of automotive city.

Finally, another interviewed policymaker suggests that, according to his experience, his colleagues policymakers generally prefer the tram because they want something different: apparently, there is the idea that if the goal is to improve public transport, major steps in the network quality have to be made to show that something different has been created, and often the tram is the way policymakers consider to achieve that difference.

9.2. BRT/LRT decision making: beyond the technology

During the interviews, a common topic that appeared important to policymakers was that during the early planning stages the question should not be about what kind of technology should be realized (BRT or LRT, but this is true also for other systems), but rather what the city or region wants to achieve with the new system.

One policymakers emphasizes the importance of being first committed to the quality that the new system should have, in terms of frequencies, travel times, reliability, and leave the technical discussion for the type of technology to be selected for a later stage.

Another policymaker extends this idea on the type of discussion to be done during the early planning phases by suggesting a more conceptual discussion. During the first stages of every new transport projects these questions should be answered: what kind of connections have to be established in the city/region? What are the most important axes? And why are these axes important? And aspects other than transport demand should be considered as well, such as urban renovation, urban extensions, improvement of the economic structure of a certain area, improve social cohesion, improvement of the connection between home and work, environment (car shift to public transport, emissions reduction). It is all about the vision of what kind of city/region they want to have. Only after these considerations it is possible to move the discussion on how to achieve those goals and with which technology.

Another theme that appeared in all interviews when discussing about the decision making relates to the costs. It seems that bus systems are implemented only when there is not sufficient demand or funding available for a rail-based system. Cost is often the final indicator which often determines what system will be implemented.

One policymaker suggests that, in most cases, a well-implemented bus system would achieve the same quality/level of service for a much lower cost, and that only when passenger volumes become high enough then other options can be explored. However, another policymaker replies to this statement saying that to have a good bus system (especially if the aim is to have a true BRT), the infrastructure has to be of high quality, because it should include elevated sections, viaducts, tunnels, stations, which are very expensive.

Another policymaker adds on the arguments that trams are often proposed as a more cost-efficient system compared to bus, however, he suggests that tram is also very expensive and that the big cost component related to maintenance is often neglected. A more "fair" cost comparison between bus and rail systems is necessary to make a well-reasoned decision.

Costs for new infrastructure seem to become a higher issue in the near future: one policymaker says that until now, the Dutch national government contributed to building new tram lines, but this is most likely not going to happen anymore, there will be budget only for national railways. This is a major game-changing, he says, because now cities and regions have to enter in the mindset that they have to finance these projects by themselves. This will hugely impact the way of making decisions for new transport infrastructures.

9.3. Involving citizens into the decision making: yes or no?

A final topic that was thoroughly discussed during two interviews, relates to the dilemma if the public should be involved into the decision making for new transport infrastructures.

One policymaker tells that it is always good to talk with potential users and ask them what they like and what they prefer. However, someone should be very careful into transforming users wishes and demands into a real system. He gives the example of an interview carried out in the 80s in which people were asked if they would want a mobile phone: the majority said they would not need it. Clearly, the answers were influenced by the fact that people did not have a clue about the potentials of this new technology. The same holds for a new transport system: people would not know. Therefore, it is very inappropriate to ask people if they prefer BRT or LRT, especially if they are not familiar with them. Most probably, when answering, they would think about the old style bus and tram.

When designing a new transport mode, the policymaker continues, the solution is not a translation of all individual wishes. Hard trade-offs are necessary, policymakers have to go after the common interest, and it is not possible to derive this from individual views and standpoints. It is not always wise to totally involve the public in these kinds of decisions. The best is to involve people in the political discussion about the trade-offs that need to be traded off. He concludes, that people should be involved, but they cannot be put in the position to answer questions they cannot answer for the good of the collectivity.

The second policymaker that discussed about this theme, affirms that when deciding for BRT or LRT, the public should always be involved to a certain extent, because the public can influence the political arena. Of course, it is not always possible to fulfil all the needs of the individuals (they are often different and conflicting), the goal should always look at the collectivity benefits. However, if there is a constructive conversation, if people receive all the information, if they are told how the choice has to be made, and also why certain things can or cannot be done, and maybe trying to include some of their wishes, policymakers can get a good understanding from the public side.

9.4. Conclusions policymakers interviews

In this chapter, the main points covered during the interviews with six policymakers have been illustrated, in particular for what concerns the perceptions that policymakers have for BRT and LRT, for the existence of a "blind commitment", the decision making and the involvement of the citizens.

It appears that for policymakers the main difference in perception between BRT and LRT refers to two main points: first, the infrastructure is seen as a landmark for the city, which is perceived to stay there for longer time compared to bus systems; second, rail-based systems are seen as being higher in the status hierarchy, while busses are considered of lower image and quality.

From the interviews it seems that this blind commitment is present among policymakers, but that this commitment is not only related to rail, but also to other systems and relations with industrial lobbies.

Regarding the decision making, the main point is that the question about which technology between BRT and LRT should be implemented is essentially wrong, especially during the early planning phases. Before discussing about the technology, it should be discussed about the vision that the city or region has, about what it is wanted to achieve in terms of urban aspects, economy and quality of the public transport service. Costs appear to be a factor that policy makers are increasingly considering when deciding for a new systems, in particular because the national government is not willing anymore to invest for new transport infrastructures within cities, which have to be funded in other ways.

Finally, the interviews with two policymakers show that citizens should be involved into the decision making process only up to a certain extent and that not all their wishes can be accommodate if the goal is the benefit for the collectivity, because often people are not familiar with certain systems and do not always know what they truly want.

10. DISCUSSION

This study wanted to put some light behind a topic which is highly controversial among policy makers. The big question that many cities ask is: should we build a BRT or an LRT? These two systems are very similar and could both be used to serve the same transport demand. Therefore, additional information that could help the decision making is to try understanding what people prefer and why.

Throughout this work, one of the objectives was to explore the existence of the rail bonus, already found in previous studies. This bonus might say something about the additional preference for rail-based systems, but it does not say why. Knowing the factors inside this black box, could tell something about how to improve bus-based systems in a way that they match the quality of the rail ones. And if this quality cannot be achieved, unveiling the factors inside the black-box could be used as input for a business case for new rail projects and for their decision-making.

To do so, an eclectic approach has been followed by integrating three different methodologies: discrete choice modelling, network psychometrics and interviews. This was required to provide a complete overview of a topic that involved two main target groups (public transport users and policymakers) and that tried to give insights into the results of one methodology (the rail bonus found in the MNL model) with another methodology (network modelling).

This study confirms that LRT has a bonus, that is large and that is a major determinant in the prediction of market share between BRT and LRT. The bonus is defined by the alternative specific constant included in the utility function for LRT. From a monetary perspective, as shown in 7.3, this bonus is worth €1.15, meaning that users are willing to spend this additional amount on the total fare to travel on a rail vehicle instead of a bus one. However, finding this bonus cannot be considered as a major achievement, because it means that the black box remains a black box. In this regard, perceptions might be the "can opener" that allow to look inside the box. The perception analysis performed in 5.3 has shown that, on average, LRT is perceived as 19% better than BRT on a one to five scale. However, to give an explanation why one mode is preferred more than the other, analysing single perception characteristics does not give a satisfying answer. There is the need to verify the strength of the relations between perceptions and how their construct varies between the two modes.

What was found with the network modelling seems to be on the right direction for understanding what's inside that black box. From the networks estimated in section 8.1, it was observed for LRT the presence of a dense cluster composed by perceptions related to modern and appealing look of the vehicle, speed, comfort, smoothness of the ride, and internal space and atmosphere. These same items, in the perception analysis performed in 5.3, determined a difference in perceptions between BRT and LRT varying between 10% and 23%. These items are not the ones that obtained the highest absolute score difference, but the fact that they are so much clustered and related in the network model could say something about the rail bonus. There is no proof that this is the case and further research is required to confirm this speculation, however, the fact that this cluster is very well visible in one network and is disappeared in the other is an important sign that requires further detailed study.

The results of all the analyses also showed that smoothness of the ride and level of crowdedness alone cannot explain the bonus. However, the perception analysis and the network modelling showed that they are relevant. From the discrete choice model, it was found that for crowdedness, people tolerate very much negatively a ride on a crowded LRT vehicle, such that in certain situations the rail bonus would not be able to give to the LRT the primate in the total choice probabilities (as shown in 7.5), while for the bus it appears that users are used to it, and they give more importance to the smoothness of the ride. However, from the analysis of the perceptions, it can be seen that comparing BRT and LRT, the latest seems to be perceived as generally less crowded and with more internal space: in the perception analysis, crowding during peaks, capacity for people transferring from train, seats available and standing space are evaluated for LRT between 22% and 32% higher than for BRT.

The MNL also showed that smoothness of the ride is particularly important and rather negatively evaluated for BRT. This was confirmed in the perception analysis as well, where the items relative to smoothness in general (bumpiness, smoothness on curves, smoothness during acceleration and braking) determined a perception difference between BRT and LRT varying between 22% and 27%, being among the items with the highest perception difference between the two modes. This is observed in network modelling as well: in the LRT network, smoothness of the ride is included in the cluster mentioned before, meaning that is one of the factors that highly relates to other positive perception variables, while in the BRT network these relations are much weaker.

The idea of rail vehicles being perceived as "smoother" appeared also during the interviews with policymakers, together with the feeling of "being guided". However, the perception policymakers have, go far beyond the vehicle characteristics, especially when it comes to the decision-making. Policymakers agree that most of their colleagues (and sometimes themselves as well) have a "blind commitment" for rail systems. Rail infrastructure is perceived as a landmark in the city that is intended to stay there for a long time, and that rail systems are considered higher in the status hierarchy.

This sort of commitment and perception is a recognized issue by the policymakers themselves, since the decision-making should not follow personal preferences. Even the entire discussion BRT vs. LRT seems wrong, especially during the early design phases. The vision about the type of city or region that is wanted to achieve should be the core discussion, leaving the technicalities for a later stage. However, finding the budget for new urban transport infrastructure is becoming more difficult, and cost is becoming the main determinant for the final decision-making, surpassing the needs for a vision one should have for its city and even the "blind commitment" someone have towards a certain type of system.

Although the two target groups of this research are different (public transport users and policymakers) and have different interests when involved into the mode choice discussion (BRT vs. LRT), these two are still related since policymakers need to fulfil the needs of the collectivity. Although the main conclusion from the interviews is more related to the decision-making process while the result of the MNL model and perception analysis is more related to the user experience, a common result can be found: in both cases it was observed a higher preference for rail-based systems compared to bus, although the sources of these higher preferences are different.

This research can be considered as a first step towards a new understanding of peoples' perceptions for public transport. The main message that this work would like to transmit is that perceptions are too important to be considered as a mere academic topic. Discrete Choice Models have proved to be a very powerful tool for predicting choices, but since they consider the respondent as a fully rational human being, they lead to misleading results, especially when two products, services, alternatives in general are very similar to each other. When the two alternatives are very much similar, as in the case of BRT and LRT, choice models fail at giving the required insights that can be used to understand a phenomena (in this case, a transport phenomenon). It is at this point that perceptions come into play by filling the explanatory power gap left by choice models. A further integration of econometric and psychological approaches seem the right way to be followed to have a more realistic representation of the behavioural aspect of the decision-making and to more realistically model the way people make choices.

Perceptions are important not only to understand how people see BRT and LRT, but public transport in general. There is more than the actual service and quality. The service can be perfect and quality of the highest standards, but if people perceive it differently than the way it was designed, then investing in that high quality is just an useless effort and a loss of money. Other industries understood this already a long time ago, putting perceptions at the core of product design, branding and marketing, even before quality [(Zarrel V., 1970), (Mitra & Golder , 2006)]. In their book "*The 22 Immutable Laws of Marketing*" Ries & Trout (1994) say this about perceptions:

Marketing is not about products (their features or quality) but about perceptions (how people perceive products). Reality doesn't exists, what we call "reality" is just a perception of reality that we create in our minds.

