Taking the self-driving bus
A passenger choice experiment

Winter, M.K.E.; Wien, Joost; Molin, Eric; Cats, Oded; Morsink, Peter; Van Arem, Bart

DOI
10.1109/MTITS.2019.8883310

Publication date
2019

Document Version
Final published version

Published in
MT-ITS 2019 - 6th International Conference on Models and Technologies for Intelligent Transportation Systems

Taking The Self-Driving Bus: A Passenger Choice Experiment

Konstanze Winter
Transport and Planning
Delft University of Technology
Delft, the Netherland
m.k.e.winter@tudelft.nl

Joost Wien
Technology, Policy and Management
Delft University of Technology
Delft, the Netherland
joost_wien@hotmail.com

Eric Molin
Technology, Policy and Management
Delft University of Technology
Delft, the Netherland
e.j.e.molin@tudelft.nl

Oded Cats
Transport and Planning
Delft University of Technology
Delft, the Netherland
o.cats@tudelft.nl

Peter Morsink
Transport & Road Safety
Royal Haskoning DHV
Amersfoort, the Netherland
peter.morsink@rhdhv.com

Bart van Arem
Transport and Planning
Delft University of Technology
Delft, the Netherland
b.vanarem@tudelft.nl

***Abstract*— At the brink of the introduction of self-driving vehicles, only little is known about how potential users perceive them. This is especially true for self-driving vehicles deployed in public transport services. In this study, the relative preferences for a trip with a self-driving bus is assessed compared to a trip with a regular bus, based on a stated preference experiment. Based on the responses of 282 respondents from the Netherlands and Germany, a discrete choice model is estimated as a Mixed Logit model including attitudes towards trust in self-driving vehicles and interest in technology. The results show that currently public transport passengers prefer the self-driving bus over the regular bus only for short trips. This is due to the finding that the value of travel time is about twice as high for the self-driving bus as for the regular bus for a short commuting trip. Findings from this study further suggest that the popularity of self-driving busses decreases with the presence of a human steward on-board, or if they are operated as a demand-responsive service with fixed routes. People who currently show a strong interest in technology or trust in automated vehicle technology perceive the self-driving busses better than others. The trust-effect is especially strong for women. In general, men are found to be more inclined to choose the self-driving bus than women. Preferences towards automated public transport services are expected to evolve along with the transition from demonstration pilots to their deployment in regular operations.**

***Keywords*—Self-driving buses, Automated public transport, Public transport passengers, Stated choice, Mixed Logit, Bus systems**

I. INTRODUCTION

Automated vehicles (AVs) are becoming increasingly accessible to the public and first trials with self-driving vehicles are made around the globe. Self-driving vehicles could provide benefits in the efficiency of use of resources, as well as reduced road congestion [1]. Furthermore, they might increase the mobility of people without driver's license and they can contribute to improved road safety [1], [2]. However, these advantages might lead to increase car travel and consequently to an increase in the total vehicle miles travelled contributing to more congestion [2]. For this reason it is important to follow closely the way automated vehicles are employed and used, as only with this knowledge the introduction of automated and self-driving vehicles can be guided successfully.

A concept that could diminish the detrimental effects of an increasing use of motorized vehicles due to vehicle automation could be to use self-driving vehicles to enhance the service on public transport lines or to complement public transport in last-mile solutions [3], [4]. In addition, by introducing self-driving pods or busses, public transport services could provide more flexible on-demand services, as the costs of operating such services are expected to be considerably lower when operated by self-driving vehicles.

User demand for the self-driving vehicle is a prerequisite for its successful implementation [4]. Currently travellers do not seem to embrace self-driving vehicles yet [1], [5]. Integrating automated driving and public transport could be key to the development of automated vehicles [4]. However, only little is known regarding the travellers' preferences and attitudes in regard to self-driving vehicles within a public transport system [3]–[6].

This study addresses this open research gap by assessing the preferences of public transport passengers in regard to a self-driving bus for an urban commute trip. By having conducted a stated choice experiment, this study sheds light on passengers' preferences towards self-driving busses and how they trade-off travel time and travel cost linked to using a self-driving bus.

The remainder of this paper is structured as follows: in section II a review on previous stated choice experiments featuring self-driving vehicles is given. In chapter III, a brief description of the pilot test with a self-driving bus, on which this study is based, is given. The methods used to investigate the public transport passengers' preferences for a self-driving bus is presented in section IV. In section V, the results of the conducted survey and the collected sample are discussed. At last, the conclusions and recommendations for further research are presented in section VI.

II. LITERATURE REVIEW

Complimentary to existing public transport modes, automated vehicles could be deployed as self-driving buses, which could benefit public transport in its efficiency of the operations, traffic safety and lower its costs [6].

To be able to assess passenger preferences towards self-driving vehicles, the behaviour of passengers needs to be inferred and analysed. Since self-driving vehicles are currently not a common mode to travel, primary sources of information of passenger preferences are stated preference experiments. In these experiments observable factors are used which represent attributes describing alternatives, such

978-1-5386-9484-8/19/$31.00 ©2019 IEEE

as travel time and travel costs. An overview of conducted stated choice experiments featuring self-driving vehicles is presented in [7], [8]. These overviews however do not hold insights on the perception of self-driving busses in particular. In an early stated preference study introducing AV used for public transport services, it has been found that people are in general more worried about larger self-driving vehicles such as self-driving busses than smaller self-driving vehicles, such as self-driving taxis [9]. Findings from stated preference experiments featuring shared automated vehicles (SAV) can therefore not directly be put on a level with preferences for self-driving busses. As there are however only very few studies on specifically the perception of self-driving busses, this literature review includes also findings on AV introduced in stated preference studies in a broader sense.

