Preferences toward bus alternatives in rural areas of the netherlands
A stated choice experiment

Bronsvoort, Kristel; Alonso-González, María; Van Oort, Niels; Molin, Eric; Hoogendoorn, Serge

DOI
10.1177/03611981211029919

Publication date
2021

Document Version
Final published version

Published in
Transportation Research Record

TRR
JOURNAL OF THE TRANSPORTATION RESEARCH BOARD

Research Article

Transportation Research Record
2021, Vol. 2675(12) 524–533

DOI: 10.1177/03611981211029919
journals.sagepub.com/home/trr
SAGE

Preferences toward Bus Alternatives in Rural Areas of the Netherlands: A Stated Choice Experiment

Kristel Bronsvoort[1], María Alonso-González[1], Niels Van Oort[1], Eric Molin[2], and Serge Hoogendoorn[1]

Abstract

Public transport in rural areas is under pressure because demand is low and dispersed. To reduce costs, flexible and on-demand services are often proposed as alternatives for conventional bus services. Conventional services are generally not suitable for rural areas, because the demand is low and dispersed. In this paper, a stated preference survey is designed to identify the preferences of rural bus users for alternative services. Other than the traditional bus, two other modes are included in this study: a demand responsive transport (DRT) service and an express bus service with bike-sharing services for last mile transport. Given the on-demand nature of these alternatives, flexibility- and reliability-related attributes are included in the stated preference survey. The results from the choice model indicate that the reliability and flexibility aspects do not have a large effect on the preference for the on-demand alternatives. Instead, cost, access and egress times, and in-vehicle time play a bigger role in individuals' preferences toward the different alternatives. A sensitivity analysis shows that changes in the operational characteristics can make the on-demand alternatives more attractive. However, many bus users still prefer the conventional bus service over the on-demand alternatives.

Public transport in rural areas is under pressure worldwide. In rural areas, transport flows are thin and the demand is dispersed. Consequently, it is difficult for public transport operators to operate a financially viable bus service in these areas (*1*). However, governments often regard public transport accessibility as a basic need for everyone. To provide transport in low-density areas, traditional bus services are often replaced by on-demand transport with flexible routes and schedules (*2*). Although, on multiple occasions, unprofitable bus services in rural areas have been canceled and replaced with on-demand services, not much is known about the preferences of rural bus users for alternative services (*1*, *3*). This research tries to partially fill this gap by investigating the preferences of rural bus users in the Netherlands toward on-demand services.

Recently, several on-demand services have emerged. Examples of individual on-demand services are car-sharing, bike-sharing, car rental, taxis, and ride-sourcing (such as Uber and Lyft). Concerning collective on-demand services, there is demand responsive transport (DRT), which includes shared ride-sourcing and micro-transit (*4*, *5*).

In this paper, the preferences for two on-demand alternatives are investigated: a DRT service and a multimodal alternative that combines an express bus service with bike-sharing for last mile transport. DRT is chosen as an alternative because, similar to private cars, it can offer flexibility and convenience (*6*). Furthermore, DRT has been implemented on several occasions as a substitute to traditional bus lines in areas where the demand is low or dispersed (*3*, *6*). The multimodal alternative with bike-sharing as last mile transportation is chosen because the combination of public transport and bicycles can offer speed and availability: public transport can cover longer distances and bike-sharing provides door-to-door accessibility (*7*).

Several studies exist that investigate DRT as a substitute for fixed lines from an operational standpoint

[1]Department of Transport and Planning, Delft University of Technology, Delft, the Netherlands
[2]Department of Engineering Systems and Services, Delft University of Technology, Delft, the Netherlands

Corresponding Author:
Kristel Bronsvoort, K.A.Bronsvoort@tudelft.nl

(*8–10*). Others have studied preferences toward DRT from a behavioral standpoint using stated choice (SC) experiments (*11–13*). Research on bike-sharing systems concluded that bike-sharing systems can improve the first and last mile part of a bus trip in smaller cities (*14*).

However, to the best of the authors' knowledge, the preferences of rural bus users for DRT and express bus with bike-sharing services for last mile transport have not been thoroughly researched. This research is performed using a stated preference survey targeting rural bus users in the Netherlands. The results from this research can help identify which attributes are important for rural passengers when choosing between traditional bus and different on-demand services. Both operators and public transport authorities can benefit from this knowledge when considering on-demand services as bus replacements for the offered rural services.

This paper is structured as follows: first, the methodology of this research is discussed, which includes a detailed description of the design of the survey; then, the results are presented; finally, the results are discussed and the research conclusions are drawn.

Methodology

To gain insights into the preferences of rural bus users for alternative services, a questionnaire was designed. The questionnaire includes a choice experiment, questions on travel characteristics, six attitudinal statements, and questions on socio-demographic characteristics. The SC experiment is used to collect data on the preferences of bus users in hypothetical choice situations; this makes it possible to include hypothetical alternatives (*15*). To prevent respondents from being afraid their bus line would be canceled, respondents are asked to choose between bus, DRT, and express bus with bike-sharing as last mile transport. This approach also makes it possible to determine the preference for the alternatives relative to the preference for the regular bus.