To conclude this section, perception should be analysed in an increasing number of studies, and network models seem to be the right tool to do it. Although psychological network models are a new technique mostly used in psychological and medical studies never been applied to research travel behaviour and transport phenomena (thus also posing concerns on how to approach the problem and how to interpret the findings), the road seems open for new transport research opportunities.

11. CONCLUSIONS AND RECOMMENDATIONS

This chapter concludes the report with the main findings and recommendations. In particular, section 11.1 gives the answer to the research questions; 11.2 lists some of the limitations of this study and gives some advises for further research; finally, 11.3 gives some practical recommendations based on the main results of this study.

11.1. Answer to the main research question

The aim of this study is to answer this main research question formulated in 1.3:

In what way do preferences and perceptions between BRT and LRT differ for public transport users and policymakers?

It is clearly difficult to provide a single concise answer, since numerous aspects are involved and different methodologies have been applied. Therefore, the sub-questions will help to give an answer to the main question.

a) *To what extend does the public transport users' preference between BRT and LRT differ and for which mode-related characteristics?*

The MNL model from 7.2 showed that there exists a bonus for LRT, which is positive and highly significant. In monetary terms, the difference in preferences between BRT and LRT is estimated to be €1.15, meaning that people are willing to pay this amount to travel on an LRT instead of a BRT, while in terms of time, people are willing to wait or travel six minutes longer if the journey is made on a tram vehicle rather than on a bus. The model also showed that travel time, waiting time and travel cost are particularly important for both BRT and LRT, but also that smoothness of the ride is a rather relevant attribute for BRT and crowdedness a relevant one for LRT. On the other hand, the fact that the rail bonus exists, implies that the attributes included in the model cannot explain it.

The application of the results in the scenarios, showed that the preferences vary substantially according to which attributes are varied and to what extent. The scenarios where the attributes for smoothness of the ride and crowdedness are kept equal for both BRT and LRT, allow to estimate the impact of the rail bonus on the mode share probabilities: if crowdedness and smoothness of the ride are set to their most favourable level (seats available and very smooth ride), 74% of the market share goes to LRT and 26% goes to BRT. In this situation, the LRT bonus greatly contributes at predicting higher preferences for LRT, as confirmed in the same scenario that ignores the existence of the constant, in which BRT gets the higher market share with a probability of 68%. If, on the other hand, crowdedness and smoothness of the ride are set to their worst levels (standing in a crowded vehicle and jerky ride), the negative weight carried by the crowdedness on the LRT outweighs the constant, resulting in slightly higher mode share for BRT (52%).

From the analysis of the other scenarios, it can be concluded that, while controlling for travel time, waiting time and travel cost, smoothness of the ride has a high negative impact for BRT, while crowdedness has a high negative impact for LRT.

b) *In what way do public transport users' perceptions between BRT and LRT differ?*

The analysis of the perception scores differences between BRT and LRT performed in 5.3 allows to conclude that, on average, LRT is perceived 19% better than BRT on a one to five points scale. The three characteristics that mostly seem to determine the difference in perception are bumpiness of the route (a difference of 30%), capacity for passengers transferring from train (a difference of 26%) and environmental friendliness (again, a difference of 26%). On the other hand, it appears that BRT and LRT do not differ in terms of time spent by the vehicle at the stops and frequency of the service.

c) *How do public transport users' perceptions influence each other?*

From the network modelling performed in Chapter 8, it emerges that BRT and LRT differ both in terms of network construct and edge strengths. The analysis of the network structure, shows that BRT network is more sparse, while in the one for LRT a cluster is observed formed by characteristics such as look of the vehicle, speed, smoothness of the ride, comfort and internal space, which all seem highly correlated to each other. This same cluster disappears in the BRT network. The analysis of the differences in edge strengths, reveals that the main differences between BRT and LRT networks relates to delays (for BRT highly related to crowding during peak hours), capacity and ease of boarding (in BRT particularly related to the number of doors) and environmental friendliness.

d) How do policymakers differently perceive BRT and LRT and how would they make a choice?

Policymakers perceive BRT and LRT differently mainly for two points: first, the infrastructure is seen as a landmark for the city, which is perceived to stay there for longer time compared to bus systems; second, rail-based systems are seen as being higher in the status hierarchy, while busses are considered of lower image and quality. Moreover, BRT and LRT are perceived differently also in terms of costs, which is becoming an increasingly considered decision-making factor due to the lack of available funds for new transport infrastructures, although this difference in costs also depends on the quality that the system aims to achieve.

11.2. Limitations and recommendations for future research

Although great care has been put to assure reliable results, this research has some limitations. The first, consists on the misrepresentation of the Utrecht population, with a higher amount of young respondents. This might have implications in the results and further research would be required to validate the results here obtained. Estimation of different choice models and different networks per age categories can be a valid approach to verify how preferences and perceptions vary among age groups.

The second limitation refers to the applicability of the results to other cities. As it was shown in Bunschoten et al. (2013) and other studies, the magnitude and even the existence of the tram bonus is highly related to the familiarity local people have towards modes. In the case of Utrecht, public transport users are generally familiar with both BRT and LRT and, according to their experience, certain results have been found. Things might change if, for example, bus line 28 was operated with higher level of separations (such as the BRT in Bogota or Curitiba) or if the tram was operating the new low floor vehicles that will start running on the Uithoflijn, instead of the current high floor ones. Results would be even more different if the city did not have either BRT or LRT, or both. Therefore, the results obtained in this study, should be used to assess the rail bonus or attribute trade-offs in other cities with particular care. Further research could study multiple cities: those with only a BRT, those with only LRT, those with both and those without, and compare the results in terms of both rail bonus and perception construct. Moreover, the study should be replicated few months after the opening of the Uithoflijn to see if the new low floor vehicles bring a change into the perceptions users have for BRT and LRT.

Another important limitation of this study refers to the cost attribute of the MNL model. A number of respondents commented at the end of the questionnaire that they never looked at the cost attribute while making choices in the choice experiment because they own a business/student card, or because the employer pays the travel expenses. This is an issue, because it might lead to wrong estimates for the parameters for cost, other than overestimating or underestimating the monetary trade-offs. For future research, it is recommended to include a question asking if respondents own a business/student card, or if the employer pays their travel expenses and estimate different MNL models with and without them to verify the impact this information have on the final attribute for cost.

A limitation is also the total amount of respondents. Although the number of respondents obtained in this study is more than enough for the MNL estimation (as discussed in 7.2), network models are data hungry, they need as many respondents as possible to be reliable. The bootstrapping analysis showed that results are somewhat reliable, although some care should be put on the interpretation of the centrality indicators. From literature it is still unclear what is the optimal number of respondents required for a correct network estimation, for now the rule is “the more, the better”.

Finally, the last limitation of this study refers to the amount of policymakers interviewed. Six seems a rather limited amount to draw meaningful conclusions (although some points were common to all of them and seemed somewhat realistic). More policymakers opinions would give additional insights into the idea of the "blind commitment" and their perceptions of BRT and LRT.

The network analysis revealed the presence of a cluster in the LRT network composed by variables such as look of the vehicle, speed, smoothness of the ride, comfort and internal space, cluster that disappears in the BRT one. It was speculated that this cluster might explain the rail bonus. Further research should investigate further if this is the case, for example by including these perceptions in the choice model and see if the value of the constant shrinks. A reduction of the value of the alternative specific constant would be a sign that those aspects are indeed explaining the rail bonus.

Additional research would need to focus more at exploring if other factors lie within the rail bonus black-box by making a questionnaire only for perceptions, including additional statements, possibly images to verify the modal image as it was done by Hensher & Mulley (2015).

11.3. Recommendations for practice

Although this study is profoundly theoretical, the results might have practical implications. This section gives practical recommendations for strategic planning (11.3.1), operations (11.3.2)and vehicles (11.3.3).

11.3.1. Strategic planning

What emerged from some of the interviews with policymakers, is that too often the discussion about the technology to be selected is done too early. The first practical recommendation is to focus first on the vision that the city has for the medium-long term, on the urban planning developments that are intended to be realized and the economic (re)developments of certain areas. At the same time, should be defined what quality of mobility is intended to be provided in the new areas. Urban development and new transport infrastructures should complement each other, following the concept of Transit Oriented Development. When it is more clear how the city or the region will look like, the local authority can start merging the urban vision with the more technical requirements, including the choice of rail or bus systems. For this, it is recommended the development of a decision making tool that would help decide which technology suits best the urban environment and constrained by a fixed budget, and that would work both for new and existing urban areas. The tool could follow the work already done in Schlickmann et al. (2017), Willer (2019) and Brispat (2017).

11.3.2. Operations

In section 8.1 it has been mentioned the cluster observed in the BRT network model between the variables related to easy and fast boarding, capacity for passengers transferring from train, number of seats and number of doors. It has also been explained that most probably, by making the bus vehicle easier to access (by also increasing the number of doors) it would increase the perception of more capacity available for passengers transferring from train, and it was explained that it is well possible that this perception structure might be related to the queues formed for boarding a vehicle at major transfer nodes. Reducing the queues formed for boarding might reduce the perception of the limited capacity. This problem might be solved by using vehicles with a higher number of doors, although for busses it would be rather difficult, especially if the intention is to improve the system with the current fleet.

A valid solution comes from a study conducted by Jara-Díaz & Tirachini (2013) in which it is proposed to open all doors for boarding in combination with new fare payment solutions. Usually, at transfer nodes in particular, only the front door is opened for boarding, to verify that everyone validates the ticket or checks-in with the personal card. However, if alternative payment solutions are implemented in such a way that all doors might be open for boarding, the bus operations would be greatly improved. In the study, in fact, it was found that by keeping all the doors open, the time spent at the stop is reduced in a way that it could reduce the system optimal bus frequency and increasing the optimal bus capacity. Moreover, it would reduce the queues with implications on the perceived internal capacity. Alternative payment systems that would help the implementation of this practice, could be the payment at the platform (as it already happens in numerous BRT systems where platforms are provided with gates), or using technologies that are already being used for electronic toll payment on highways without the need to stop at the toll bridge. Instead of a classic transport card, users would just need to carry a special magnetic card that, combined with sensors and cameras, would recognize when the user has boarded or alighted. The system would signal to the driver when someone has boarded from one of the doors without having this payment system.

The problem with transfer nodes, especially when people change from train to bus, is that "vehicle capacity" is more important than "service capacity", because a high amount of passengers goes to the bus stop at the same time. A solution to this problem could be to implement a bus system which consists of two services: an express point-to-point service which only serves those passengers that travel from the transfer node to a common destination; and a second service running on the same route, that would depart from a different platform and would serve all the stops along the route. In the case of Utrecht, for example, passengers of line 18/28 during peaks mostly travel between the central station and the Rijnsweerd area and the USP. Line 18 could be the point-to-point one, using the double-articulated vehicles, while line 28 could be the one serving the intermediate stops, using single-articulated vehicles. The drawback of this service, however, is that it requires overtaking lanes and high reliability to avoid that the express bus would have to wait behind the slow one.

Finally, from the results of the MNL model, and more in particular from the non-monetary trade-offs discussed in 7.4, it was found that users would be willing to wait about four minutes longer to be able to avoid travelling standing in a crowded bus. In that case, it would be an option reducing the frequencies while guaranteeing a higher capacity, although this would require to solve an optimization problem that includes capacity, costs, number of vehicles needed to increase the capacity, while considering the lower number of vehicles operating because of the reduced frequencies.

11.3.3. Vehicles

Some recommendations are given for vehicles as well. First, it is recommended to replace the fleet with electric vehicles, starting from those operating mainly within the urban area. The perception analysis has shown that electric vehicles are perceived as being less noisy and more modern and comfortable. Moreover, electric vehicles are perceived to run in a much smoother way. Would be ideal to operate busses equipped with supercapacitors, which can be recharged in few seconds during the stop at the stop. Supercapacitors can be a very suitable solution also for those cities that would like to have entire or partial tram or light rail lines without the overhead contact line (because of maintenance costs or to preserve the view of particularly prestigious and beautiful city centres). Cities that already implemented such system are Seville, Zaragoza and Guangzhou.