Past findings on the relative preferences for self-driving vehicles over other modes offer inconclusive and sometimes contradictory results: people were found to prefer self-driving busses over conventional minibuses [10], but also have shown to prefer the conventional car and bus over a self-driving vehicle as egress mode [5] and rather choose their usual (non-automated) mode over a self-driving vehicle for their reference trip [3]. Looking a bit more into detail into the preferences towards automated vehicles, it has been reported that young people, in particular men and people with a positive attitude towards environmental concerns, tend to be more favourable towards self-driving vehicles [1], [3], [7], [8], [11]–[14]. Also public transport passengers and people without a car or drivers' licence are significantly more positive towards shared self-driving vehicles than those currently relying on a private car [14], [15]. Additionally, the preference for self-driving vehicles is strongly influenced by the level of trust in self-driving vehicles [4], [5], [8]. People tend to trust self-driving vehicles in controlled environments more than in mixed traffic [10].

In one of the first studies on the position of the self-driving vehicle in the public transport market [5], the authors assumed, based on findings in [2], [3], that travellers would be willing to pay less for reducing travel time than in conventional egress modes, like the bus. However, they found the willingness to pay for a reduction of in-vehicle time for a self-driving vehicle to be higher than for conventional buses and cars. Reasons for this could be that people might not value the advantage of performing other activities while travelling or that they might feel uncomfortable traveling in a self-driving vehicle because of a lack of trust in the technology [5].

These results were contradicted by the findings from a stated preference experiment conducted to explore how people experience a trip with a self-driving vehicle compared to a regular car [16]. In this study it was found that the value of travel time is lower for a self-driving vehicle with an office interior than the conventional car. This result corroborates the expectations that people are willing to work in a self-driving vehicle [16].

Considering trust in self-driving vehicles, the presence of a steward monitoring the bus movements showed a higher intentional usage, suggesting that trust is higher when a steward is present [6], [12]. Moreover, the ability to communicate with the bus operator might improve passenger preferences for self-driving buses, for example, with a communication system for information and remote supervision [6], [17].

Other attitudes that showed a positive effect on the intention to use self-driving vehicles are the perceived convenience of the self-driving bus and a general interest in technology [1], [16].

Overall the understanding about if and under what conditions people would appreciate the introduction of self-driving busses is very limited. To the best of the authors' knowledge, there is currently no discrete choice model available that features self-driving busses as a mode choice option. In the course of a pilot test with an automated bus, this study presents a discrete mode choice model capturing the choices between a self-driving bus and a regular bus in a situation similar to the one in the pilot region.

III. Testing the Self-Driving Bus in a Pilot Study

This study is part of a pilot study testing the implementation of a self-driving bus as a border-crossing public transport service. The pilot study will be set up in the border region between the Netherlands and Germany, connecting the campus of a university in the city of Aachen on the German side and the municipality of Vaals on the Dutch side. The self-driving bus will be operated as a dispatched-on-demand service with a fixed route, allowing passengers to request its service. The pilot study is planned to start in fall 2019 [18]. The pilot study is a follow-up to the WEpods project conducted in the year 2016 [19].

IV. Choice Experiment and Model Estimation

Since the self-driving bus is currently not a common alternative within the public transport sector, passenger choices cannot be observed yet. Therefore a stated choice experiment has been conducted in order to gain a better understanding of the preferences of public transport passenger in regard to self-driving vehicles, based on which a Mixed Logit discrete choice model is estimated. In the model, attitudes towards self-driving busses are included.

A. Choice Experiment: Trip Purpose, Mode Alternatives and Their Attributes

For this study, a hypothetical commuting trip from home to a work or study location is described in the choice experiment. For this trip, respondents can choose between three mode alternatives: (1) The first alternative describes a regular bus service, based on the current bus services available in the region of the planned pilot described in chapter III. (2) The second alternative is a self-driving bus, which differs from the regular bus in not having a driver and being small in size and thus having fewer seats. (3) The third option is an opt-out alternative, which was added in order to increase the realism of the experiment. The opt-out option is phrased as "I would choose for another alternative", and thus represents any alternative the respondent can imagine beyond the previous two alternatives.

The regular and self-driving busses are described by the attributes travel time, travel costs and waiting time. The presented attribute levels were based on the current bus line operating in the pilot area and represent a bus trip of approximately 3 kilometres in a (sub-)urban area. Two additional attributes for the self-driving bus are considered: (1) 'Surveillance and information' pertains to the presence of either a steward, an interactive screen for communication with the bus operator and a visualisation of what the sensors and cameras of the self-driving bus are detecting, or no extra surveillance. (2) The attribute 'Service' defines the operation of the self-driving bus either as a scheduled service or an on-demand service with fixed routes. TABLE I provides an overview of the attributes and attribute levels considered in the stated choice experiment.