Design of the choice experiment

Bus users in Dutch rural areas with limited public transportation options were targeted. The following context was presented to the respondents: *"Assume you are making a trip. You are making a trip with the travel purpose < here the most common travel purpose of the respondent is inserted >. The temperature is around 16 degrees Celsius and there is no rainfall. You are not carrying luggage. The starting point of the trip is your home and the endpoint your destination."*

The three available mode alternatives were described as follows:

1. Express bus + bike-sharing: The express bus + bike-sharing trip consists of three parts: walking to the bus stop, traveling with an express bus, and using a shared bicycle for the egress part of the trip. The express bus has a higher speed than the regular bus and stops less frequently. Shared bicycles can be used by everyone, reservation is not possible, and the possibility exists that no bicycle is available at the desired place and time. Shared bicycles are available at bus stops and can be parked at any destination. A bicycle can be rented via a smartphone application.
2. DRT: The DRT trip consists of three parts: walking to the bus stop, in-vehicle travel time and walking to the final destination. DRT is an on-demand transport service that operates with small buses between any combination of bus stops. A seat in a DRT vehicle can be reserved via a smartphone application. During the trip, the vehicle can stop or make a detour to pick up or drop off other passengers. DRT has no fixed schedule and realized travel times and departure times can differ from the scheduled times.
3. Bus: this alternative is similar to existing bus services in rural areas.

The bus is included as a status quo alternative and represents a typical bus trip in a rural area. This alternative has fixed attribute values that remain constant in all choice sets; therefore no parameters can be estimated for the bus alternative other than the alternative specific constant.

Because of the on-demand nature of DRT, attributes other than those that are used for fixed public transport services have to be taken into account. New attributes are related to the reliability and flexibility of DRT, because of their lack of fixed schedules and the booking interval (*12*). Frei at al., Alonso-González et al., and Ryley et al. all include waiting time (specified as the difference between the scheduled and actual starting time) as an attribute (*11–13*). Alonso-González et al. also include the minimum booking time and the probability of the ride being offered at the requested time as attributes of DRT (*12*).

In this experiment, the attributes of minimum booking time, departure delay, and travel time uncertainty are included as attributes for DRT to get a better understanding of the influence that reliability and flexibility attributes have on the mode choice of bus users. The minimum booking time is the number of minutes in advance an individual has to book DRT before the desired departure time. The departure delay is presented to respondents as the difference between the planned and actual departure time of the trip with DRT. The travel time

Table 1. Attribute Levels Used in the Choice Experiment

Attribute	Attribute levels		
	Express bus + bike-sharing	Demand responsive transport (DRT)	Bus
Access (and egress) time (min)	(2, 6, 10)	(2, 4, 6)	(4)
In-vehicle travel time (min)	(22, 27, 32)	(24, 32, 40)	(37)
Egress bike-sharing (min)	(2, 7, 12)	na	na
Costs (€)	(1.50, 3.50, 5.50)	(1.50, 3.50, 5.50)	(3.00)
Headway (min)	(10, 35, 60)	na	(60)
Minimum booking time (min)	na	(10, 35, 60)	na
Bicycle availability (#bicycles)	(1, 6, 11)	na	na
Departure delay (min)	na	(0–3, 0–9, 0–15)	na
Travel time uncertainty (min)	na	(0–2, 0–6, 0–10)	na

Note: na= not applicable.

uncertainty is presented as the difference between planned and actual travel time. To represent the uncertainty of finding a bicycle, the number of bicycles available at the arrival bus stop at the starting time of the trip is included as an attribute for the bus + bike alternative.

The other attributes included in the experiment are: access time, travel time, costs, and headway. Table 1 provides an overview of the attributes and attribute levels used per alternative. The attribute levels are based on existing Dutch transport services. An orthogonal fractional factorial design is used that resulted in 27 choice sets. The experiment is divided into three blocks of nine choice sets. An example of a choice situation presented to the respondents is visible in Figure 1.

Discrete choice modeling

The SC data is analyzed using discrete choice models (DCM). The random utility model (RUM) assumption is used in the model formulation, which assumes that decision-makers select the alternative that gives them the highest utility (*15*). For more information on DCM, the reader is referred to Train (*15*).

Model types. Several models can be used to predict choices. In this study the widely used multinomial logit (MNL) model is estimated to function as a reference for the more advanced models. The MNL model is derived under the assumption that ϵ_{in} is independently and identically distributed (IID) for each alternative, meaning that there are no correlations between error terms over alternatives, and the error terms have the same variance for all alternatives (*15*). The MNL model also assumes that each choice is independent of the other choices. The MNL model holds the independence from irrelevant alternative (IIA) property (*15*). This means that the preferences between any two alternatives are independent of the preference for another alternative in the choice set (*15*). The MNL has some limitations because of its simplicity. It cannot take into account differences in tastes between individuals (taste heterogeneity), correlations between unobserved factors over time for each decision maker (panel effects), and correlations between unobserved factors of alternatives (nesting effects) (*15*).

In this study, it is assumed that the alternatives intuitively have something in common and can be grouped into so-called nests; to test this hypothesis, nested logit (NL) models are estimated to verify the presence of nests. NL can capture correlations between (unobserved) utilities of alternatives within the same nest. For the NL model, the following properties hold, as described by Train (*15*):

1. The preferences between any two alternatives in the same nest are independent of preferences for all other alternatives. The IIA holds within each nest.
2. The preferences between two alternatives in different nests can depend on other alternatives in the two nests. The IIA does not hold for alternatives in different nests.