Throughout all methods used in this research, it was highlighted how much smoothness of the ride for bus is negatively sensed. Smoothness of the ride can be related to curves, accelerations/brakes or bumpiness of the road. This negative feeling could be solved by using more rigid dampers, limiting the swinging of the vehicle body when riding at speed on narrow curves. Additionally, the busses could be equipped with systems that electronically regulate the rates of acceleration and deceleration, limiting the brusque foot movement of the driver. For reducing the bumpiness, a regular road maintenance is required. However, for BRT systems, the road needs to be realized with special materials that would not be ruined due to the transit of heavy vehicles.

To conclude, the perception analysis has shown the great importance of the perceived look and internal space of the vehicles. It is believed that making busses look like trams would solve all these differences in perception existing between BRT and LRT. Such a system now exists and is called Autonomous Rail Rapid Transit (often referred to as ART). These 30 meters long vehicles are designed and developed in China and look exactly like a tram, but they run on normal roads without the need of the tracks. They are guided by sensor that follow special lines drawn on the road. They are low floor and cable-free. Will they be the key to solve the debate? Hensher seems very enthusiastic about it and writes:

"*If we have to make our buses look like light rail to win the debate then so be it!*" (Hensher, 2018).

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Appendix

1. *Background information about BRT and LRT*

BRT

Multiple definitions for Bus Rapid Transit can be found in literature. According to the Institute for Transportation and Development Policy (2015), BRT is a system “that can achieve high capacity and speed at relatively low cost by combining segregated bus lanes that are typically median aligned, off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (such as information technology and strong branding)”.

According to Deng and Nelson, instead, “BRT is a rapid mass transit mode of PT [=public transport] which combines the speed and dependability of rail service through having access to dedicated infrastructure with the operating flexibility and cost-effectiveness of a conventional/regular bus service” (Deng & Nelson, 2011).

Rob van de Bijl et al. (2019) give the following: “Bus Rapid Transit is a largely independent Right-Of-Way (ROW)-bound form of public transport that is used on the scale of the urban region and the city”.

For the purpose of this thesis, it is considered BRT a bus system which runs for the greater extent of its route within dedicated lanes, separated by the external traffic and with higher average speed compared to the normal bus service.

This new transit system concept started its trend in Latin America in the 1970s and it quickly spread around the world 2 (Luis Antonio Lindau et al. 2010). Its success lies in its low infrastructure costs and its flexibility, in particular in case of road disruptions or construction works. According to UITP, in 2015 there were 190 systems operating all around the world carrying more than 31 million passengers per day (UITP 2015). Figure 32 gives an overview of the spread of this system worldwide (data for 2015).

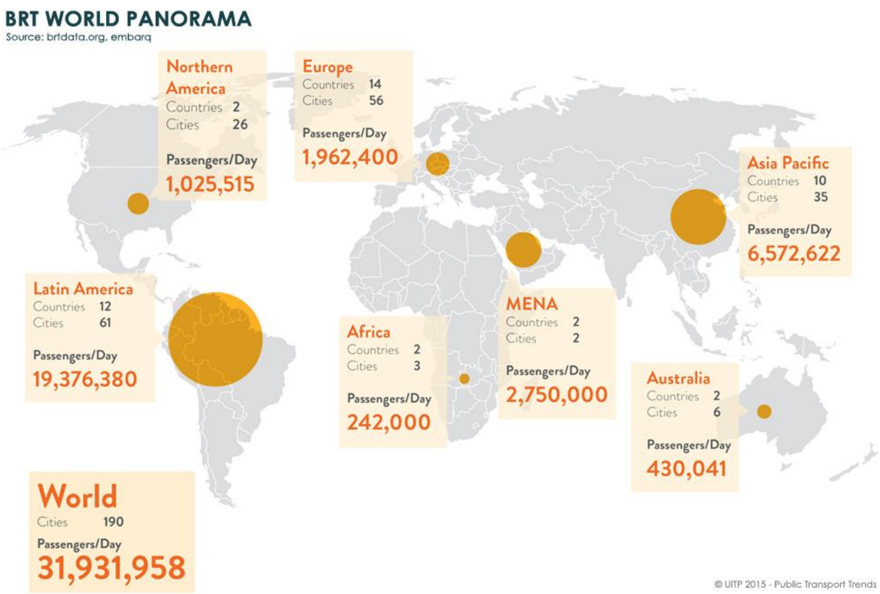

Figure 32: distribution of BRT systems around the world

It can be seen that on 2015 Latin America was leading with 61 cities where BRT was implemented, carrying about 20 million passengers per day. Considering the number of cities where BRT was operating, Europe follows with 56 systems. Considering the number of passengers instead, the second place should be awarded to the Asia-Pacific region, with a total of 6.5 million passengers transported per day. These numbers nowadays are even larger considering that new BRT systems have been put into operation in the last 3 years.

Nowadays, BRT is not a single technology and its characteristics vary widely across cities, in particular for what concerns the interaction with private cars (presence of dedicated lanes), vehicle attributes, stop spacing, speed and frequency (Levine et al. 2018). According to these characteristics, there are different classifications of the BRT systems.

In one of the definitions presented previously, the concept of "Right-Of-Way" (ROW) was introduced. According to Vuchic (2007), the ROW is the most important characteristic used to classify BRT systems and, as described by Van de Bijl et al. (2019), the following classes can be defined:

ROW A: fully separated, without intervention of any other vehicle;
ROW B: partially separated by barriers, curbs, grade separation and having regular street intersections;
ROW C: no separation, running in common streets with mixed traffic.

The Institute for Transportation and Development Policy (2007) proposes to classify BRT systems in 'BRT-lite' (for the systems that do not comply with all aspects of the definition of BRT), 'BRT' and 'Full BRT'.

Some BRT corridors around the world are ranked by the Institute for Transportation and Development Policy according to a wide range of metrics, and recognizes high-quality systems with either Bronze, Silver or Gold rankings. According to these metrics, points are assigned to particular items classified as: BRT basics, service planning, infrastructure, stations, communications, access and integration. Points are deducted for particular situations such as low off-peak frequencies, overcrowding or low commercial speeds.

Among the systems awarded with a gold ranking, it is worth to mention the high performing systems of Curitiba, Bogota and Guangzhou.

Curitiba (Brazil)

Known as Rede Integrada de Transporte (RIT), it is a BRT system put in operation since 1974. It is one of the first and most successful BRT systems in the world. It consists of 8 lines extending for 85km with 329 stops. All lines run on dedicated lanes and stops have a particular tubular-design, elevated from the ground surface (allowing for level boarding) and equipped with access gates as in common metro systems, smoothing the boarding phase with lower dwell times since the ticketing process is done at the stops rather than on-board of the vehicles. The vehicles used are long bi-articulated which are able to transport 270 passengers. Their average speed is 27km/h. The Linha Verde (green line) on 2013 was awarded as BRT Gold by the Institute for Transportation and Development Policy.

Figure 33: BRT system of Curitiba (Source: Wikipedia)

Bogota (Colombia)

The BRT system in Bogota is called TransMilenio because it started its operation during the year 2000. The system was designed following the Curitiba RIT success, from which it took major inspiration. TransMilenio consists of 12 lines extending for 113km with 147 stops. At some stations, there are four dedicated lanes for busses, two for the local busses stopping at all stops, and two for the express busses which can bypass the local ones during their stops. As in Curitiba, ticketing and fare process are done at the station, allowing for shorter dwell times. According to 2017 data, 2027

Figure 34: BRT system of Bogota (credit: Jason Margolis)

bi-articulated and articulated vehicles are in operation with an average speed of 26km/h. 5 of the 12 lines on 2013 have been awarded as BRT Gold by the Institute for Transportation and Development Policy.

Guangzhou (China)

The Guangzhou Bus Rapid Transit (GBRT) started its operations on 2010. It is one of the busiest systems in the world with frequencies of one bus every ten seconds during the peaks. The system runs along Zhongshan Dadao, where the bus lanes are located at the centre of the road. GBRT consists of a single corridor 23km long with 26 stops. On 2013 it has been awarded as BRT Gold by the Institute for Transportation and Development Policy.

Figure 35: BRT system of Guangzhou (source: Google images)

As a final note, it is worth to mention that all the three systems fully comply with all the definitions of BRT presented in the previous paragraph, meaning that they represent a true example of how a fully functional BRT system should look like.

In Europe, and in particular in the Netherlands, there are no examples of BRT systems which include all the features implemented in the examples briefly illustrated before. There are, however, bus rapid systems which have high level of service due to the dedicated infrastructure and the longer vehicle in operation. Due to the lower level of service offered compared to those operating in other continents, these systems are often referred to as BHLS (Bus with High Level of Service). However, due to the definition that was assumed earlier on, they will still be considered as BRT.

Amsterdam (Netherlands)

Figure 36: BRT system between Haarlem-Schiphol-Amsterdam (credit: Shirley de Jong)

Formerly known as Zuidtangent, this bus rapid system opened on 2002 and was later included within the R-Net brand on 2011. It runs on dedicated infrastructure between Haarlem and Schiphol, while the segment to Amsterdam uses the motorway and normal roads with priority at the intersections. Some intersections are protected with barriers. Platforms are designed in such a way to guarantee a single-level access to the vehicles. It did not receive a score from the BRT standard, but according to Rob van der Bijl et al. (2019) line 300 could be awarded as Silver standard. It is under discussion whether this system should be upgraded as an LRT.

Eindhoven (Netherlands)

A bus rapid system is present in Eindhoven between the central station and the airport. The project started with the Phileas system on 2004, which used guided busses specially designed to offer a tram-like service. The system failed on 2014 and replaced by articulated electric busses. The BRT line is almost completely operating on dedicated infrastructure, excluding the last short section between the stop Luchthavenweg and the airport. Plans to convert this line into an LRT system are being currently discussed.

LRT

The term 'LRT' (acronym of Light Rail Transit) was coined in the 70s as, but its definition evolved over time. Nowadays, a light rail system stands somewhere in between tram and metro, and often even between train and metro (van de Bijl, van Oort, & Bukman, 2018). Van de Bijl et al. propose the following definition: "*A light rail is a rail-bound form of public transport that is used on the scale of the urban region and the city. In contrast to train and metro, light rail is suitable for integration to a certain extent in public space and, if desired, for mixing with regular road traffic*" (van de Bijl, van Oort, & Bukman, 2018).

Light rail systems usually use low floor vehicles similar to those used for tramways systems (although this is not always the case, such in Manchester Metrolink), but they do not have a specific infrastructure: their flexibility allow them to use tram, metro and train infrastructure, depending on the type of operations they are designed to perform. As mentioned by van De Bijl et al. (2019), the word "light" does not refer to the weight of the vehicles, but to the fact that "*infrastructure and associated operations can be flexibly integrated into urban environments*".

While between the 1930s and 1950s all around Europe the urban tramway networks were being dismissed, Germany decided to keep the system and, in particular in Western Germany, the tramway networks have been expanded and modernized to obtain what was called "Stadtbahnen". It is, however, in France that the modern concept of light rail emerged: a couple of decades after dismissing their tramway networks, a large number of medium-size cities decided to reintroduce them under a new concept, which included fewer lines, larger stop spacing and longer vehicles. Nantes and Grenoble were the first cities introducing this new "modernized" tram. The main goal was not only to provide a valid mobility alternative, but was also the opportunity for urban redevelopment. The introduction of LRT systems contributed to completely change and renovate the inner cities which were suffering from unsustainable car traffic, pollution and bad economy. This trend quickly spread in other cities in France and established a new standard that is increasingly applied in cities around the world.

According to van de Bijl et al. (2018), there are various types of light rail systems, which can be classified as shown in Figure 37.

	Light rail		Non- light rail
1	Tram *)	6	Train
2	TramTrain	7	Metro
3	TrainTram	8	MetroTrain
4	TramMetro	9	TrainMetro
5	MetroTram		

*) Tram: includes
Urban tram
(traditional, 2nd generation tram, and American streetcar),
Regional tram (sometimes branded as 'regiotram').