B. Choice Set

The design of the choice sets is based on a orthogonal fractional factorial design, derived with the software NGENE [20]. This design allows to select a subset of all possible choice situations. The design features 24 choice sets, which are blocked in four blocks. Each respondent is thus faced with six choice sets.

TABLE I. OVERVIEW OF ATTRIBUTES AND ATTRIBUTE LEVELS

Travel time	Travel costs	Waiting time	Surveillance & Information	Service
7 min	€1,00	2 min	Standard	Scheduled
10 min	€1,60	4 min	Interactive screen	On-demand
13 min	€2,20	6 min	Steward	--
16 min	€2,80	8 min	--	--

TABLE II. STATEMENTS INCLUDED IN THE SURVEY

Variable	Trust in self-driving vehicles
TRUST_1	I believe a self-driving vehicle would drive better than the average human driver.
TRUST_2	I am afraid that the self-driving vehicle will not be fully aware of what is happening around it.
TRUST_3	I think that the self-driving system offers more safety than manual driving.
TRUST_4	I would entrust the safety of a close relative to a self-driving vehicle.
TRUST_5	I think that the self-driving bus is only safe when a steward is present.
Variable	**Technology interest**
TI_6	I try new products before others do.
TI_7	I am excited by the possibilities offered by new technologies.
TI_8	I have little to no interest in new technology.
TI_9	New technologies create more problems than they solve.
Variable	**Convenience**
CONV_10	Self-driving vehicles will make life easier.
CONV_11	The best part of the self-driving bus is that it can be requested on demand.
CONV_12	I think that using the self-driving bus is more convenient than using regular buses.
Variable	**Vehicle characteristics**
CHAR_13	I would feel more comfortable in a self-driving bus with several passengers than with a few passengers.
CHAR_14	An interactive screen is a good replacement for a bus employee in the self-driving bus.
CHAR_15	I would feel more comfortable in a self-driving bus than in a regular bus.

C. Attitudes

To explore if attitudes towards the self-driving vehicle influence the choices made by the respondents in this experiment, a set of attitudinal statements has been included in the survey, see TABLE II. The respondents were asked to rate their level of agreement with these statements using a five-point Likert scale. The provided statements are derived from variables that were found to significantly influence the choice behaviour in regard to self-driving vehicles in previous research [1], [11], [21]. Based on the statements, attitudinal factors are formulated, which are included in the model as described in the following. The attitudinal factors are incorporated as mean sum scores for each individual into the discrete choice model.

D. Specification of the Mixed Logit Model

Based on the results from the stated choice experiment and the determined attitudinal factors, a discrete choice Mixed Logit model is estimated. From the various models estimated, only the one with the highest explanatory power is hereby presented. The model describes the perceived utility U_i of a mode alternative i, which is described in Eq.1. This model includes β_x, which is the vector estimating the taste parameters associated with the attributes of alternative i and x_i, which is a vector that contains the attribute levels of alternative i. In addition, β_τ is the vector that reflects the importance of the socio-economic variables τ_s of individual s. The model also includes factors representing the respondents' attitudes, as described in the previous section. Mean sum scores represent the attitudinal factors for each individual s and are represented by the vector φ_s, which contains the parameters that estimate the marginal utility of the attitudinal factors. Finally, ε_i is the independent and identically distributed (i.i.d.) error term capturing the unobserved part of the utility U_i.

$$U_i = \beta_x x_i + \beta_\tau \tau_s + \beta_\varphi \varphi_s + \varepsilon_i \tag{1}$$

E. Model Application

Based on the estimated discrete choice model, the choice probabilities for the collected sample are approximated in a model application. For this, a Monte Carlo simulation based on 1000 draws from the estimated distributions for the estimated values for travel time and travel costs is performed. This approach is not interpreted as a forecast for a future modal split, but is rather used for determining the threshold values for travel times and travel costs for the self-driving bus in order to become a competitive alternative to the regular bus.

V. RESULTS AND DISCUSSION

A. Sample Description

The survey was distributed through several online platforms, both in Dutch and German. In particular, citizens from the pilot region were invited to participate on the website of the municipality of Vaals and the municipality of Aachen. In total, the answers of 282 participants are included for the model estimation. See TABLE III for an overview of the sample characteristics in detail. All respondents use public transport at least once a year, with a share of 71.6% using public transport every week. In regard to the gender of the public transport passengers, the sample is comparable with the Dutch and German average of public transport passengers [22], [23]. Young people and people with higher education are overrepresented compared to the Dutch and German average general population. This has to do with the primary respondent groups targeted with the survey, namely students and employs of the university campus in Aachen, who are commuting between the municipality of Vaals and the campus. Having captured many students also explains the overrepresentation of people with a low income.

B. *Factor Analysis*

From the responses to the statements shown in TABLE II, attitudinal factors are derived by performing an exploratory factor analysis. With the factor analysis, the statements are grouped based on the underlying pattern of correlations within the statements. This allows to reduce the number of variables introduced to the choice model by replacing the full set of statements with a few factors that explain most of the observed variance. The results of the factor analysis are shown in TABLE IV.