However, NL models cannot capture taste heterogeneity and panel effects (*15*). Because respondents answered multiple choice sets and taste variations between groups of individuals are expected, more advanced mixed logit (ML) models are also estimated. Like NL models, ML models can capture nests. Furthermore, they can overcome some of the limitations of the MNL model and NL model, by capturing taste heterogeneity and panel effects (*15*). Taste variations between individuals can be captured by varying β across individuals for the attribute parameters or alternative specific constants (*15*). Panel effects are described as the correlations between choices made by the same individual across time. ML can capture panel effects by taking the complete sequence of choices made by an individual as the unit of observation (*15*). The ML model can account for correlations

Characteristics	Express bus + bike-sharing	DRT	Bus
Total planned travel time	39 min.	32 min.	45 min.
Of which:			
- To stop	10 min. walking	4 min. walking	4 min. walking
- In vehicle	22 min.	24 min.	37 min.
- To destination	7 min. cycling	4 min. walking	4 min. walking
Frequency	Every 60 min.		Every 60 min.
Minimum booking time	--	10 min.	--
Number of bicycles available	6	--	--
Departure delay	--	0 to 15 min. delay	--
Travel time uncertainty	--	0 to 6 min. delay	--
Cost	€1.50	€5.50	€3.00

Figure 1. Example of a choice set presented to respondents.
Note: DRT = demand responsive transport.

between error components by adding an additional error term that represents the utility of common unobserved factors (*15*).

Results

Data collection and sample description

It is difficult to target bus users in rural areas because, where flows are thin, few users can be found. Therefore, it was decided to hand out flyers at bus stations where multiple regional lines come together, to reach more respondents. By using this method to target respondents, it is likely that the sample is a realistic reflection of bus passengers (the people who would be found if going into a random bus) in rural areas. Flyers were handed out in November, 2018, on bus stations in the Dutch province Overijssel. Most of the data was gathered this way (71%). Dutch public transport traveler organizations were also contacted to distribute the survey among their members (20% of respondents), and a link to the survey was shared on the social media platform Facebook (9% of respondents were reached this way). A total of 119 respondents filled in the complete survey, of which 112 were considered valid for choice modeling (responses quicker than six minutes time were considered too quick and thus, invalid).

The sample is compared with the population of Dutch bus users (people that have used the bus at least once in the past half year), bus passengers and bus users in the capillaries of the network (*16*) in Table 2. In the sample the share of males is slightly higher than the share of females. In general more females use the bus than males (*16*). Most of the respondents are younger than 30 years (66%). This corresponds with bus passengers being mainly students and commuters (*16*). The large share of students in the sample corresponds with the large share of respondents in the age group 12–29 and vice versa. More than one third of the respondents had a low level of education. A possible explanation for this big share is that a lot of the respondents are still students and have not finished their education and are therefore categorized as having a low level of education.

The sample is representative for Dutch bus passengers in relation to travel purpose. The travel purpose "education" is slightly over-represented in the sample (+ 7%); again, this can be the result of having many students in the sample. The number of respondents with a driving license in the sample is almost equal to that of bus users in the capillaries (+ 4%), and higher than within the population of bus passengers (+ 11%).

For this survey, a specific group, rural bus users, was targeted. Almost 50% of the respondents live in the province Overijssel, and 25% of the respondents live in the province Gelderland; these provinces differ from other provinces because of their lower population density and rural character (*17*). Therefore, although there are significant differences between the sample and the Dutch bus passenger population, the sample is found to be representative for bus passengers in rural areas.

Not all respondents were familiar with or had any experience with on-demand modes. Few respondents had experience with using bike-sharing or DRT: 27% and 4%, respectively. More respondents were familiar with bike-sharing than with DRT: 84% and 42%, respectively. Almost half of the respondents chose all three alternatives presented to them in the choice experiment at least once. Over one-third of respondents always chose between two alternatives. In total, 17% of the respondents always chose the same alternative (15% always chose the bus and 2% always chose bus + bike). There is not enough information to conclude that these respondents were showing non-trading behavior. It is possible that respondents are willing to choose another mode, but that the threshold values for choosing another alternative were outside of the range of attribute levels used in this experiment.

Model estimation

Estimated models. Models are estimated using the PythonBiogeme software package (*18*). The MNL model is used as a base model. To test whether nests are present, NL models are estimated. Different nests are tested, and the nest between the two new modes is found to be significant at the 95% confidence interval. The ML model includes an error component that captures nesting effects between the two new modalities. The ML structure also captures panel effects by capturing the correlations

Table 2. Sample Compared with Bus Users and Bus Passengers

Socio-demographic variable	Category	Sample (%)	Bus passengers*,*** (%)	Regular bus users*,** (%)	Bus users*,** in the capillaries of the network (%)
Gender	Male	54	43	43	43
	Female	46	57	57	57
Age (years)	12–19	26	31	8	14
	20–29	40	36	21	15
	30–39	9	9	15	14
	40–49	6	8	15	13
	50–59	7	8	15	12
	60–69	6	6	14	17
	>70	6	3	12	15
Education level	High[I]	44	25	49	40
	Medium[II]	19	42	34	36
	Low[III]	37	34	17	24
Employment status	Other	3	Primarily students, school children, and commuters	22	31
	Retired	9		18	20
	Employed	34		47	34
	Student	54	NA	13	15
Travel purpose	Education	40	33	Shopping, visiting, and recreation are the most common travel purposes.	
	Commuting	23	24		
	Leisure	23****	NA		
	Shopping	NA	12		
	Visiting	NA	12		
	Other	14	19		
Driving license	Yes	68	57	75	64
	No	32	43	25	36
Experience with bike-sharing	Yes	27	NA	NA	NA
	No	73	NA	NA	NA
Experience with demand responsive transport (DRT)	Yes	4	NA	NA	NA
	No	96	NA	NA	NA
Familiar with the concept of bike-sharing	Yes	84	NA	NA	NA
	No	16	NA	NA	NA
Familiar with the concept of DRT	Yes	42	NA	NA	NA
	No	58	NA	NA	NA