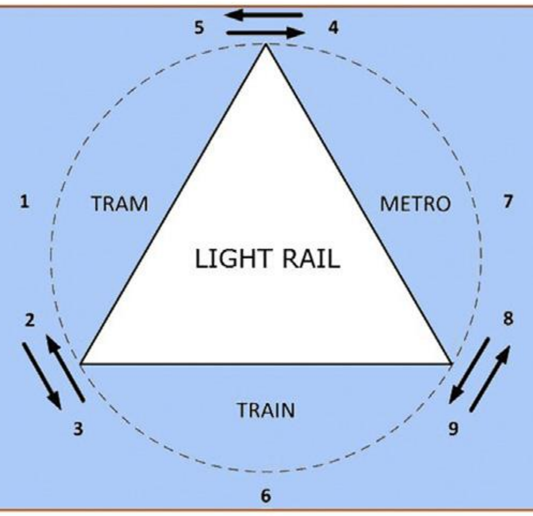

Figure 37: what is and what is not a light rail (van de Bijl, van Oort, & Bukman, 2018)

Main examples of light rail systems are the RandstadRail between The Hague and Zoetermeer, the tram system in Dublin and the Manchester Metrolink.

RandstadRail The Hague-Zoetermeer

Opened between 2006 and 2007, the RandstadRail between The Hague and Zoetermeer is an example of LRT system of the type “tram-train” and it consists of two lines (3 and 4). It operates as street-level tramway in the city centre of The Hague (and partially in tunnel under Marktstraat), runs on viaduct between The Hague central station and Laan van NOI, it shares the infrastructure with metro line E between Laan van NOI and Leidschenveen, while the rest of the route uses the infrastructure of the former Zoetermeer Stadslijn. The average speed is 31km/h while the maximum speed is 80km/h.

Figure 38: RandstadRail between The Hague and Zoetermeer (source: Wikipedia)

Dublin LUAS light rail system

The tram system in Dublin begun its operations in 2004 and it currently consist of two lines: red (connecting the west with the east part of the city) and green (connecting the north with the south part of the city). The lines run on shared infrastructure in the city centre while they have dedicated infrastructure in the external sections. The average speed is 16km/h and the maximum speed is 70km/h.

Figure 39: LUAS tram system in Dublin (personally taken picture)

Manchester Metrolink

Metrolink is the name coined for the new light rail system operated in Manchester. It currently consists of seven lines operating at street level in the central area and on recuperated tracks in the outer branches. This is one of the few modern light rail systems adopting high level platforms. The average speed is 20km/h and the maximum speed is 80km/h.

Figure 40: Metrolink in Manchester (personally taken picture)

Figure 41 provides an overview of the strengths and weaknesses of BRT and LRT according to Steer Group (2015). Some statements are highly debated in the academic world, in particular for what concerns the costs (Levine, Singer, Merlin, & Grengs, 2018).

	Strengths	Weaknesses
BRT	• Fast and reliable journey times • Close peak headway possible • Higher total capacity than conventional bus services on street • Distinctive route/brand identity and at-station amenities including real-time information raise the profile of the system • Total capacity can be varied with rigid or articulated vehicles in conjunction with peak headway	• Vehicles may not be able to overtake each other easily (depending on infrastructure) • Total capacity limited by articulated vehicle and frequency • Curb-guided systems may be subject to operational difficulties during periods of ice / snow • Segregated / guided route may be vulnerable to disruption during incidents • Segregation can be intrusive to urban landscape

	Strengths	Weaknesses
LRT	• Flexible alignment criteria allow LRT to be fully integrated with urban realm • Higher capacity than bus or BRT • Low Noise • Zero emissions at the point of use • Segregation and priority provide reliable journey times • Provision of fixed infrastructure, demonstrates a commitment to the provision of high quality public transport services • May act as a catalyst for wider urban development	• Relatively high capital cost (including need for extensive utilities diversions in many cases) • Significant disruption during construction • Total capacity limited by vehicle and frequency • Speed and travel time benefits require priority over other traffic • On street rail-based route vulnerable to disruption during incidents

Figure 41: overview of strength and weakenesses of BRT and LRT according to Steer Group (2015)

2. NGene code

```
design
;alts = brt,lrt
;rows = 27
;orth = sim
;block = 3
;model:
U(brt)   = wt * WT[1,3,5] + tt * TT[14,19,24] + tc * TC[1.35,1.85,2.35] + sr * SR[0,1,2] + cr * CR[0,1,2]/
U(lrt)   = wt * WT[1,3,5] + tt * TT[14,19,24] + tc * TC[1.35,1.85,2.35] + sr * SR[0,1,2] + cr * CR[0,1,2] + b0
$
```

3. Generated choice scenarios

BLOCK	SCENARIO	brt.wt	brt.tt	brt.tc	brt.cr	brt.sr	lrt.wt	lrt.tt	lrt.tc	lrt.cr	lrt.sr
1	1	1	14	1.35	0	0	1	14	1.35	0	0
1	2	3	19	1.85	1	1	3	14	1.85	1	0
1	3	5	24	2.35	2	2	5	14	2.35	2	0
1	4	1	24	2.35	0	1	3	19	1.85	2	2
1	5	3	14	1.35	1	2	5	19	2.35	0	2
1	6	5	19	1.85	2	0	1	19	1.35	1	2
1	7	1	19	1.85	0	2	5	24	2.35	1	1
1	8	3	24	2.35	1	0	1	24	1.35	2	1
1	9	5	14	1.35	2	1	3	24	1.85	0	1
2	1	5	24	1.85	1	1	5	14	1.35	0	1
2	2	1	14	2.35	2	2	1	14	1.85	1	1
2	3	3	19	1.35	0	0	3	14	2.35	2	1
2	4	5	19	1.35	1	2	1	19	1.85	2	0
2	5	1	24	1.85	2	0	3	19	2.35	0	0
2	6	3	14	2.35	0	1	5	19	1.35	1	0
2	7	5	14	2.35	1	0	3	24	2.35	1	2
2	8	1	19	1.35	2	1	5	24	1.35	2	2
2	9	3	24	1.85	0	2	1	24	1.85	0	2
3	1	3	19	2.35	2	2	3	14	1.35	0	2
3	2	5	24	1.35	0	0	5	14	1.85	1	2
3	3	1	14	1.85	1	1	1	14	2.35	2	2
3	4	3	14	1.85	2	0	5	19	1.85	2	1
3	5	5	19	2.35	0	1	1	19	2.35	0	1
3	6	1	24	1.35	1	2	3	19	1.35	1	1
3	7	3	24	1.35	2	1	1	24	2.35	1	0
3	8	5	14	1.85	0	2	3	24	1.35	2	0
3	9	1	19	2.35	1	0	5	24	1.85	0	0

Table 29: generated choice sets in Ngene

4. Additional data Utrecht case study

The city of Utrecht has a population of 347,483 inhabitants (CBS StatLine, 2018) and the modal split in the region, according to 2017 statistics, is the following: car: 29%, train: 1%, bus/tram/metro: 6%, bike: 51%, other: 13% (Kennisinstituut voor Mobiliteitsbeleid, 2017).

Table 30 summarizes the main characteristics of the BRT and LRT lines in Utrecht [sources: wiki.ovinnederland.nl, brtdata.org, Provincie Utrecht].

	BRT (LINE 28)	LRT (LINES 60-61)
OPENING YEAR	2013	Line 60: 1983 Line 61: 1985
LENGTH [KM]	8.20	Line 60: 13.3 Line 61: 17.7
STOPS [NUMBER]	32	Line 60: 15 Line 61: 18
FREQUENCY ON PEAKS [RUNS PER HOUR]	8 (18 together line 18)	8 (60+61 combined)
AVERAGE STOP SPACING [M]	680	870
PASSENGER DEMAND [PAX PER DAY]	40,000	38,000
FLEET/ROLLING STOCK	Mercedes-Benz Citaro G Van Hool newAGG300	Swiss SIG

Table 30: main figures for the BRT and LRT lines in Utrecht

Table 31 summarizes the average appreciation scores for items relative to the tram and bus system in the Utrecht Region for the year 2017 (CROW, 2017).

	TRAM	BUS
NOISE IN THE VEHICLE	6,7	6,4
CUSTOMER FRIENDLINESS STAFF	7,3	7,6
CLEANLINESS / VEHICLE CLEAN	6,9	7,4
VEHICLE LAYOUT	-	-
DRIVING STYLE DRIVER	7,3	7,3
NUISANCE FELLOW TRAVELERS	-	-
CHANCE OF SEATING	8,2	8,4
EASE OF ENTRY	8,6	8,6
CLIMATE IN VEHICLE	-	-
EASE OF USE OV CHIP CARD	8,2	8,2
PURCHASE / RECHARGE TICKET	8,3	7,9
INFORMATION WHILE DRIVING	-	-
INFORMATION DELAY / PROBLEMS	5,5	5,8
INFORMATION AT THE STOP / STATION	7,8	7,6
PUNCTUALITY	7,6	7,3
TRAVEL SPEED	7,7	7,6
TRANSFER TIME	6,5	6,8
FREQUENCY	7,4	7,4
SAFETY IN GENERAL	7,6	8
SAFETY IN VEHICLE	7,8	8,2
SAFETY AT THE STOP / STATION	7,6	8
STRESSED OUT / RELAXED	-	-
JUDGMENT STOP / STATION	-	-
PRICE	5,7	5,9
OVERALL ASSESSMENT	7,6	7,6

Table 31: evaluation scores of the tram and bus systems in Utrecht

5. *Mann-Whitney U Test*

	Easy fast board	Enough capacity train	Service feels reliable	Peak hours crowded	Enough seats	Route many bumps	Rides smoothly curves
Mann-Whitney U	39436.500	33068.500	37423.500	36910.000	37827.000	31564.000	34238.500
Wilcoxon W	101212.500	94844.500	99199.500	98686.000	99603.000	93340.000	96014.500
Z	-8.610	-11.065	-9.317	-9.513	-9.191	-11.592	-10.616
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	Often delayed	Modern appealing	Fast	Sufficient number doors	Waits too long stops	Driverless	Comfortable
Mann-Whitney U	42756.500	50154.000	40695.500	39913.500	58519.000	42415.500	41753.000
Wilcoxon W	104532.500	111930.000	102471.500	101689.500	120295.000	104191.500	103529.000
Z	-7.304	-4.417	-8.126	-8.370	-1.202	-7.297	-7.716
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	**0.229**	0.000	0.000

	Accelerates decelerates smoothly	Environmentally friendly	Rides without noise	Enough space sit comfortably	Enough standing space	Inside spacious pleasant atmosphere	Frequent service
Mann-Whitney U	37881.000	34627.000	48668.500	44756.000	39620.000	45269.500	59356.500
Wilcoxon W	99657.000	96403.000	110444.500	106532.000	101396.000	107045.500	121132.500
Z	-9.212	-10.420	-5.002	-6.492	-8.461	-6.349	-0.876
Asymp. Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	**0.381**

Table 32: Mann-Whitney U Test for perception differences

6. *Additional results in perception differences analysis*

Comparing the results obtained on perception scores for BRT and LRT users, some differences are observed. For BRT users, the statement with the higher score difference between BRT and LRT modes remains, as for the general data, the one related to bumpiness of the route, while for LRT users this same statement is found in second place. For LRT users, the item that seems to have a larger perception difference is the one related to the capacity offered to passengers transferring from train. It is interesting to notice that this statement has a lower score difference for BRT users (which ends up on 7th position): it appears that LRT users find much more unacceptable the lower capacity offered by the bus for those who transfer from train, while BRT users are probably used to that situation and focus their attention on other aspects.

BRT users have on second position the statement "during peak hours the vehicle feels uncomfortably crowded", which is found lower in the list for LRT users (8th position). Third in the list for BRT users there is "the vehicle accelerates and brakes smoothly" which is found in much lower position in the list for LRT users (15th position): it is possible that frequent LRT users give it for granted that a vehicle runs smoothly regardless the type of vehicle, while frequent BRT users find the current bus accelerations and brakings much less smoother than those of the tram. Another difference between the two groups concerns the perception of standing space and available seats: the difference between BRT and LRT is much larger for LRT users, probably due to the higher familiarity with tram vehicles that provide more seats and the chances of standing are much lower.