The factor analysis has been performed step-wise, resulting ultimately in a 2-factor solution, incorporating 10 out of the original 15 variables. The other five variables were excluded, as they showed a communality lower than 0.25 and factor loadings of less than 0.5. A simple structure for the factors is reached by performing a VARIMAX rotation. A similar outcome is found for a skewed rotation. However, the interpretability of the VARIMAX rotation and its replicability make this rotation the preferred one and is thus selected in this case.

The first of the derived factor can be described as *'trust in self-driving vehicles'*, as it includes variables that describe attitudes towards safety and performance of the self-driving bus. The leading statement for this factor is "I think that the self-driving system offers more safety than manual driving". The second factor describes the general *'interest in technology'* of the respondents, dominated by the statement "I am excited by the possibilities offered by new technologies". The variables TI_6 and TI_9 have low factor loadings (below 0.5). However, they are included in the second factor as they fit the interpreted factor and do not have high double loadings. The reliability of the extracted factors is analysed in regard to how close the variables of one factor are related, indicated by the tau-equivalent reliability (Cronbach's alpha). The factor *'trust in self-driving vehicles'* has a value of 0.84, the factor *'interest in technology'* has a value of 0.75, therefore both factors have a high internal consistency.

C. *Discrete Choice Model*

The best discrete choice model for the collected sample is derived by estimating a Mixed Logit model correcting for panel effects, including a nesting effect for the two buses and taking possible taste heterogeneity into account for the alternative specific constants and the travel time parameters. The model is estimated with 1000 Halton draws from a normal distribution, which gives stable parameter results. TABLE V shows the estimation results of the discrete choice model.

TABLE III. SAMPLE CHARACTERISTICS

Socio-economic variable	Category	Sample [in %]
Gender	Female	48.9
	Male	51.1
Age	18 - 24 years	37.2
	25 - 34 year	39.4
	35 - 49 year	13.1
	50 - 64 year	9.9
	>64 year	0.4
Education	Low	1.1
	Middle	8.5
	High	90.4
Employment	Full time	45.0
	Part time	16.7
	Student	36.2
	Jobless	1.8
	Retired	0.4
Income	<€10.001	30.1
	€10.001 - €20.000	7.8
	€20.001 - €30.000	20.9
	€30.001 - €40.000	13.8
	€40.001 - €50.000	8.5
	>€50.000	6.7
	No information	12.1
Public transport Usage	(almost) Every day	15.6
	5 days a week	16.0
	4 days a week	13.1
	3 days a week	11.0
	2 days a week	11.0
	1 day per week	5.0
	A few times per month	11.7
	One time per month	5.7
	A few times per year	11.0
Country of Residence	The Netherlands	84
	Germany	16

TABLE IV. ESTIMATION RESULTS ROTATED FACTOR MATRIX (FACTOR LOADINGS <0.3 ARE NOT SHOWN)

Variable	Factor 1: "trust in self-driving vehicles"	Factor 2: "interest in technology"	Communality
TRUST_3	0.791		0.663
TRUST_1	0.742		0.577
TRUST_4	0.716		0.562
TRUST_2	0.670		0.485
CHAR_15	0.578		0.416
TRUST_5	0.506		0.303
TI_7		0.916	0.898
TI_8		0.658	0.442
TI_6		0.498	0.329
TI_9		0.451	0.250

TABLE V. ESTIMATION RESULTS DISCRETE CHOICE MODEL

Parameter	Mixed Logit model with nesting effect and taste heterogeneity	p-value
σ nesting effect	-4.88 ***	0.00
α_i		
Constant REB	11.8 [10.7, 12.9] ***	0.00
Constant SDB	10.2 [8.8, 11.6] ***	0.00
σ constant REB	0.57 *	0.07
σ constant SDB	0.71 ***	0.00
β_x		
Travel cost REB	-1.8 ***	0.00
Travel cost SDB	-2.08 ***	0.00
Travel time REB	-0.15 [-0.27, -0.04] ***	0.00
Travel time SDB	-0.37 [-0.46, -0.27] ***	0.00
σ travel time REB	0.06 ***	0.00
σ travel time SDB	0.05 ***	0.00
Waiting time REB	-0.26 ***	0.00
Waiting time SDB	-0.19 ***	0.00
DRT service SDB	-0.37 **	0.02
Steward SDB	-0.30 **	0.01
Interactive SDB	0.04	0.68
β_τ		
Female REB	0.74 **	0.04
PT every month SDB	0.22	0.14
Pilot provinces SDB	0.07	0.51
β_φ		
Tech. interest (TI) SDB	0.35 **	0.04
Trust in AVs SDB	0.96 ***	0.00
Female TI SDB	-0.11	0.41
Female AV trust SDB	0.40 ***	0.01
No. parameters	23	
Initial log-likelihood	-1858.85	
Final log-likelihood	-964.39	
Adjusted ρ^2	0.469	

*** = significant at a 99% CI; ** = significant at a 95% CI;
* = significant at a 90% CI;
[..] interval estimate from standard deviation σ;
REB = Regular bus; SDB = Self-driving bus

1) Unobserved Factors

A significant nesting effect is found in the estimation (σ *nesting effect* = -4.88 [p<0.01]), implying that the self-driving bus and regular bus have common unobserved factors in contrast to the third alternative, representing all other possible travel options combined.