Note: NA = not available.
*Zijlstra et al. (*16*).
**Bus users are described as people who have used the bus at least once in the past half year (*16*).
***Bus passengers are described as people who would be founnd in a random bus on an average day (*16*).
****Combined value for all leisure purposes (shopping, visiting, sports, etc.).
[I]Bachelor's, Master's degree, or higher.
[II]Completed vocational education.
[III]Completed primary or secondary education.

between choices made by the same individual. The ML model is extended with socio-demographic variables.

The model outcomes are displayed in Table 3. The extended ML model has a statistically significant improvement in model fit compared with the normal ML model and, therefore, is the best model.

Model formulation. The bus alternative represents the current mode used by respondents; this is the base alternative. The bus alternative has fixed attribute levels that are equal in every choice set; therefore, no parameters are estimated for the bus alternative and the alternative specific constant (ASC) of the bus is fixed to zero. The utility functions of express bus + bike-sharing, DRT, and bus are provided in Equations 1, 2, and 3.

$$\begin{aligned} V_{\text{bus + bike}} = {} & ASC_{\text{bus + bike}} + \beta_{\text{AT\_bus + bike}} * AT_{\text{bus + bike}} \\ & + \beta_{\text{TTbus\_bus + bike}} * TTBus_{\text{bus + bike}} \\ & + \beta_{\text{TTBike\_bus + bike}} * TTBike_{\text{bus + bike}} \\ & + \beta_{\text{H\_bus + bike}} * H_{\text{bus + bike}} \\ & + \beta_{\text{BA\_bus + bike}} * BA_{\text{bus + bike}} \\ & + \beta_{\text{C\_bus + bike}} * C_{\text{bus + bike}} \\ & + \beta_{\text{License\_bus + bike}} * License \\ & + \beta_{\text{Age}_1\text{-bus + bike}} * Age1 \\ & + \beta_{\text{Age2\_bus + bike}} * Age2 + \sigma_{\text{NewMode}} \end{aligned} \tag{1}$$

Table 3. Estimated Models with Model Scores

Model	# of observations	# of parameters	ρ^2	$\bar{\rho}^2$	Null Log-likelihood	Final Log-likelihood	Likelihood Ratio Test Statistic
Multinomial logit (MNL) base	990	13	0.160	0.149	−1,087.626	−913.086	349.08
Nested logit (NL)	990	14	0.163	0.15	−1,087.626	−910.281	354.691
Mixed logit (ML) error component (EC)	990	14	0.296	0.283	−1,087.626	−765.805	643.643
ML EC extended	990	21	0.315	0.296	−1,087.626	−744.925	685.402

$$\begin{aligned} V_{\mathrm{DRT}} = {} & ASC_{\mathrm{DRT}} + \beta_{\mathrm{AT\text{-}DRT}} * AT_{\mathrm{DRT}} \\ & + \beta_{\mathrm{TT\_DRT}} * TT_{\mathrm{DRT}} \\ & + \beta_{\mathrm{MBT\text{-}DRT}} * MBT_{\mathrm{DRT}} \\ & + \beta_{\mathrm{DD\text{-}DRT}} * DD_{\mathrm{DRT}} \\ & + \beta_{\mathrm{C\_DRT}} * C_{\mathrm{DRT}} \\ & + \beta_{\mathrm{Gender\_DRT}} * Gender \\ & + \beta_{\mathrm{License\_DRT}} * License \\ & + \beta_{\mathrm{Age1\text{-}DRT}} * Age1 \\ & + \beta_{\mathrm{ST4\text{-}DRT}} * ST4 + \sigma_{\mathrm{NewMode}} \end{aligned} \tag{2}$$

$$V_{\mathrm{bus}} = 0 \tag{3}$$

where
$\mathrm{ASC_m}$ = alternative specific constant of alternative m;
β_{AT_m} = parameter for access time of alternative m;
$\beta_{TTbus\_bus + bike}$ = parameter for travel time bus of express bus + bike-sharing;
$\beta_{TTBike\_bus + bike}$ = parameter for travel time with express bus + bike-sharing;
β_{TT_DRT} = parameter for travel time with DRT;
$\beta_{H\_bus + bike}$ = parameter for headway of express bus + bike-sharing;
β_{MBT_DRT} = parameter for minimum booking time of DRT;
$\beta_{BA\_bus + bike}$ = parameter for bicycle availability of express bus + bike-sharing;
β_{DD_DRT} = parameter for departure delay of DRT;
β_{C_m} = parameter for cost of alternative m;
$\beta_{License\_bus + bike}$ = dummy for driving license possession;
β_{Gender_DRT} = dummy for male gender;
β_{Age1_m} = dummy for age 15–29 for alternative m;
$\beta_{Age2\_bus + bike}$ = dummy for age 30–59;
β_{ST4_DRT} = dummy for trust in transport services without fixed schedules;
$\sigma_{NewMode}$ = σ for nests between new modes.