Overall, the LRT scores 17% higher than BRT for frequent BRT users and 21% higher for frequent LRT users.

The comparison of the two sub-groups of PT and non-PT users has some interesting results as well. PT users have, again, a larger score difference for the statement related to bumpiness of the route. Interestingly enough, non-PT users have the largest score difference for the environmentally friendliness of the vehicle: it appears that non-PT users have a strong negative opinion about the emissions produced by bus vehicles in Utrecht, while for PT users, the same item is on 6th position. The difference in willingness to ride on an automated BRT and LRT appears to be also different between PT and non-PT users: non-PT users have a larger preference for riding on an LRT in case of automation (30% higher), while the difference between BRT and LRT is lower for PT users (about 20%).

Overall, the LRT scores 17% higher than BRT for PT users and 21% higher for non-PT users.

Statement (frequent BRT users)	Avg. BRT	Avg. LRT	Difference	%
The route has many bumps making the ride not enjoyable	3.16	4.11	0.95	29.0%
During peak hours the vehicle feels uncomfortably crowded	1.78	2.66	0.88	26.8%
The vehicle accelerates and brakes smoothly	2.65	3.52	0.87	26.6%
The vehicle rides smoothly on curves	2.81	3.65	0.84	25.6%
The vehicle is environmentally friendly	2.67	3.49	0.82	25.1%
If this vehicle is driverless (automated), I would be willing to use it	2.83	3.60	0.77	23.4%
The vehicle provides enough capacity for passengers transferring from train	2.74	3.48	0.73	22.4%
The vehicle has enough seats	2.56	3.19	0.64	19.4%
The service feels reliable (every time almost equal travel time and is punctual)	3.10	3.69	0.59	17.9%
The vehicle is fast	3.16	3.75	0.59	17.9%
The vehicle is comfortable	3.06	3.62	0.56	17.2%
The vehicle rides without making noise	2.77	3.31	0.55	16.7%
The vehicle has enough standing space	2.95	3.50	0.55	16.7%
The vehicle looks modern and appealing	3.10	3.65	0.55	16.7%
The vehicle has enough leg space to sit comfortably	2.90	3.39	0.48	14.8%
The vehicle is often delayed	3.05	3.52	0.47	14.3%
From the inside the vehicle feels spacious and has a pleasant design	3.06	3.48	0.42	12.8%
The vehicle has a sufficient number of doors	3.43	3.80	0.37	11.3%
The vehicle has easy and fast boarding	3.63	3.92	0.29	8.9%
It is a frequent service	3.78	3.58	-0.20	6.1%
The vehicle waits too long at stops	3.87	3.83	-0.04	1.2%
Average	**3.00**	**3.56**	**0.56**	**16.95%**

Table 33: perception differences for frequent BRT users

Statement (frequent LRT users)	Avg. BRT	Avg. LRT	Difference	%
The vehicle provides enough capacity for passengers transferring from train	2.62	3.68	1.07	32.7%
The route has many bumps making the ride not enjoyable	3.23	4.28	1.05	32.1%
The vehicle has easy and fast boarding	3.20	4.14	0.93	28.7%
The vehicle has enough standing space	2.76	3.69	0.93	28.5%
The vehicle rides smoothly on curves	2.84	3.76	0.92	28.1%
The vehicle has a sufficient number of doors	3.08	3.99	0.91	28.0%
The vehicle has enough seats	2.54	3.41	0.86	26.5%
During peak hours the vehicle feels uncomfortably crowded	2.09	2.91	0.82	25.1%
The service feels reliable (every time almost equal travel time and is punctual)	2.92	3.70	0.78	24.0%
The vehicle is environmentally friendly	2.62	3.40	0.78	23.8%
If this vehicle is driverless (automated), I would be willing to use it	2.82	3.56	0.74	22.7%
The vehicle has enough leg space to sit comfortably	2.88	3.57	0.69	21.2%
The vehicle is fast	3.01	3.67	0.66	20.1%
The vehicle is often delayed	2.96	3.58	0.62	18.9%
The vehicle accelerates and brakes smoothly	2.69	3.30	0.60	18.5%
The vehicle is comfortable	3.01	3.55	0.54	16.5%
From the inside the vehicle feels spacious and has a pleasant design	2.88	3.36	0.47	14.5%
The vehicle rides without making noise	2.70	3.07	0.37	11.3%
The vehicle waits too long at stops	3.81	4.05	0.24	7.4%
It is a frequent service	3.40	3.60	0.20	6.2%
The vehicle looks modern and appealing	3.21	3.36	0.15	4.7%
Average	**2.92**	**3.60**	**0.68**	**20.93%**

Table 34: perception differences for frequent LRT users

Statement (PT users)	Avg. BRT	Avg. LRT	Difference	%
The route has many bumps making the ride not enjoyable	3.21	4.12	0.91	28.1%
The vehicle provides enough capacity for passengers transferring from train	2.69	3.50	0.81	25.1%
The vehicle rides smoothly on curves	2.81	3.61	0.80	24.6%
During peak hours the vehicle feels uncomfortably crowded	1.99	2.73	0.74	22.8%
The vehicle has enough seats	2.53	3.27	0.74	22.7%
The vehicle is environmentally friendly	2.73	3.42	0.69	21.3%
The vehicle has enough standing space	2.88	3.55	0.67	20.8%
The service feels reliable (every time almost equal travel time and is punctual)	2.96	3.64	0.67	20.8%
The vehicle has a sufficient number of doors	3.22	3.87	0.65	20.1%
If this vehicle is driverless (automated), I would be willing to use it	2.83	3.48	0.64	19.8%
The vehicle accelerates and brakes smoothly	2.70	3.32	0.63	19.4%
The vehicle is often delayed	2.95	3.52	0.57	17.7%
The vehicle has easy and fast boarding	3.41	3.98	0.57	17.7%
The vehicle has enough leg space to sit comfortably	2.91	3.42	0.51	15.8%
The vehicle is fast	3.14	3.65	0.50	15.5%
The vehicle is comfortable	3.02	3.51	0.49	15.1%
From the inside the vehicle feels spacious and has a pleasant design	2.92	3.33	0.41	12.7%
The vehicle rides without making noise	2.76	3.15	0.39	11.9%
The vehicle looks modern and appealing	3.23	3.45	0.22	6.6%
The vehicle waits too long at stops	3.74	3.85	0.11	3.3%
It is a frequent service	3.53	3.53	0.00	0.0%
Average	**2.96**	**3.52**	**0.56**	**17.23%**

Table 35: perception differences for public transport users

Statement (non-PT users)	Avg. BRT	Avg. LRT	Difference	%
The vehicle is environmentally friendly	2.62	3.72	1.10	33.0%
The route has many bumps making the ride not enjoyable	3.14	4.25	1.10	33.0%
If this vehicle is driverless (automated), I would be willing to use it	2.73	3.73	1.00	30.0%
The vehicle provides enough capacity for passengers transferring from train	2.81	3.74	0.93	27.8%
The service feels reliable (every time almost equal travel time and is punctual)	2.94	3.84	0.90	27.1%
The vehicle accelerates and brakes smoothly	2.71	3.57	0.87	25.9%
The vehicle rides smoothly on curves	2.98	3.83	0.86	25.7%
During peak hours the vehicle feels uncomfortably crowded	2.06	2.89	0.83	24.7%
The vehicle has easy and fast boarding	3.39	4.14	0.75	22.6%
The vehicle has enough standing space	2.95	3.70	0.75	22.3%
The vehicle is fast	3.05	3.79	0.74	22.1%
The vehicle has a sufficient number of doors	3.24	3.97	0.73	21.9%
The vehicle is comfortable	3.01	3.72	0.71	21.4%
The vehicle has enough seats	2.71	3.43	0.71	21.4%
The vehicle is often delayed	3.06	3.66	0.60	18.1%
From the inside the vehicle feels spacious and has a pleasant design	3.00	3.59	0.59	17.6%
The vehicle looks modern and appealing	3.10	3.67	0.58	17.4%
The vehicle has enough leg space to sit comfortably	2.99	3.55	0.56	16.6%
The vehicle rides without making noise	2.79	3.21	0.42	12.6%
It is a frequent service	3.56	3.74	0.18	5.5%
The vehicle waits too long at stops	3.79	3.85	0.06	1.9%
Average	**2.98**	**3.69**	**0.71**	**21.36%**

Table 36: perception differences for non-public transport users

7. Biogeme estimation code

```
from biogeme import *
from headers import *
from loglikelihood import *
from statistics import *

# Parameters to be estimated
BETA_WT_BRT  = Beta('BETA_WT_BRT',0,-1000,1000,0)
BETA_TT_BRT   = Beta('BETA_TT_BRT',0,-1000,1000,0)
BETA_TC_BRT   = Beta('BETA_TC_BRT',0,-1000,1000,0)
BETA_CR1_BRT = Beta('BETA_CR1_BRT',0,-1000,1000,0)
BETA_CR2_BRT = Beta('BETA_CR2_BRT',0,-1000,1000,0)
BETA_SR1_BRT = Beta('BETA_SR1_BRT',0,-1000,1000,0)
BETA_SR2_BRT = Beta('BETA_SR2_BRT',0,-1000,1000,0)
BETA_WT_LRT  = Beta('BETA_WT_LRT',0,-1000,1000,0)
BETA_TT_LRT   = Beta('BETA_TT_LRT',0,-1000,1000,0)
BETA_TC_LRT   = Beta('BETA_TC_LRT',0,-1000,1000,0)
BETA_CR1_LRT = Beta('BETA_CR1_LRT',0,-1000,1000,0)
BETA_CR2_LRT = Beta('BETA_CR2_LRT',0,-1000,1000,0)
BETA_SR1_LRT = Beta('BETA_SR1_LRT',0,-1000,1000,0)
BETA_SR2_LRT = Beta('BETA_SR2_LRT',0,-1000,1000,0)
ASC_LRT          = Beta('ASC_LRT',0,-1000,1000,0)


V1 = brt_wt * BETA_WT_BRT + brt_tt * BETA_TT_BRT + brt_tc * BETA_TC_BRT + brt_cr1 * BETA_CR1_BRT +
brt_cr2 * BETA_CR2_BRT + brt_sr1 * BETA_SR1_BRT + brt_sr2 * BETA_SR2_BRT

V2 = lrt_wt * BETA_WT_LRT + lrt_tt * BETA_TT_LRT + lrt_tc * BETA_TC_LRT + lrt_cr1 * BETA_CR1_LRT +
lrt_cr2 * BETA_CR2_LRT + lrt_sr1 * BETA_SR1_LRT + lrt_sr2 * BETA_SR2_LRT + ASC_LRT


# Associate utility functions with the numbering of alternatives
V = {1: V1,
   2: V2}

AV1 = 1
AV2 = 1

# Associate the availability conditions with the alternatives
av = {1: AV1,
    2: AV2}

# The choice model is a logit, with availability conditions
logprob = bioLogLogit(V,av,Choice)

# Defines an itertor on the data
rowIterator('obsIter')

# DEfine the likelihood function for the estimation
BIOGEME_OBJECT.ESTIMATE = Sum(logprob,'obsIter')
```

8. Additional results in peoples 'preferences

Here are reported the results obtained in the MNL models for sub groups: BRT, LRT, public transport and non-public transport users.