The alternative specific constants of the regular bus *Constant REB* (11.8 [p<0.01]) and self-driving bus *Constant SDB* (10.2 [p<0.01]) show that the bus alternatives are preferred over the option to choose any other mode. The difference between *Constant REB* and *Constant SDB* is statistically not significant, which indicates that there is no difference in the unobserved preferences within the population based on the data. The standard deviations for the alternative specific constants however show that there is significant individual specific taste heterogeneity in the perceived utility of the self-driving bus and the regular bus. The standard deviation (σ *constant SDB* = 0.71) is significant for the self-driving bus with p-value < 0.01. The standard deviation of the regular bus (σ *constant REB* = 0.57) is also considered significant with a p-value of 0.07.

2) Travel Time and Travel Cost

The marginal utility of the travel cost for the self-driving bus (-2.08 [p = 0.0]) is more negative than for the regular bus (-1.8 [p = 0.0]). The mean parameter for the marginal utility of travel time on a self-driving bus (-0.37 [p<0.01]) is significantly more negative than the one for the regular bus (-0.15 [p<0.01]). This means that the time spent while travelling in a self-driving bus has a lower perceived utility than time spent travelling in the regular bus. The standard deviations for the mode-specific travel times are significantly different from zero. This means that there is individual-specific taste heterogeneity for travel times. Based on the parameters for travel time and travel costs, the value of travel time (VOTT) is estimated, which reflects the willingness to pay for travel time reduction. For the regular bus, a mean VOTT of €5.13 per hour is estimated, the one for the self-driving is €10.59 per hour (see TABLE VI). These two values lie in the expected range, given that the current VOTT for travelling in a regular bus in the Netherlands ranges between €7.75 and €10.50 per hour [24]. The results for the VOTT values show that respondents would pay more than double the marginal costs for reducing marginal in-vehicle time spent in a self-driving bus in comparison to a regular bus. This result is in line with findings on how much people would pay for savings in marginal in-vehicle time for public transport in comparison to self-driving vehicles as egress modes [1], [5].

TABLE VI. VOTT ESTIMATES AND STANDARD DEVIATIONS [€/HOUR]

Alternative	Mean VOTT [per hour]	Standard deviations VOTT [per hour]	95% confidence interval
Self-driving bus	€ 10.59	€ 1.38	[€ 7.87, € 13.30]
Regular bus	€ 5.13	€ 1.94	[€ 1.32, € 8.94]

3) Waiting Times and Serivce Specifications

Waiting time for the self-driving bus (-0.19 [p<0.01]) is valued less negative than the waiting time associated with the regular bus (-0.26 [p<0.01]). The disutility of waiting time is perceived about four times larger than the disutility for travel times. The interpretation of the values for waiting time for the self-driving bus is however difficult, as it combines the waiting time for the schedule-bound service and for the demand-responsive service. Understanding how passengers perceive waiting times for flexible dispatching transport services will be an important step for implementing these kind of services successfully.

The on-demand service decreases the perceived utility of the self-driving bus (-0.37 [p<0.05]), travellers prefer a scheduled-based service over the flexible one. An explanation for this observation could be that an on-demand service requires extra effort of the traveller, who has to actively send a request in order to make use of the service. This finding is specific to the formulation of the route-based demand-responsive service and does not allow drawing conclusions on the perceived utility of fully flexible services.

4) Survaillance on the Self-Driving Bus

Regarding the surveillance present in a self-driving bus, respondents prefer to have no extra surveillance on-board the self-driving bus. The presence of a steward is found to reduce the perceived utility (-0.30 [p<0.05]), whereas the interactive system is not significantly different from zero (0.04 [p=0.68]). This outcome contradicts the findings reported in previous studies [6], [12]. The differences in outcome may be caused by the way data has been gathered: in this study surveillance was presented as one attribute among other attributes such as travel times and travel costs, while in the previous studies respondents were directly asked about their preferences for using a self-driving bus with or without an employee present. This could be an indication that in the trade-offs made during the choice processes captured in this study, surveillance is regarded as less important compared to the other attributes and therefore has a lower impact on the choices made. It could also be that the respondents might not have understood the attribute, as it is part of an unfamiliar alternative. In regard to the steward, it could be that the respondents dislike the presence of extra surveillance personnel, as this can cause the feeling of being watched. Another explanation could be that the extra surveillance might be perceived as a compensation for possible unreliable technical shortcomings of the self-driving bus. This opens a research gap, which is particularly relevant to the success of future trials with self-driving busses and their accompanying policies.

5) Socio-Economic Factors and Attitudes

A detailed investigation of the results reveals that gender influences the choice made in the experiment. The indicator variable *Female REB* (0.74 [p<0.05]) shows that women have a stronger preference for the regular bus than men. Conversely it has been shown that male respondents are more likely to opt for the self-driving bus than female ones. This difference between men and women is in line with previous studies that showed that women have a less favourable attitude towards self-driving vehicles than men [1], [5], [12], [13]. Moreover, the attitudinal factor of *"trust in self-driving vehicles",* which relates to the safety and performance perception of a self-driving bus, has a larger impact on the choices made by women than men. The interaction variable of trust in AVs and gender shows a positive value (0.04 [p<0.01]), indicating that the trust in the automated vehicles has a stronger effect on the preference for the self-driving bus among women than men.

