POTENTIAL UPTAKE OF ADAPTIVE TRANSPORT SERVICES: AN EXPLORATION OF SERVICE ATTRIBUTES AND ATTITUDES

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ABSTRACT

This paper describes an examination of people's preferences regarding a wide range of flexible and demand-responsive adaptive transport services in the Netherlands. We used a stated choice experiment, which included a set of attributes, such as access to the service, schedule, window of departure and arrival time, travel costs and travel time. Four mixed logit models were estimated based on a dataset of 3,632 observations (454 respondents). Various service attributes were found to have a significant influence on the potential of alternatives, including fixed stops and a wide time window (valued negatively) and door-to-door transport and unscheduled transport (valued positively). In addition, attitudes towards conventional and modern service types were relevant determinants for the potential uptake of ATS. In particular, having a positive attitude towards public transport was found to increase the likelihood of using stop-based (defined mobility) services. Finally, our results reveal that existing public transport users displayed a greater willingness to use flexible public transport alternatives, whereas car drivers were more inclined to use car- and ride-sharing services.

Key words: adaptive transport services, public transport, choice modeling, travel behavior, stated choice experiments

1. INTRODUCTION

The need for public transport services to tackle problems related to accessibility and mobility is indisputable (Currie, 2010). In the Netherlands, the public transport network has come under pressure over the years, particularly in rural areas. Demographic changes (such as an ageing population), higher fuel costs and the increasing use of cars and e-bikes, particularly in less densely populated areas are making public transport more expensive and increasingly unprofitable, leading to the need for high(er) government subsidies (Dutch Ministry of Transport, 2010). Public transport services in these areas therefore have to be run as efficiently as possible, potentially leading to a cutback in services (KpVV CROW, 2015). Providing efficient and high-quality public transport alternatives at a fair price is a major challenge for the Dutch government, and is often hampered by financial pressures.

According to Brake and Nelson (2007), public transport in an ideal world would be as convenient and flexible as private transport, suggesting that public transport services would be completely demand-responsive and that travellers could use a service whenever desired. Such a level of flexibility or convenience is rarely achieved by conventional public transport services. To tackle the inefficiency and inflexibility of conventional public transport services, new forms of public transport need to be explored (Jain et al., 2017). Already a myriad of adaptive transport services have been developed, in which the demands and needs of the users influence service provision, for example through flexible routing or demand-responsive scheduling (Mageean et al., 2013; Nelson and Phonphitakchai, 2012).

However, Ferreira et al. (2007) concluded from a review of international experiences that the adoption of flexible transport services up to the early 2000s has generally been poor for several reasons, including marketing, cultural and technological issues and a lack of community ownership. A recent ex post evaluation of the unsuccessful Kutsuplus pilot with a flexible public transport service in Helsinki highlighted a lack of understanding among end user target groups, insufficient marketing and financial obstacles as main reasons for the pilot's failure (Weckström et al., 2018).

This paper presents an exploration of factors that influence the potential uptake of adaptive transport services in a low-density rural to medium-density urbanised region in the eastern part of the Netherlands. We use the term adaptive transport services (ATS) instead of demand-responsive transport or flexible transport services, both of which are often used in the literature, to emphasise that not all services necessarily have to be purely demand-responsive or flexible (as we show in this paper).

In our study, we examined service attributes and user attitudes for a wide variety of adaptive transport services, ranging from conventional pre-booked dial-a-ride to new (app-/web-based) ride- and car-sharing services. The novelty of the paper lies in the exploration of full range of service attributes and exploration of attitudes towards ATS, as these factors appear to be critical for the successful development and operation of new transport initiatives. In the existing literature, however, we found very little studies on the effects of attitudinal variables on the uptake of ATS.

The remainder of the paper is structured as follows. Section 2 further introduces the concept of ATS and presents the literature study on service characteristics and service type categorisations. Section 3 describes the research method and the survey development, followed by Section 4, which focuses on the data obtained in the survey. Section 5 presents the model estimation process and results and Section 6 contains our conclusions.