Name	All data	BRT users	LRT users	PT users	Non-PT users
Alternative Specific Constant LRT	1.8	2.44	2.72	1.19	2.82
Crowdedness 1 BRT	-0.523	-0.425	-0.739	-0.485	-0.587
Crowdedness 1 LRT	-1.25	-1.11	-1.59	-1.32	-1.16
Crowdedness 2 BRT	-0.69	-0.498	-1.07	-0.774	-0.612
Crowdedness 2 LRT	-2.31	-2	-2.49	-2.3	-2.35
Smoothness of the ride 1 BRT	-0.551	-0.664	-0.514	-0.548	-0.537
Smoothness of the ride 1 LRT	0.249	0.085	0.192	0.107	0.518
Smoothness of the ride 2 BRT	-1.27	-1.22	-1.27	-1.36	-1.18
Smoothness of the ride 2 LRT	-0.746	-0.908	-0.833	-0.858	-0.597
Travel Cost BRT	-1.44	-1.11	-1.45	-1.56	-1.27
Travel Cost LRT	-1.56	-1.64	-1.75	-1.37	-1.92
Travel Time BRT	-0.263	-0.252	-0.275	-0.262	-0.273
Travel Time LRT	-0.271	-0.265	-0.307	-0.274	-0.273
Waiting Time BRT	-0.189	-0.153	-0.204	-0.236	-0.115
Waiting Time LRT	-0.322	-0.278	-0.285	-0.324	-0.306

Table 37: MNL results for all groups

The ASC is large, positive and significant for all models. The largest value is interestingly observed for non-PT users, meaning that although they use neither of the two modes for daily commute, they perceive the LRT as more attractive. The second largest value is carried by tram users: it is possible that mode familiarity contributes to their overall preference. The lowest value (excluding the model without CR and SR) is related to the overall PT users, which includes bus, tram and train users. The value of the ASC for the model that included all the data is a form of average between the highest and lowest values estimated in the other models.

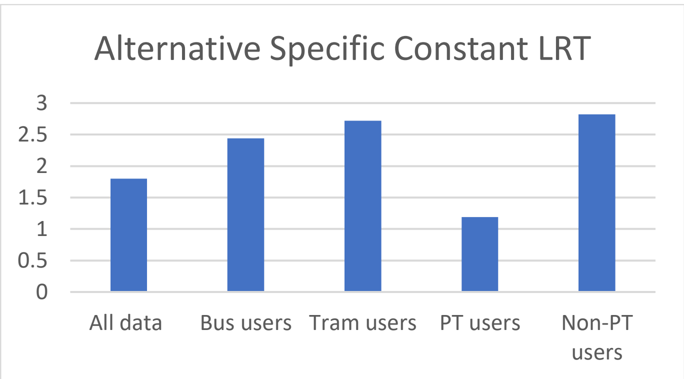

Figure 42: comparison of the estimated ASC values

Moving to the non-categorical attributes, the estimated parameters for travel cost, travel time and waiting time, are all significant at 5% level for all models, excluding the waiting time parameter for BRT in the model for non-PT users.

The parameter for travel cost is overall more negative for LRT in all models, excluding the model for all PT users. This means that users have a higher cost sensitivity for LRT compared to the BRT. This higher sensitivity is particularly evident for non-PT and for bus users.

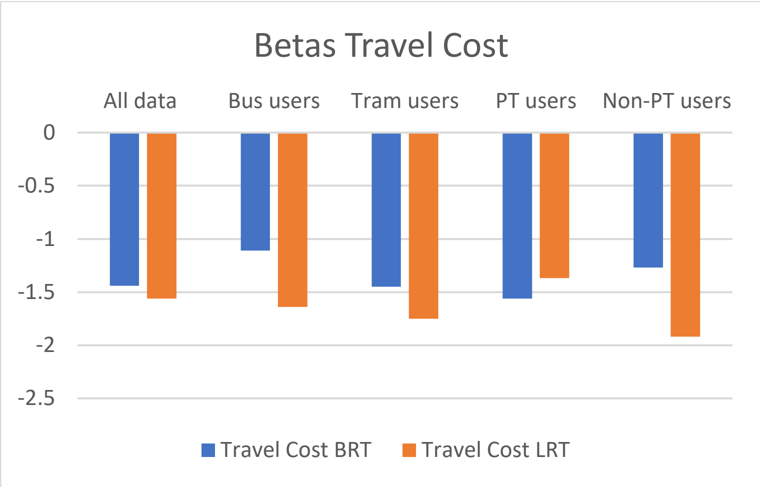

Figure 43: comparison of the estimated travel cost parameters

The difference in sensitivity for travel time is less marked, which gets about equal values for the non-PT users with slightly larger variations for the tram users.

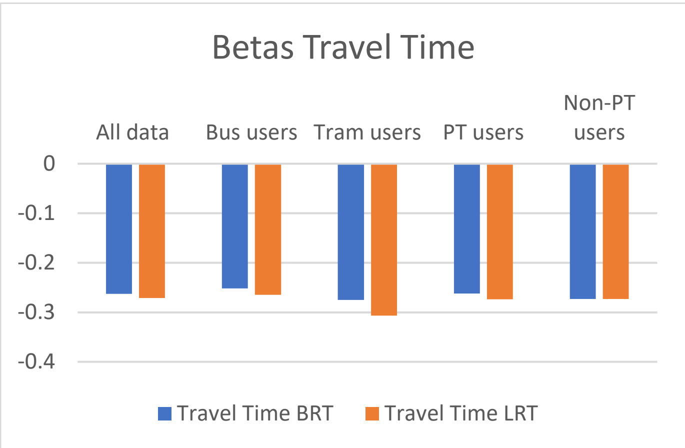

Figure 44: comparison of the estimated travel time parameters

Regarding the parameters for waiting time, the largest variation between BRT and LRT is observed among the non PT-users, who perceive LRT waiting times as too high. This result might be due to the fact that the current frequencies of tram lines 60/61 are relatively low compared to the express bus 28. It needs to be considered that for non-PT users the BRT parameter for waiting time is not significant. This means that non-PT users, put in the condition to choose between BRT and LRT, do not consider waiting time for BRT as one of the factors influencing their final choice. It is interesting to notice that for bus users the waiting time weighs less than the travel time, meaning that people prefer to wait longer at the stop than travel longer on the bus vehicles. The opposite situation is observed for LRT, for which users would rather travel longer than waiting at the stop.

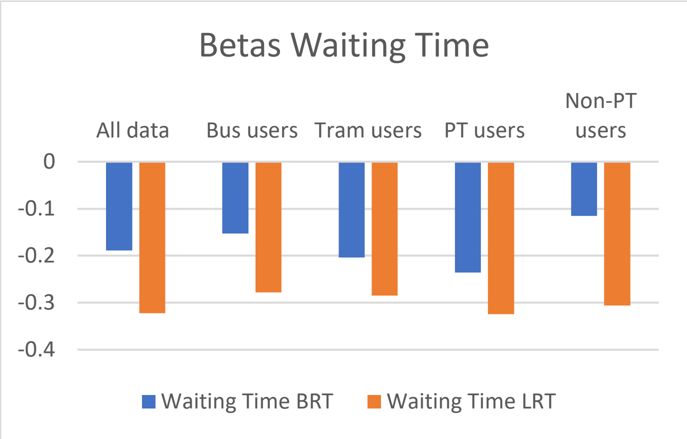

Figure 45: comparison of the estimated waiting time parameters

Focusing on the crowdedness, it is immediately visible that LRT has more negative values compared to BRT for both levels. The difference between the two levels is also wider for LRT. According to these values, people perceive crowdedness on LRT vehicles more negatively than for BRT. This is true for all models. Particularly evident is the high disutility for going from standing in non-crowded vehicles to standing in crowded vehicles. The highest values are observed for tram users, who are probably used to have much higher chance of finding a seat on the current tram lines 60/61 compared to bus users, who might take for granted that they will need to stand for the entire route, therefore resulting in lower values (less negative) for the crowdedness parameters.

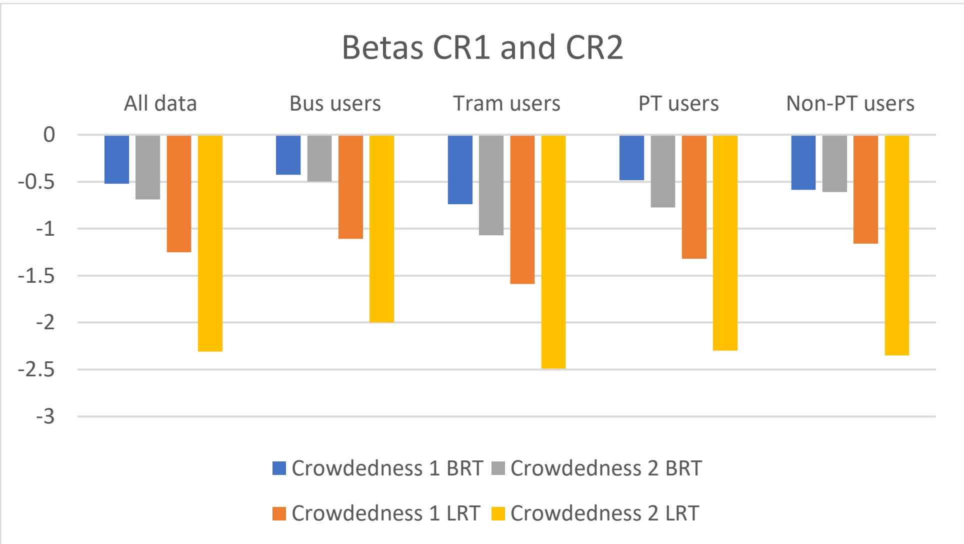

Figure 46: comparison of the estimated crowdedness parameters

The estimates for smoothness of the ride have an opposite situation: values for BRT are more negative than those for LRT. To notice that the LRT parameter representing the difference in levels between a very smooth ride and a generally smooth ride (SR1) is positive in all models. However, this parameter is not significant at 5% level (for non-PT users is not significant at 1% level). Thus. for LRT users it can be assumed that there is no difference between a smooth and a generally smooth ride with rare sudden breakings. Only the level associated to jerky rides plays a role. For BRT, on the other hand, both levels are large, negative and significant, meaning that users perceive the bus rides as not comfortably smooth. This result is confirmed also from the perceptions

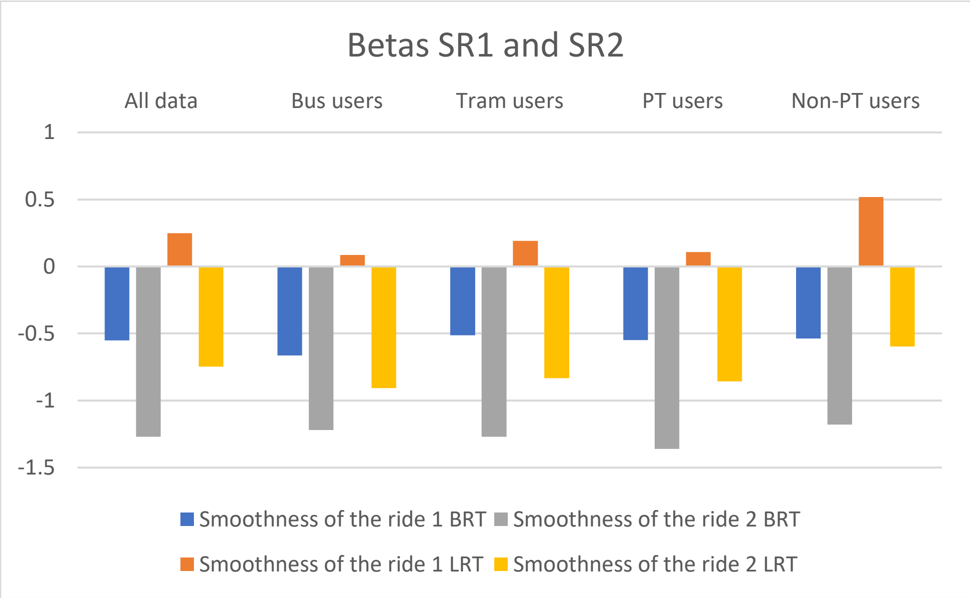

Figure 47: comparison of the estimated smoothness of the ride parameters

9. Content of the interviews with policymakers

Policymaker 1

The conversation started with the case of Eindhoven, where a BRT system is currently in operation and for which various improvement proposals are on the table. Among the solutions, the conversion of the BRT into LRT is also proposed. However, PM1 tells that it would not be the solution at the moment since there is already a high-quality public transport that, with minor adjustments, could drastically be improved. Other solutions would be too expensive for the gains. If there is political pressure, then other solutions might be worth investigating, but with the current traffic flows it is not convenient.