In regard to the frequency in public transport use, we find that respondents who use public transport services once per month or more perceive the utility of travelling in a self-driving bus higher than those using public transport less frequently. However, the parameter is only significant at the 85% confidence interval, which might be due to the small share of only 11% of the respondents who use public transport services less than once per month. This outcome is in line with previous findings that people who travel with public transport services at least once a month show a more positive attitude towards self-driving vehicles [15].

Given that the survey with the choice experiment has been distributed often with a link to the upcoming pilot trial, it is tested whether people living within the region where the pilot test will take place have a different perceived utility than those living elsewhere. The parameter that corresponds with the respondents living in the pilot region shows a positive influence on utility of the self-driving bus (0.07 [p = 0.51]), however it is highly insignificant. Therefore it is concluded that having distributed the survey together with the information that a respondent potentially might be affected by the upcoming pilot trial has not influenced the results significantly. We also find no differences between German and Dutch participants.

Additionally, the general attitude *"interest in technology*" affects the perceived utility of a self-driving bus positively (0.35 [p<0.05]), but less so than the attitude *"trust in self-driving vehicles"* (0.96 [p<0.01]). No significant differences between men and women are found for the factor capturing interest in technology, while the factor capturing trust is influenced by gender. The impact of trust is especially important for women. As can be expected, having generally a high interest in technology and trusting self-driving vehicles have both a positive effect on the choice for a self-driving bus.

6) Model Application

The estimated values for travel time and travel costs have been used in a Monte Carlo simulation to approximate the choice probabilities for the collected sample based on 1000 draws from the estimated distributions for the results described in TABLE V. Based on this, the threshold value for travel times and travel costs is determined for two selected scenarios, which are based on the two bus lines currently operating in the pilot region: (1) The "longer trip", based on a trip with the regular bus which has a fare of € 2.70 and a travel time of 14 minutes. If the self-driving bus would have the same attribute levels, about 28% of the respondents would opt for self-driving bus and about 57% of the respondents would opt for regular bus, while 15% would prefer the option to choose any other mode. The break-even point in modal shares between the two busses could be reached by either reducing the fares of the self-driving bus to €2.20 (Figure 1a) , or reducing its travel time to 11 minutes (Figure 1b), while keeping the respective other attribute at the same level as the regular bus. (2) The "shorter trip", based on a trip with the regular bus which has a fare of € 1.50 and a travel time of 7 minutes. If the self-driving bus would have the same attribute levels, 62% of the respondents would opt for self-driving bus and 34% would opt for regular bus, while 4% would prefer the option to choose any other mode. The break-even point in modal shares between the two busses is reached by either increasing the fares of the self-driving bus to €1.90 (Figure 1a), or increasing its travel time to 9.2 minutes (Figure 1b), while keeping the respective other attribute at the same level as the regular bus.

This application of the model illustrates that in the choice situation discussed in this paper, the self-driving bus is more competitive on shorter trips than on longer ones, which would make it ideal for feeder services or short-distance connections in urban settings. If the self-driving bus is supposed to provide its services also on longer trips, reduced fees would be required in order to turn it into an attractive alternative. Offering such a cost reduction for longer trips is not unrealistic, since it is expected that in the future the operating costs of self-driving busses could fall below the ones of regular busses due to reduced personnel costs.