Parameter interpretation. The ML model with error components and socio-demographic variables is chosen as the best model. It has 21 estimated parameters and an adjusted ρ^2 of 0.296. Table 4 displays the estimated parameter values. All parameters are significant at the 95% confidence interval, except for the parameters for headway, bicycle availability, and departure delay.

Contrary to what was expected, the attributes of reliability and flexibility do not have a large influence on the preference for the on-demand alternatives. The parameter for travel time uncertainty was removed because it had a positive sign, whereas a negative sign was expected. The parameter for the departure delay is insignificant, and no statement can be made about the influence of this attribute. The parameter for minimum booking time has a small influence on the utility per minute of change compared with the parameters for travel time and access time. The estimated parameter for in-vehicle travel time of bus is lower than the estimated parameter for the in-vehicle time of DRT, indicating that the time spent in the DRT vehicle is perceived as more negative than time spent in the express bus. A possible explanation for this effect could be that respondents perceive DRT as a service mainly for elderly and limited mobility. The access time of the bus + bike alternative is perceived less negative than the access time of DRT. Possibly, people perceive access time more negative if the speed of the vehicle is lower. The minutes of egress time with the shared bicycle of the bus + bike alternative is perceived as more negative than the minutes of walking on the access side of the trip. Respondents perceive the same amount of minutes less negative when walking than making use of the shared bicycle. The estimated parameters for cost of DRT and express bus + bike-sharing are not statistically different from each other. An increase of one Euro is valued almost equally negative for express bus + bike-sharing as for DRT.

The personal characteristics that have an influence on the preference for the three alternatives are age, gender, and driving license possession. Men have a lower preference toward DRT than women, and men have a higher preference for express bus + bike-sharing and bus than for DRT. The results indicate that young individuals are more attracted to the on-demand alternatives than older individuals. The young individuals have a higher preference for the express bus + bike alternative than for the DRT alternative. A possible explanation for this is that younger people are, in general, more open to trying new

Table 4. Parameter Estimates of Extended Mixed Logit (ML) error compontent (EC) Model

Parameter	Value	Robust standard error	Robust t-test	P-value
ASCbus+bike	2.170	1.050	2.07	0.04
$TTBus_{bus+bike}$	−0.086	0.022	−3.88	0
$TTBike_{bus+bike}$	−0.148	0.021	−7.00	0
$AT_{bus+bike}$	−0.117	0.028	−4.20	0
$C_{bus+bike}$	−0.426	0.067	−6.33	0
$BA_{bus+bike}$	0.053	0.027	1.95	0.05*
$H_{bus+bike}$	−0.008	0.005	−1.56	0.12*
$License_{bus+bike}$	1.320	0.491	2.69	0.01
$Age1_{bus+bike}$	1.920	0.687	2.79	0.01
$Age2_{bus+bike}$	1.350	0.586	2.30	0.02
ASCDRT	4.710	0.948	4.97	0
TT_{DRT}	−0.106	0.018	−5.86	0
AT_{DRT}	−0.174	0.064	−2.70	0.01
C_{DRT}	−0.416	0.081	−5.15	0
MBT_{DRT}	−0.011	0.005	−2.14	0.03
DD_{DRT}	−0.011	0.020	−0.55	0.58*
$License_{DRT}$	1.260	0.456	2.77	0.01
$Age1_{DRT}$	1.130	0.524	2.16	0.03
$ST4_{DRT}$	−0.374	0.125	−3.00	0
$Gender_{DRT}$	−0.846	0.295	−2.87	0
$\sigma_{NewMode}$	2.060	0.208	9.92	0

*Not significant at a 95% confidence interval.

things. Individuals with a driving license prefer DRT and express bus + bike-sharing over the bus. Individuals with a driving license have a higher preference for express bus + bike-sharing and DRT than individuals without a driving license. Having a driving license probably makes them less dependent on the current bus service.

It was not possible to estimate a factor from the attitudinal statements included in the survey. Therefore, although attitudinal indicators should be best included in the model indirectly by means of a latent variable (given that the attitudinal indicators do not directly explain choice behaviour), they are included directly in the model specification (*19*). This makes it possible to better understand if a link between certain attitudes and mode preferences exists. Having a high distrust in transport services without fixed schedules results in a lower preference for DRT. Logically, individuals with a high distrust in transport services without fixed schedules have a lower preference for DRT than for express bus + bike-sharing and bus.

Finally, the sigma for new modes is significantly different from zero. The sigma captures the correlation between DRT and express bus + bike-sharing, meaning that a nest is present that captures what DRT and express bus + bike-sharing intuitively have in common, namely, that both express bus + bike-sharing and DRT are (relatively) new forms of transport for respondents (*15*).

Value of travel time savings. The values of travel time savings (VoTTS) are calculated to gain insight into how respondents value different trip parts. Overall, respondents are willing to pay more for a decrease in access and egress time, than for a decrease in in-vehicle times. The VoTTS for access time of DRT, egress time with shared bicycle, and access time of express bus + bike-sharing are €25.10/hour, €20.85/hour, and €16.48/hour respectively. Respondents are willing to pay more for a decrease of in-vehicle time of DRT (€15.29/hour) than for a decrease in in-vehicle time of express bus + bike-sharing (€12.08/hour). The obtained VoTTS differ from the Dutch VoTTS for bus, tram, and metro, which was estimated at €6.75 (*20*). The differences could be caused by DRT and express bus + bike-sharing being more personalized modes, or because travelers in rural populations are willing to pay more for improved transport services than the average traveler.