According to his experience, PM1 tells that politicians always ask for large ambitious solutions, but when the money issue comes on the table, the discussion suddenly changes. Often politicians push for solutions without looking at costs, existing system performance and actual benefits of those solutions and they often realize about the high costs only when it is too late.

An LRT system, to be convenient, requires very high volumes of passengers. It also depends what the municipality/region wants to achieve. LRT per se does not provide higher speeds (with dedicated infrastructure it is possible to achieve the same speed with bus systems), however, there is this idea that LRT is smoother, more comfortable, “it feels better”, and if the improvement compared to the current bus system is high enough, it might also be able to attract new passengers and achieve the modal shift from cars, but the advantages are visible only when the volumes are large enough.

At the question of what would be the added comfort of a rail-based system, PM1 suggests that those who suffer from the sickness from travelling, for example, would not have that issue on rail-based vehicles, especially because the tram is less influenced by the drivers’ driving style.

At the question about why many policymakers are so committed to rail systems, PM1 replies that, from the policymakers' perspective, LRT is a landmark in the city, they perceive that once constructed it stays there longer than a bus, and it "shows" more quality. Moreover, LRT would also be able to attract businesses, which are more willing to relocate near an LRT infrastructure.

In most cases, with a well-implemented bus system, it would be possible to achieve the same quality/level of service. Only when volumes become too high, then alternative systems need to be explored.

The interview concluded about the case of Utrecht: the Uithoflijn had a lot of problems, especially political, and it costed a lot of money, PM1 says, and it will probably take a long time before a real project for the tramway in the city centre will take place. But it will always be an option on the table, because the current corridor in the city centre is too crowded with busses, and sooner or later a rail connection will be realized, also because the Uithoflijn, already when starting its operations, will be already full. It is a very unique situation the case of Utrecht, because the Uithof has a high concentration of educational institutions, hospitals, research centres, and mobility to and from that area is becoming a real challenge.

Policymaker 2

The first topic covered together with PM2 was about the reasons behind the commitment of some policymakers towards BRT or LRT. PM2 suggests that the strong debate BRT/LRT around the world is mostly related to the commercial interests of various industries. For example, there is a huge BRT lobby in the US linked to industries, seminars, websites. Searching for information online it is quite easy to find entire websites dedicated to BRT with tons of information and reasons why they are a good system, while for LRT there is much less of this. Internationally, the lobby is well organized in BRT services. A clear example is here in the Netherlands, in Eindhoven to be precise, where there is a strong pressure on BRT systems because the city wants to be an example of automotive city (with automotive industries located there).

In some parts of the world, such as South America and China, BRT is very suitable because of the low-cost labour market and the particular type of urban environment. In those contexts, the European type of LRT does not work (with very few exceptions). And also the type of BRT implemented in Bogota, would be completely unsuitable for European cities. One of the few European exceptions is here in the Netherlands, with the Zuidtangent, which has dedicated infrastructure, viaducts, stations, very similar to the Bogota system.

PM2 emphasizes that to have a good/real BRT, the type of infrastructure to be realized is key: elevated sections, viaducts, tunnels, stations (instead of stops).

At the question about how policymakers make their decisions, PM2 tells that unfortunately, many public projects are politically driven, and politicians often take wrong decision because they do not look into the real problems that they are trying to solve. PM2 gives the example of the Noord/Zuid Lijn in Amsterdam: since the beginning, the question was never "what do we want to achieve?". There was the need for a north/south connection, no doubts, but then why did they need this particular type of technology? No one ever explored solutions, it all immediately started with the idea of a metro. There were two main reasons for this: first political, politicians wanted a metro at all costs. Second, lobby: the at-the-time public transport company in Amsterdam was strongly pushing for metro technology, especially because for them it would have been easier and less risky to operate a metro than a tram-kind of system.

PM2 suggests that before deciding what type of technology to implement, there should be a conceptual discussion: what kind of connections has to be established in the city/region? What are the most important axes? And why are these axes important? And aspects other than transport demand should be considered as well, such as urban renovation, urban extensions, improvement of the economic structure of a certain area, improve social cohesion, improvement of the connection between home and work, environment (car shift to public transport, emissions reduction). It is all about the vision of what kind of city/region they want to be. Only after it is possible to move the discussion on how to achieve that and with which technology.

At the question about why many policymakers have a preference for rail-based systems, PM2 tells that it is not true that there is only a blind commitment for LRT, many politicians/policymakers are also blindly committed to BRT. To the same extent as many are blindly committed to cars, metros, etc. It is often a question of how they are familiar with a particular system. In Australia, for example, politicians and academic people often oppose any light rail solution. There, when they think about LRT, they think about Melbourne, where the tram system is a total failure (long lines, many stops, no platforms at the stops but stop directly on the road, no priority at intersections, an old fashioned tram system).

Often, it is claimed that BRT is better because it is more flexible. PM2 replies that flexibility is exactly their main disadvantage, a good system should not be flexible, otherwise, it would not be a BRT anymore. Reliability is key, not flexibility. A flexible system cannot be also reliable.

At the question if it is a good idea to involve people during the decision-making process, PM2 tells that it is always good to talk with potential users and asking them what they like and what they prefer. However, someone should be very careful into transforming users wishes and demands into a real system. PM2 gives the example of an interview carried out in the 80s in which people were asked if they would want a mobile phone: the majority said they would not need it. Clearly the answers were influenced by the fact that people did not have a clue about the potentials of this new technology. The same holds for a new transport system, people would not know. Therefore, it is very inappropriate to ask people if they prefer BRT or LRT, especially if they are not familiar with them. Most probably, when answering, they would think about the old style bus and tram.

When designing a new transport mode, PM2 continues, the solution is not a translation of all individual wishes. Hard trade-offs are necessary, policymakers have to go after the common interest, and it is not possible to derive this from individual views and standpoints. It is not always wise to totally involve the public in these kinds of decisions. The best is to involve people in the political discussion about the trade-offs that need to be traded off.

In conclusion, according to PM2 people should be involved, but they cannot be put in the position to answer questions they cannot answer for the good of the collectivity.

Policymaker 3

The interview started with a discussion about why many policymakers prefer tram over the bus. PM3 suggests that, in his experience, often politicians propose a tram because they want something different.

They have this idea that if they want to improve public transport, they have to make major steps in the quality of the network to show a difference, and often the tram is the way to achieve this difference. For example, in a city corridor where there are only busses, if there is the idea to improve public transport on that corridor, policymakers want to make something different: getting rid of the busses and put a tram is for them the natural choice.

However, PM3 continues, if the idea is to improve public transport, the first discussion should be related to the quality you want to achieve, and leave the technical part about which system to use for a later stage. There should be a commitment to quality (frequencies, travel times, reliability), not on technology.

Moving the discussion towards the main differences between bus and rail-based systems, PM3 suggests that the main difference concerns safety (for cyclists and pedestrians, but cars as well): the movement of a tram is much more predictable because is constrained by the rails, while with a bus, even giving to the driver the same information systems, same instruments, do everything the same, it is easier to make exceptions on the vehicle movements, creating issues for safety.

The conversation moved to the hybrid bus/tram systems that are currently being tested in China (tram vehicles without tracks). PM3 says that if the system works, it would be a very interesting solution to experiment: if it is seen as a tram, it would make the tram a bit cheaper, if it is seen as a bus, it would make the bus a bit less flexible.

Then, the discussion touched the topic of the Zuidtangent, and if it would make sense to convert this BRT into an LRT, as someone is proposing. PM3 says that right now the system works very well (where the infrastructure is completely separated): it operates like a fast tram, high speed, high reliability, no interactions with other traffic, wide platforms. The only negative side is that in many sections the road is realized with concrete panels which are slightly separated, and the fissures between them cause a very bumpy ride. A tram would have a smoother ride because of the rails. But it would be sufficient to fill these gaps on the road to solve the problem. So, with small improvements, it is possible to highly improve the system. Currently, there is a very high frequency on this corridor. If the demand keeps growing, for a business case it would make sense to consider a conversion, but for now it works very well as a bus system.

Generally speaking, there should not be any difference in the quality of comfort between bus and tram, if both systems are well implemented, PM3 says. The main issue with busses is that they move too much (too many vibrations, harsh driving style, curves at speed), while on the tram you feel that it is "more guided", there is more stability on the movement of the vehicle, which might impact the different perception in the comfort levels.

Talking about tram systems in the Netherlands, PM3 says that while Eindhoven wants to be an automotive city, Amsterdam is very rail oriented. This is not always positive, because the current tram network, for example, is very old fashioned, slow, with old vehicles, no priorities and no dedicated infrastructure (and often mixed with car traffic).

Until now the national government contributed to building new tram lines, but this is most likely not going to happen anymore, there will be budget only for national railways. And this is a major game-changing, because now cities and regions have to enter in the mindset that they have to finance these projects by themselves, and they are only at the beginning of thinking that way, impacting also decisions that involve the discussion rail versus bus systems.

When deciding for BRT or LRT, PM3 suggests that the public should always be involved to a certain extent, because the public can influence the politicians. Of course, it is not always possible to fulfil all the needs of the individuals (they are often different and conflicting), the goals should always be the collectivity benefits. However, if there is a constructive conversation, people receive all the information, they are told how things work and how the choice has to be made, maybe trying to fit in some of their wishes, and if they are told why certain things can or cannot be done, policymakers can get a good understanding from the public side.

Moreover, it is always possible to "play" a little bit with their wishes, they are usually very small compared to the majority of the large projects and do not impact the total budget (e.g. more trees, more pedestrian areas): if policymakers do not do it because they do not have a communication line with the public, then there is the risk of getting a lot of resistance (as it happened in Groningen with the failed LRT project), that could have been avoided with very small interventions and a clear communication. And if some big/impacting decision needs to be made, they have to be calmly and clearly explained to the public, with the right communication they will understand.

Policymaker 4

Tram is often proposed as a more cost-efficient system compared to the bus. However, PM4 suggests that looking at the experience of the Utrecht region, the tram is quite expensive, and compared to bus systems there is a big cost component related to maintenance which is often neglected. It is true that for busses there is the need for a higher frequency to have the same capacity, and therefore more drivers, but for tram systems it is often neglected the fact that there are people working at the control centre, maintenance crew, etc, so in terms of human resources it is also quite intensive. It is like an iceberg: people only see the peak above the water, but only a few see the entire picture under the sea level.

PM4 adds that it is true that the tram can achieve higher capacity, but busses can reach many more areas of the suburbs, allowing people to reach the city centre directly without forcing them to change.

The main issue with the bus is the following: when designing a tram system, there is always a list of design criteria that need to be implemented, and those are usually quite non-negotiable. But when designing a bus system, there are always discussions to compromise/change/reduce the quality of the system, so in the end, the bus system always ends up being of lower quality. A BRT system can be designed as an LRT system if there is really the will to do it.

PM4 continues saying that it is true that busses still have a lower image compared to trams, but things are changing, especially with the introduction of electric busses. Looking at the surveys made on busses it can be seen that people give a higher score to electric bus compared to a diesel bus. Just the perception of less noise in the vehicle gives actually a positive experience. So things are changing but people need to experience it in scale before the global image will also take over.

On the bus/tram discussion, PM4 says that the main issue with the academic comparison between BRT and LRT is that they are not compared equally, there is the feeling that to busses is not given a good chance in the discussion. From the perspective of policymakers and politicians, usually a rail connection is perceived as "sexy" while a bus is not. A city with tram looks of a higher social status.

PM4 concludes that, for both politicians and policymakers, the most important aspect to take into account when deciding between BRT and LRT is the FAIR cost comparison.

Policymaker 5

PM5 starts affirming that politicians have a preference for rail public transport systems because they give the impression of a higher status compared to the bus. There is also the idea that when the rail tracks are introduced, the system is there to stay for a long time, while with the bus it is very easy to change. In this way flexibility, while considered an advantage by some, is viewed as a big disadvantage by others, because a flexible system is also perceived as less likely to stay there for long time.