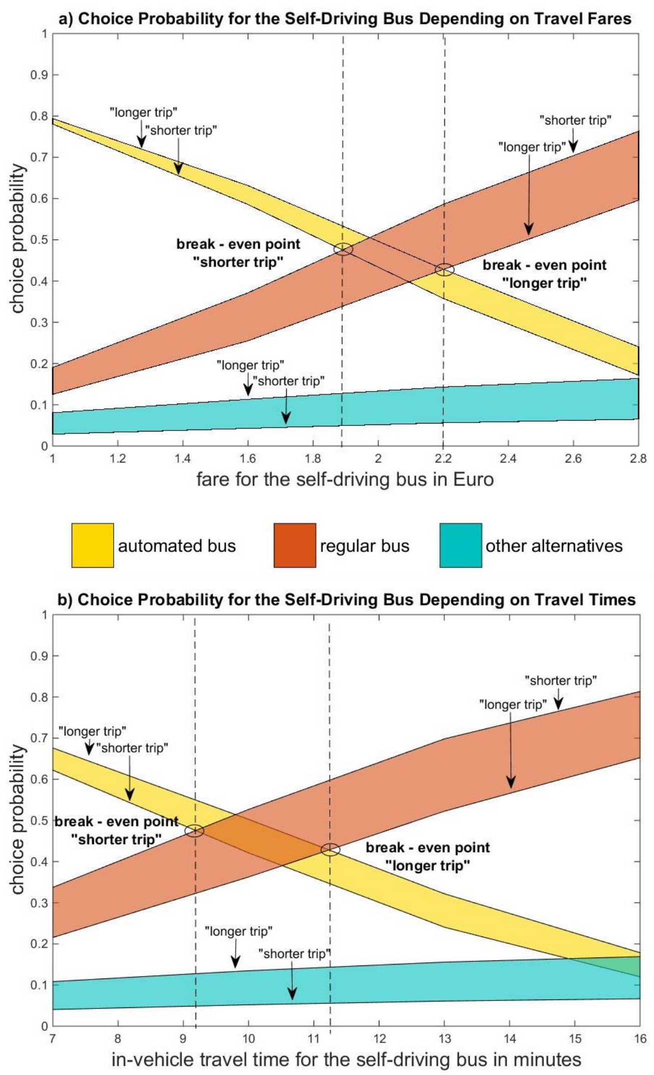

FIGURE 1: CHOICE PROBABILITIES FOR THE AUTOMATED BUS (YELLOW), REGULAR BUS (RED) AND OTHER ALTERNATIVES (TURQUOISE) FOR DIFFERENT TRAVEL FARES (A) AND TRAVEL TIMES (B) FOR THE SELF-DRIVING BUS FOR TWO SCENARIOS. THE BREAK-EVEN POINTS ARE MARKED BY A DOTTED LINE.

VI. CONCLUSION

The aim of this study is to shed light on the preferences of public transport passengers in regard to self-driving busses. A stated choice experiment has been conducted in order to capture the choice behaviour along with certain attitudes towards self-driving vehicles and technology for an urban commuting trip. Based on this experiment, a discrete choice model in the form of a Mixed Logit model is estimated in order to assess the relative preferences.

Overall, it can be concluded that in the specific choice situation presented to the participants, the self-driving bus is preferred over the regular bus only for shorter trips, while the regular bus is preferred for longer trips. Travellers are found to perceive the travel time in a self-driving bus worse than in a regular bus, and thus they are willing to pay more for saving travel time while traveling in a self-driving bus. The value of travel time for the self-driving bus has been found to be more than twice as high as the one for the regular bus.

Based on the findings in this choice experiment, it can be concluded that in order to increase the perceived utility of travelling in a self-driving bus, the attention has to be given to the following two operational decisions: (1) operating the self-driving bus as a scheduled-based service and not as a flexible dispatching transport service with fixed routes has shown to increase the perceived utility of the self-driving bus and (2) installing an interactive surveillance systems or introducing human stewards on board has shown to decrease the perceived utility. However, the perception of self-driving busses operating flexibly also in regard to their routes and stop locations has not been examined in this research. Furthermore, the results for the on-board surveillance are not fully in line with the expectations for self-driving busses: It is currently a legal requirement in the Netherlands and Germany to have a steward on board of a self-driving bus and previous studies have shown that passengers are also in favour of a steward being present. That the results of this experiment draw an unexpected picture in regard to demand-responsiveness and on-board surveillance stresses the importance of performing further research into these subjects.

Concerning potential early adaptors and future user groups, it can be concluded that, in general, men have a higher inclination to opt for a self-driving bus than woman. Also having a general interest in technology and having a trusting attitude towards self-driving vehicles increases the probability of opting for the self-driving bus over the regular bus. The latter is especially true for women, for whom the influence of the trust attitude is particularly strong. Respondents travelling by public transport services more than once a month also have shown a higher probability of opting for the self-driving bus than those using public transport services less often. To further investigate potential user groups and causal relationships with attitudinal factors, it would be worthwhile to extend the model estimation of the choices for self-driving buses with an integrated choice and latent variable model.

This study is performed at the brink of the start of a pilot test with self-driving busses in the border region between the Netherlands and Germany. The findings from the conducted stated choice experiment allow sharpening our understanding of the preferences in regard to self-driving vehicles used for public transport services. However, it has been shown that in stated choice experiments respondents are inclined to choose for the alternative they are familiar with [25], which could have influenced the outcome of the choice experiment featuring the self-driving bus as an unknown alternative. Thus, an even better understanding could be gained by also collecting data from observed choices during the pilot trail and by performing a second stated choice experiment after the introduction of self-driving busses tested in the pilot trial. This would allow detecting any changes in preferences of self-driving busses caused by an increasing degree of familiarity with these kinds of vehicles.

ACKNOWLEDGMENT

The author thanks Ben Kals of the municipality of Vaals, Marco van Riemsdijk of the student apartments Katzensprung, Lex Schellevis of the province of Gelderland and Julia Schmidt from IKEM Berlin for assisting with the distribution of the survey. The research was made possible with the help from the Interreg Interregional Automated Transport (I-AT) project. The work of the first author is funded by the NWO TRAIL Graduate Programme. Part of this work was supported by the CriticalMaaS project (no. 804469) which is financed by a European Research Council and Amsterdam Institute of Advanced Metropolitan Solutions.

REFERENCES

[1] C. J. Haboucha, R. Ishaq, and Y. Shiftan, "User preferences regarding autonomous vehicles," *Transp. Res. Part C Emerg. Technol.*, vol. 78, pp. 37–49, 2017.

[2] D. J. Fagnant and K. Kockelman, "Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations," *Transp. Res. Part A Policy Pract.*, vol. 77, pp. 167–181, Jul. 2015.

[3] R. Krueger, T. H. Rashidi, and J. M. Rose, "Preferences for shared autonomous vehicles," *Transp. Res. Part C Emerg. Technol.*, vol. 69, pp. 343–355, 2016.

[4] S. Nordhoff, B. van Arem, and R. Happee, "Conceptual Model to Explain, Predict, and Improve User Acceptance of Driverless Podlike Vehicles," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2602, pp. 60–67, 2016.