Sensitivity analysis

The sensitivity of the estimated choice model for changes in the design attributes of the alternatives was tested by means of Monte Carlo simulation using 1,000 Halton draws. A reference scenario, presented in Table 5, was used to measure the effects of different changes in operational characteristics of the alternatives. The values for the attributes in the reference scenario are based on existing services where possible. In the situation of the reference scenario the modal shares are 31%, 16%, and 53% for express bus + bike-sharing, DRT, and bus, respectively.

The sensitivity of the attributes cost, in-vehicle time, access time, and egress time of DRT and shared bicycle travel time was tested. Changes in the operational

Table 5. Reference Scenario

Reference scenario	Express bus + bike-sharing	Demand responsive transport (DRT)	Bus
Access time (min)	6	4	4
In-vehicle travel time (min)	26	32	37
Egress time (min)	na	4	4
Shared bicycle travel time (min)	6	na	na
Minimum booking time (min)	na	30	na
Headway (min)	30	na	60
Cost (€)	3.50	3.50	3.00
Bicycle availability (# shared bicycles)	6	na	na
Departure delay (min)	na	0–10	na

Note: na = not applicable.

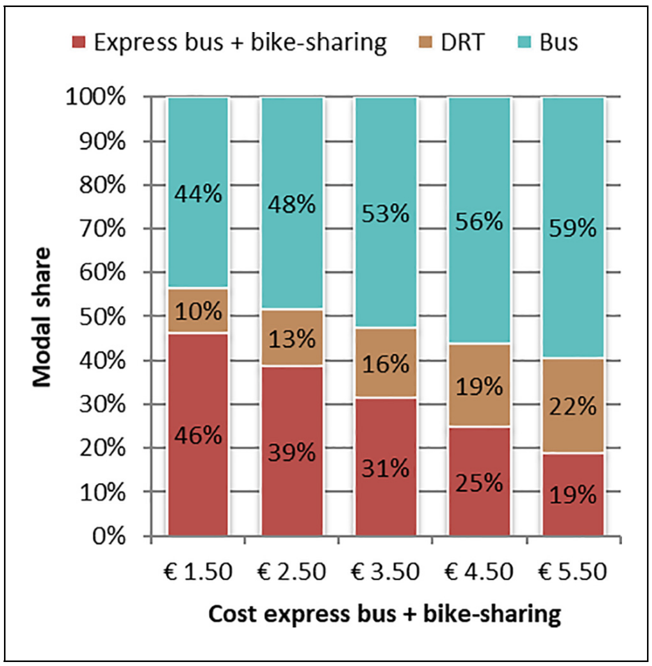

Figure 2. Sensitivity analysis of the cost of the express bus + bike-sharing alternative.
Note: DRT = demand responsive transport.

characteristics travel time with shared bicycle and the cost of express bus + bike-sharing have the largest influence on the modal share of bus + bike and also influence the shift away from the bus.

The sensitivity of the cost of the bus + bike alternative on the modal split is visualized in Figure 2. Varying the cost of the bus + bike alternative has a large effect on the modal split between the three modes; the share of bus increases by 15% and the share of DRT increases from 10% to 22%. The bus + bike alternative and bus alternative have an equal modal share when the costs of bike + bus are €1.65. Varying the cost of the bus + bike alternative has a larger effect on the bus share than on the DRT share. Even if the costs of the bus + bike alternative are high, €5.50, the modal share is still 19%. The conclusion is drawn that individuals are willing to trade comfort, in other words not having to cycle, for a lower fare.

The influence of shared bicycle travel time on modal split is visualized in Figure 3. A lower shared bicycle travel time attracts travelers from bus and DRT toward the bus + bike alternative. Designing the bus + bike alternative network in such a way that the egress time with the shared bicycle is low can attract travelers from bus to the bus + bike alternative. For more information on the experiment, the scenarios and results the reader is referred to Bronsvoort (*21*).

Conclusions and Recommendations

This research investigated the preferences of Dutch rural bus users for alternative services. An SC experiment was used where respondents could choose between three alternatives: DRT, an alternative that combined express bus with bike-sharing, and regular bus. Because of the on-demand character of the alternatives, flexibility- and reliability-related attributes were included in the choice experiment. Contrary to expectations, the attributes of flexibility and reliability did not have a large effect on the preference for the modes, even if both bicycle availability and minimum DRT booking time proved to be significant in the model. Other attributes, namely cost, in-vehicle time, and access and egress time had a larger influence on individuals' preferences toward the offered modes. The costs have an almost equal influence on the preference for DRT as for bus + bike. In-vehicle time of DRT is perceived as more negative by respondents than the in-vehicle time of express bus, possibly because DRT has a negative image and extra travel time is caused by picking up other passengers.