There is a general consensus among policymakers, PM5 tells, that when it comes to mass transit in dense city areas, the best way to do it is by light rail or subway. This might be true, but it has to be done in the right way, not like in Amsterdam where the system is old, slow and dense, without dedicated lanes and often in mixed traffic. In Amsterdam, PM5 says, every time there is a plan to improve PT the most appreciated way to do it is by adding trams, instead of giving the bus a possibility to prove it can do the job. Of course, trams take less space and for a city centre like Amsterdam can be a valid option and it could work well (if well designed) for point to point corridors. But when it comes to suburbs, it would be too costly for the number of passengers they have to transport. A bus system in those situations would be a much better option.

Policymaker 6

Rather than an interview, it was more a discussion about possible future transport systems to be implemented in Rotterdam. PM6 started the conversation addressing some issues the municipality is facing.

There is the need for new public transport in Rotterdam to support new developments and to make areas closer together, but there is also the urgent need to free up space on the existing public transport lines which are becoming more and more heavily used, and will not be able to carry the growing demand in the near future.

There will be a new river crossing in Rotterdam and discussions are currently underway together with the ministry, the province and the municipality about the type of transport system to include on this infrastructure. It is a very expensive project. Currently, the municipality is in the phase of exploring possible public transport alternatives that will use this river crossing, but the municipality still does not know if it will be a bus or a tram. The municipality knows for sure that there is no budget for a metro. Since the budget is limited, policymakers in Rotterdam are looking for a good quality transport system which is affordable, flexible, and that can be easily upgraded in the future.

According to the modelling performed, the demand for this new route (between Rotterdam Zuid and Kralingse Zoom) would suggest the use of a tram. However, the municipality recognizes that the existing tram network is in large sections not doing what it should do: not direct enough, not fast enough, no priorities at intersections. So the question is also what to do with the tram system. The municipality, continues PM6, knows that the bus "as they know it" is not the quality they want, therefore, the municipality wonders if it is possible to find something between bus and tram, mixing the best parts of both. Maybe it still needs to be a tram, but then the municipality needs to make sure that the new tram will be better designed than the existing network. PM6 says they are exploring various options, including trams without catenary.

Towards the end of the meeting, at the question of how policymakers perceive BRT and LRT, PM6 replies that he, as a policymaker, perceives the LRT as being higher in the hierarchy than BRT, and that in his perspective it should be preferred as new system to be implemented in case of new urban developments. PM6 also perceives that LRT has "a bit of a bonus" because as a system it seems more structured.

PM6 adds that having to choose between BRT and LRT, the main thing to consider would be the cost, because nowadays it is very difficult to get the money for these new infrastructures. At the same time, the need for more public transport capacity is urging policymakers to invest more. Thus, there is the need to find a balance between deciding for new systems that are future-proof, flexible enough to be upgraded and adapted to future needs, and which do not require excessive investments for building and maintenance.

PM6 concludes saying that between his policymakers colleagues there is still a higher preference/commitment for rail-based systems, but he also notices that this is changing, with growing interest for new types of systems.

10. Flyer

TU Delft

Nederlands →

TRAM vs BUS IN UTRECHT:
ONLINE SURVEY (WIN €50)

For my master thesis at TU Delft I am conducting a research on preferences and perceptions of travelers using bus and tram.
I would like to ask you to participate to this survey, it would greatly help me with my research and **it takes less than 10 minutes**.
You can open the survey via the link below or via the QR-code. The survey can be completed via pc, smartphone or tablet.
Completing the survey, you have the chance to win a €50 bol.com voucher.

I really appreciate your participation!
Alessio Gaspardo

Link: http://bit.ly/UtrechtBusTram

TU Delft

English →

TRAM vs BUS IN UTRECHT:
ONLINE SURVEY (WIN €50)

Voor mijn afstudeerproject aan de TU Delft ben ik bezig met onderzoek naar voorkeuren en percepties voor bus en tram.
Ik zou je willen vragen om deel te nemen aan deze enquête, het zou me enorm helpen met mijn onderzoek en **het duurt minder dan 10 minuten**.
U kunt de enquête openen via de onderstaande link of via de QR-code. Het onderzoek kan worden afgerond via pc, smartphone of tablet.
Als u de vragenlijst invult, maakt u kans op een bol.com-tegoedbon van € 50.

Ik stel uw deelname zeer op prijs.
Alessio Gaspardo

Link: http://bit.ly/UtrechtBusTram

11. Survey online form

Bus Rapid Transit - Light Rail Transit

* Required

Select the language/Selecteer de taal *

- English
- Nederlands

NEXT

Introduction

Dear participant,

This survey is part of my graduation research for the Master Transport, Infrastructure and Logistics at TU Delft and is carried out in collaboration with Royal HaskoningDHV.
The aim of the research is to map Bus Rapid Transit (fast bus) and Light Rail Transit (fast tram) preferences and perceptions.
The survey takes approximately 10 minutes. The information obtained through this survey will only be used for scientific purposes.
I really appreciate your contribution.

2 bol.com gift vouchers of € 50.00 will be raffled among the participants.

Thank you for your participation.
Alessio Gaspardo
Master student at Delft University of Technology

TUDelft Royal HaskoningDHV

Description

Currently, bus line 28 connects the Utrecht central station with the Science Park (university) via the city centre.

Bus line 28 is considered to be a Bus Rapid Transit (fast bus) system, in particular in the section outside the city centre, because it has dedicated lanes and uses long and low floor vehicles (see picture below).

Vehicle used for bus line 28 (and 12)

A Light Rail is a system which can be considered to be in between a tram and a train: a fast tram. In Utrecht, the current tram between Nieuwegein and Utrecht Centraal and the new Uithoflijn (see picture below) are both light rail systems.

New Light Rail vehicle for the Uithoflijn

The aim of this research is to understand how travellers perceive fast bus and fast tram according to their service and technical characteristics.

The survey is divided into three sections:

1) General demographic questions;
2) Nine choice tasks in which you are asked to selected your preferred option;
3) Series of attitudinal questions.

BACK NEXT

Part 1: Socio-demographic questions

Gender *

- Female
- Male
- Prefer not to say

Age *

Your answer

Highest level of education completed *

- Primary school
- Lower vocational / secondary education
- Higher / intermediate / pre-university education
- Higher vocational education
- University/postgraduate

Which transport mode do you mostly use on an average day? *

- ◯ Walk
- ◯ Bike
- ◯ Car
- ◯ Train
- ◯ Bus
- ◯ Tram
- ◯ Metro
- ◯ Other: ____________

How often do you use bus line 28? *

- ◯ 4 or more days per week
- ◯ 1-3 days per week
- ◯ 1-3 days per month
- ◯ 1-11 days per year
- ◯ Never

How often do you use tram lines 60/61? *

- ◯ 4 or more days per week
- ◯ 1-3 days per week
- ◯ 1-3 days per month
- ◯ 1-11 days per year
- ◯ Never

BACK NEXT

Choice experiment

Select a number of your choice *

- ◯ 1
- ◯ 2
- ◯ 3

BACK NEXT

Part 2: choice experiment

Imagine the hypothetical situation where the fast bus line 28 connecting the central station with the Science Park (university) via the city centre is replaced by a fast tram.

You will be presented with 9 scenarios and for each of them you are requested to make a choice between "fast bus" and "fast tram".

The fifth attribute "smoothness of the ride" can assume these values:
- very smooth: no sudden braking
- generally smooth: rare sudden braking
- jerky: sudden braking occurs often

SCENARIO 1

SCENARIO 1	FAST BUS	FAST TRAM
Waiting time	5 min	5 min
Travel time	24 min	14 min
Travel cost	€1.85	€1.35
Crowdedness	only standing (not crowded)	seats available
Smoothness of the ride	generally smooth	generally smooth

Your choice: *

- ◯ FAST BUS
- ◯ FAST TRAM

SCENARIO 2

SCENARIO 2	FAST BUS	FAST TRAM
Waiting time	1 min	1 min
Travel time	14 min	14 min
Travel cost	€2.35	€1.85
Crowdedness	only standing (crowded)	only standing (not crowded)
Smoothness of the ride	jerky	generally smooth

Your choice: *

- ◯ FAST BUS
- ◯ FAST TRAM

SCENARIO 3

SCENARIO 3	FAST BUS	FAST TRAM
Waiting time	3 min	3 min
Travel time	19 min	14 min
Travel cost	€1.35	€2.35
Crowdedness	seats available	only standing (crowded)
Smoothness of the ride	very smooth	generally smooth

Your choice: *

- FAST BUS
- FAST TRAM

SCENARIO 4

SCENARIO 4	FAST BUS	FAST TRAM
Waiting time	5 min	1 min
Travel time	19 min	19 min
Travel cost	€1.35	€1.85
Crowdedness	only standing (not crowded)	only standing (crowded)
Smoothness of the ride	jerky	very smooth

Your choice: *

- FAST BUS
- FAST TRAM

SCENARIO 5

SCENARIO 5	FAST BUS	FAST TRAM
Waiting time	1 min	3 min
Travel time	24 min	19 min
Travel cost	€1.85	€2.35
Crowdedness	only standing (crowded)	seats available
Smoothness of the ride	very smooth	very smooth

Your choice: *

- FAST BUS
- FAST TRAM

SCENARIO 6

SCENARIO 6	FAST BUS	FAST TRAM
Waiting time	3 min	5 min
Travel time	14 min	19 min
Travel cost	€2.35	€1.35
Crowdedness	seats available	only standing (not crowded)
Smoothness of the ride	generally smooth	very smooth

Your choice: *

- ○ FAST BUS
- ○ FAST TRAM

SCENARIO 7

SCENARIO 7	FAST BUS	FAST TRAM
Waiting time	5 min	3 min
Travel time	14 min	24 min
Travel cost	€2.35	€2.35
Crowdedness	only standing (not crowded)	only standing (not crowded)
Smoothness of the ride	very smooth	jerky

Your choice: *

- ○ FAST BUS
- ○ FAST TRAM

SCENARIO 8

SCENARIO 8	FAST BUS	FAST TRAM
Waiting time	1 min	5 min
Travel time	19 min	24 min
Travel cost	€1.35	€1.35
Crowdedness	only standing (crowded)	only standing (crowded)
Smoothness of the ride	generally smooth	jerky

Your choice: *

- ○ FAST BUS
- ○ FAST TRAM

SCENARIO 9

SCENARIO 9	FAST BUS	FAST TRAM
Waiting time	3 min	1 min
Travel time	24 min	24 min
Travel cost	€1.85	€1.85
Crowdedness	seats available	seats available
Smoothness of the ride	jerky	jerky

Your choice: *

◯ FAST BUS

◯ FAST TRAM

BACK NEXT

Perceptions (1/3)

In this section there are 21 statements regarding both Bus Rapid Transit (indicated as "Fast bus") and Light Rail Transit (indicated as "Fast tram").
Give an answer between 1 (totally disagree) and 5 (totally agree) to each statement.

The vehicle has easy and fast boarding *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	◯	◯	◯	◯	◯
Fast tram	◯	◯	◯	◯	◯

The vehicle provides enough capacity for passengers transferring from train *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	◯	◯	◯	◯	◯
Fast tram	◯	◯	◯	◯	◯

The service feels reliable (every time almost equal travel time and is punctual) *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	◯	◯	◯	◯	◯
Fast tram	◯	◯	◯	◯	◯

During peak hours the vehicle feels uncomfortably crowded *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle has enough seats *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The route has many bumps making the ride not enjoyable *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle rides smoothly on curves *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

Perceptions (2/3)

The vehicle is often delayed *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle looks modern and appealing *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle is fast *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle has a sufficient number of doors *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle waits too long at stops *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

If this vehicle is driverless (automated), I would be willing to use it *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle is comfortable *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

Perceptions (3/3)

The vehicle accelerates and brakes smoothly *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle is environmentally friendly *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle rides without making noise *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle has enough leg space to sit comfortably *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

The vehicle has enough standing space *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

From the inside the vehicle feels spacious and has a pleasant design *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

It is a frequent service *

	1 - totally disagree	2	3	4	5 - totally agree
Fast bus	○	○	○	○	○
Fast tram	○	○	○	○	○

Conclusion

This is the end of the survey, thank you for your contribution.

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Your answer

Any comments or questions?

Your answer

BACK SUBMIT