[5] M. D. Yap, G. Correia, and B. van Arem, "Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips," *Transp. Res. Part A Policy Pract.*, vol. 94, pp. 1–16, Dec. 2016.

[6] X. Dong, M. DiScenna, and E. Guerra, "Transit user perceptions of driverless buses," *Transportation*, pp. 1–16, 2017.

[7] F. Becker and K. W. Axhausen, "Literature review on surveys investigating the acceptance of autonomous vehicles," in *TRB 96th Annual Meeting Compendium of Papers*, 2017, pp. 1–12.

[8] C. Gkartzonikas and K. Gkritza, "What have we learned ? A review of stated preference and choice studies on autonomous vehicles," *Transp. Res. Part C*, vol. 98, no. December 2018, pp. 323–337, 2019.

[9] B. Schoettle and M. Sivak, "A Survey of Public Opinion About Autonomous and Self-Driving Vehicles in the U.S., the U.K., and Australia (Report No. UMTRI-2014-21)," 2014.

[10] A. Alessandrini, P. Delle Site, D. Stam, V. Gatta, E. Marcucci, and Q. Zhang, "Using Repeated-Measurement Stated Preference Data to Investigate Users' Attitudes Towards Automated Buses Within Major Facilities," in *Advances in Systems Science*, J. Świątek and J. M. Tomczak, Eds. Cham: Springer International Publishing, 2017, pp. 189–199.

[11] W. Payre, J. Cestac, and P. Delhomme, "Intention to use a fully automated car: Attitudes and a priori acceptability," *Transp. Res. Part F Traffic Psychol. Behav.*, vol. 27, pp. 252–263, Nov. 2014.

[12] J. Piao, M. McDonald, N. Hounsell, M. Graindorge, T. Graindorge, and N. Malhene, "Public Views towards Implementation of Automated Vehicles in Urban Areas," *Transp. Res. Procedia*, vol. 14, pp. 2168–2177, Jan. 2016.

[13] M. Kyriakidis, R. Happee, and J. C. F. de Winter, "Public opinion on automated driving: Results of an international questionnaire among 5000 respondents," *Transp. Res. Part F Traffic Psychol. Behav.*, vol. 32, pp. 127–140, 2015.

[14] F. Nazari, M. Noruzoliaee, and A. Mohammadian, "Shared versus private mobility: Modeling public interest in autonomous vehicles accounting for latent attitudes," *Transp. Res. Part C Emerg. Technol.*, vol. 97, pp. 456–477, Dec. 2018.

[15] T. Liljamo, H. Liimatainen, and M. Pöllänen, "Attitudes and concerns on automated vehicles," *Transp. Res. Part F Traffic Psychol. Behav.*, vol. 59, pp. 24–44, Nov. 2018.

[16] B. Correia, Gonçalo; de Looff, Erwin; van Cranenburgh, Sander; Snelder, Maaike; an Arem, "The impact of vehicle automation on the Value of Travel Time while performing work and leisure activities in a car: theoretical insights and results from a stated preference survey," *Transp. Res. Part A*, vol. 119, pp. 359–382, 2019.

[17] S. Nordhoff, J. De Winter, M. Kyriakidis, B. Van Arem, and R. Happee, "Acceptance of Driverless Vehicles: Results from a Large Cross-National Questionnaire Study," *J. Adv. Transp.*, pp. 1–22, 2018.

[18] I-AT Interreg Automated Transport, "Living Lab WEpod-crossborder," 2019. [Online]. Available: https://www.i-at.nl/Living-Lab-WEPOD-crossborder. [Accessed: 10-Jan-2019].

[19] K. Winter, O. Cats, G. Correia, and B. van Arem, "Performance analysis and fleet requirements of automated demand-responsive transport systems as an urban public transport service," *Int. J. Transp. Sci. Technol.*, vol. 7, no. 2, pp. 151–167, 2018.

[20] ChoiceMetrics, "Ngene1.2 USER MANUAL & REFERENCE GUIDE," Australia, 2018.

[21] R. Madigan, T. Louw, M. Dziennus, T. Graindorge, E. Ortega, M. Graindorge, and N. Merat, "Acceptance of Automated Road Transport Systems (ARTS): An Adaptation of the UTAUT Model," *Transp. Res. Procedia*, vol. 14, pp. 2217–2226, 2016.

[22] Centraal Bureau voor de Statistiek (CBS), "Personenmobiliteit; aandeel van verkeersdeelnemers naar persoonskenmerken," 2018. [Online]. Available: https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83496NED/table?ts=1537792900954. [Accessed: 10-Jan-2019].

[23] Bundesministerium fuer Verkehr und digitale Infrastuktur, "Mobilität in Deutschland," Bonn, 2018.

[24] M. Kouwenhoven, G. C. de Jong, P. Koster, V. A. C. van den Berg, E. T. Verhoef, J. Bates, and P. M. J. Warffemius, "New values of time and reliability in passenger transport in The Netherlands," *Res. Transp. Econ.*, vol. 47, pp. 37–49, Nov. 2014.

[25] M. Ben-Akiva, D. McFadden, and K. Train, "Foundations of Stated Preference Elicitation - Consumer Behavior and Choice-based Conjoint Analysis," 2018.