A limitation of using stated preference experiments is that the results are only valid under the constraints presented in the experiment. This study assumed mode choices under good weather conditions and travelers carrying no heavy luggage. Therefore, the results of this study should be interpreted as the upper limit of potential demand. Future research could vary the contextual

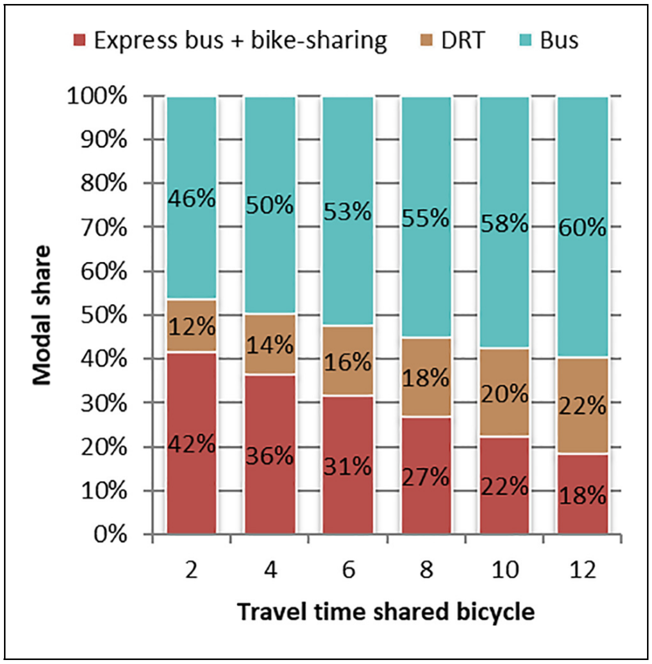

Figure 3. Sensitivity analysis of the travel time with the shared bicycle.
Note: DRT = demand responsive transport.

factors, such as weather, trip distance, and luggage, to investigate to which extend this influences preferences for DRT and express bus and bike-sharing.

The results of this study also provide insights into the preferences of different groups of individuals. Rural bus users that are under 30 are more likely to choose the bus + bike alternative than older bus users: from all age groups, people older than 60 have the lowest preference for bus + bike. Among the group of bus users under 30, the preference for bus + bike is the highest and the preference for bus the lowest. Gender also has an influence on the preference for the alternatives: men have a lower preference for DRT than women. Between the alternatives, men have a higher preference for bus + bike and bus than for DRT. Bus users that have a driving license have a higher preference for the on-demand alternatives than bus users without a driving license. A possible explanation is that having a driving license makes them less dependent on the current bus service and, therefore, less reluctant to use the alternatives.

Public transport operators that want to implement a DRT service or an express bus + bike-sharing service are advised to keep the following findings in mind. When designing the network, operators should carefully consider the number of detours made to pick up additional passengers and the stop distance of the network, as these two factors influence the access time and the in-vehicle time. The modeling results indicate that young individuals are more attracted toward DRT services, so patronage in areas with primarily current older bus users may be less suitable for this change. Similarly, the age group of current bus users should be taken into account if a express bus + bike-sharing alternative is to be implemented instead of the current bus service. The results indicate that public transport operators that want to attract passengers to bus + bike should mainly focus on low cost of the service and low egress time with shared bicycles.

The networks of express bus + bike-sharing services and DRT services can be designed in such a way that the modes are more attractive for bus users. However, in all the scenarios tested in this study, the conventional bus still has the highest modal share. This suggests that, although the design characteristics of DRT and express bus + bike-sharing networks are made more attractive, traditional bus still seems to be the most attractive alternative to a large majority of individuals.

This study focused on rural areas, which are often under researched and differ greatly from urban areas. This study can provide interesting insights for other rural regions that may be considering offering alternatives to traditional public transport. When drawing any comparisons, two aspects should be kept in mind. First, this study over-represents students. This is in line with the Dutch reality, where most bus passengers are students, but it may be different in other countries. Also, the Netherlands has a strong cycling culture. Results for express bus + bike-sharing may therefore be influenced by the popularity of cycling in the Netherlands.

Given that this research focused on the preferences toward the mentioned alternative services, bus parameters were kept constant in the stated preference experiment. Further research could also include varying bus parameters, to estimate switching potential from bus for different bus trip characteristics. Still, the findings in this research could serve as a starting point to understand preferences toward different on-demand services in the often-forgotten rural areas.

Acknowledgments

The authors would like to thank Keolis, Rover, and ROCOV for their help with distributing the survey.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: K. Bronsvoort, N. van Oort, M. Alonso-González, E. Molin, S. Hoogendoorn; data collection: K. Bronsvoort; analysis and interpretation of results: K. Bronsvoort, M. Alonso-González, N. van Oort, S. Molin; draft manuscript preparation: K. Bronsvoort. All authors reviewed the results and approved the final version of the manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Kristel Bronsvoort https://orcid.org/0000-0002-1962-1566
Niels Van Oort https://orcid.org/0000-0002-4519-2013
Serge Hoogendoorn https://orcid.org/0000-0002-1579-1939

Data Accessibility Statement

The authors do not have the respondents' permission to share their data publicly, so supporting data is not available.

References

1. Wang, C., M. Quddus, M. P. Enoch, T. Ryley, and L. Davison. Exploring the Propensity to Travel by Demand Responsive Transport in the Rural Area of Lincolnshire in England. *Case Studies on Transport Policy*, Vol. 3, No. 2, 2015, pp. 129–136. https://doi.org/10.1016/j.cstp.2014.12.006.
2. De Jong, W., J. Vogels, K. van Wijk, and O. Cazemier. The Key Factors for Providing Successful Public Transport in Low-Density Areas in The Netherlands. *Research in Transportation Business & Management*, Vol. 2, 2011, pp. 65–73. https://doi.org/10.1016/j.rtbm.2011.07.002.
3. Mulley, C. and J. D. Nelson. Flexible Transport Services: A New Market Opportunity for Public Transport. *Research in Transportation Economics*, Vol. 25, No. 1, 2009, pp. 39–45. https://doi.org/10.1016/j.retrec.2009.08.008.
4. Alonso-González, M. J., N. van Oort, O. Cats, and S. P. Hoogendoorn. Urban Demand Responsive Transport in the Mobility as a Service Ecosystem: Its Role and Potential Market Share. In *International Conference Series on Competition and Ownership in Land Passenger Transport - 2017 - Stockholm, Sweden - Thredbo 15*. 2017. http://hdl.handle.net/2123/17512
5. Nikitas, A., I. Kougias, E. Alyavina, and E. Njoya Tchouamou. How can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and mobility-as-a-service shape transport futures for the context of smart cities? *Urban Science*, Vol. 1, No. 4, 2017, p. 36.
6. Alonso-González, M. J., T. Liu, O. Cats, N. Van Oort, and S. P. Hoogendoorn. The Potential of Demand-Responsive Transport as a Complement to Public Transport: An Assessment Framework and an Empirical Evaluation. *Transportation Research Record: Journal of the Transportation Research Board*, 2018. 2672(8): 879–889. https://doi.org/10.1177/0361198118790842.
7. Kager, R., L. Bertolini, and M. Te Brömmelstroet. Characterisation of and Reflections on the Synergy of Bicycles and Public Transport. *Transportation Research Part A: Policy and Practice*, Vol. 85, 2016, pp. 208–219. https://doi.org/10.1016/j.tra.2016.01.015.
8. Barrilero, M., A. Sauerländer-Biebl, A. Sohr, and T. Hesse. Development of a Demand Responsive Transport System with Improvement Analysis on Conventional Public Transport: A Case Study for Schorndorf, Germany. *Proc., 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS)*, Naples, Italy. IEEE, 2017, pp. 821–826. https://doi.org/10.1109/MTITS.2017.8005626.
9. Chevrier, R., A. Liefooghe, L. Jourdan, and C. Dhaenens. Solving a Dial-a-Ride Problem with a Hybrid Evolutionary Multi-Objective Approach: Application to Demand Responsive Transport. *Applied Soft Computing*, Vol. 12, No. 4, 2012, pp. 1247–1258.
10. Li, X., and L. Quadrifoglio. Feeder Transit Services: Choosing between Fixed and Demand Responsive Policy. *Transportation Research Part C: Emerging Technologies*, Vol. 18, No. 5, 2010, pp. 770–780.
11. Frei, C., M. Hyland, and H. S. Mahmassani. Flexing Service Schedules: Assessing the Potential for Demand-Adaptive Hybrid Transit via a Stated Preference Approach. *Transportation Research Part C: Emerging Technologies*, Vol. 76, 2017, pp. 71–89. https://doi.org/10.1016/j.trc.2016.12.017.
12. Alonso-González, M. J., N. van Oort, O. Cats, and S. P. Hoogendoorn. Flexibility or Uncertainty? Forecasting Model Shift Towards Demand Responsive Public Transport. *Proc., International Choice Modelling Conference 2017*, Cape Town, South Africa, 2017. http://www.icmconference.org.uk/index.php/icmc/ICMC2017
13. Ryley, T. J., P. A. Stanley, M. P. Enoch, A. M. Zanni, and M. A. Quddus. Investigating the Contribution of Demand Responsive Transport to a Sustainable Local Public Transport System. *Research in Transportation Economics*, Vol. 48, 2014, pp. 364–372. https://doi.org/10.1016/j.retrec.2014.09.064.
14. Martin, E. W., and S. A. Shaheen. Evaluating Public Transit Modal Shift Dynamics in Response to Bikesharing: A Tale of Two US Cities. *Journal of Transport Geography*, Vol. 41, 2014, pp. 315–324.
15. Train, K. E. *Discrete Choice Methods with Simulation*, 2nd ed. Cambridge University Press, Cambridge, 2009.
16. Zijlstra, T., P. Bakker, A. Durand, and H. Wüst. *Busgebruikers door dik en dun [in Dutch]*. Den Haag: Kennisinstituut voor Mobiliteitsbeleid, 2018.
17. Centraal Bureau voor de Statistiek. Regionale Kerncijfers Nederland [Data set, in Dutch], 2019. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/70072NED/table?fromstatweb
18. Bierlaire, M. *PythonBiogeme: A short introduction*. Technical Report TRANSP-OR 160706, series on Biogeme, Transport and Mobility Laboratory, School of Architecture, Civil and Environmental Engineering, Ecole Polytechnique Fédérale de Lausanne, Switzerland, 2016.
19. Daly, A., S. Hess, B. Patruni, D. Potoglou, and C. Rohr. Using Ordered Attitudinal Indicators in a Latent Variable Choice Model: A Study of the Impact of Security on Rail Travel Behaviour. *Transportation*, Vol. 39, No. 2, 2012, pp. 267–297. https://doi.org/10.1007/s11116-011-9351-z.
20. Significance, VU University Amsterdam, John Bates. *Values of Time and Reliability in Passenger and Freight Transport in The Netherlands*. Report for the Ministry of Infrastructure and the Environment. The Hague, 2012.
21. Bronsvoort, K. A. *Exploring Alternative Public Transport in Rural Areas*. Master's thesis. Delft University of Technology, The Netherlands, 2019.