2. ADAPTIVE TRANSPORT SERVICES

Various phrases have been serving as a collective noun for unconventional public transport services. What all these phrases have in common is that they apply to transport service provision in accordance with the demands and needs of the users, for example through flexible routing or demand-responsive scheduling (Mageean et al., 2003; Nelson and Phonphitakchai, 2012). As described in the introduction, conventional public transport services are not always the best solution and often offer limited possibilities for spontaneous travel. By adapting services and make them more demand-responsive and flexible, ATS can possibly tackle the described problems of conventional services (Wang and Winter, 2010). Whether different types of ATS are attractive to potential travellers depends on many variables, including service-, traveller- and trip-related variables and the perceived importance of these attributes by any traveller in a choice situation (Gauthier and Mitchelson, 1981).

In this section, we describe characteristics of services, service types and variables influencing the potential uptake of ATS based on the available literature. For comprehensive overviews of demand-responsive and flexible transport services in urban and rural areas, refer to for example Mageean and Nelson (2003), Ferreira et al. (2007), Velaga et al. (2012), Ryley et al. (2014). (2014), Wright et al. (2014) and Papanikolaou et al. (2017). We used this literature review to identify variables to be included in the stated choice experiment (Section 3).

2.1. Service characteristics

Services can be adapted in many ways to achieve a certain level of flexibility or demand-responsiveness. To achieve this, many choices have to be made on various service aspects or attributes, because the flexibility or demand-responsiveness of service can vary significantly as a result of the design of the service, including the composition of service aspects (Ambrosino et al., 2004). The alternatives for the service aspects or service characteristics can vary along a continuum of demand-responsiveness; see Round and Cervero (1996), Ambrosino et al. (2004) and Enoch et al. (2004). Various researchers have attempted to define service attributes and quality criteria that influence the attractiveness, perceived performance and quality of ATS; see for example Paquette et al. (2007), Pagano and McKnight (1983), Knutsson (1999), TCRP (2013) and CROW (2016). From these studies, five service-related variables can be identified:

- Access: level of access to the vehicle and/or stops, and provision of door-to-door transport
- Schedule: fixed departure or arrival time or schedules (partly) based on the preferences of the end-user
- Departure and arrival time window: significant time windows for the desired or expected departure and arrival times or fixed times with limited margins
- Travel costs: the total trip cost compared to other modes, such as the car and willingness of end-users to pay for extra services, such as door-to-door transport.
- Travel time: the total travel time from trip origin to the destination, compared to other modes of transport.

2.2 A categorisation of service types

To explore the influence of service attributes and service aspects on the potential of ATS types, we needed a categorisation based on service aspects. This categorisation was used to define attributes in the stated choice experiment (Section 3). A categorisation based on all aspects and alternatives would, theoretically, result in a very large number of service types. Kisla et al. (2016), Mageean and Nelson (2003) and Westerlund et al. (2000) present categorisations based on service aspects such as *route type, scheduling type, booking type* *(*with two levels as yes or not) and *origin-destination service*. These categorisations focus on conventional forms of transport (bus, taxi, intermediate services between bus and taxi) and do not explicitly consider new (app-/web-based) car- and ride-sharing services in which the roles of passengers and driver are not fixed. In this paper, the categorisation is based on the service aspects that profoundly influence a service's operational flexibility and which are at the core of the operational design process.

Table 1 contains the aspects and criteria considered for the categorisation. For each criterion, a brief explanation is presented in the rightmost column of the table. A letter (A, B, C or D) is assigned to each criterion as well. These letters are used in Table 2 to refer to each criterion.

Table 1. Service aspects and alternatives used for the categorisation of ATS

Aspect	Alternative/ Categorisation criterion	Explanation
Route	A. Fixed-route	Stops are served in pre-defined order. Stops can be skipped, but order and trajectory are fixed.
	B. Semi-flexible	Stops are served in pre-defined order, but vehicle could deviate from route when a stop is skipped.
	C. Flexible route	Vehicles of service can go wherever they are requested, regardless of pre-defined stops.
Scheduling	A. Fixed-schedule	Service has scheduled arrivals at given locations.
	B. Semi-flexible	Service need to be booked in advance. Both fixed and flexible time schedule possible.
	C. Unscheduled	Service does not operate with any scheduled arrival times.
Booking	A. Reservation not required	On-board booking is sufficient.
	B. Reservation required	Service has to be booked in advance.
Origin-destination service	A. Fixed stops	Fixed locations where travellers get into and out of the vehicle.
	B. Stops flexible along route	Travellers can get on and off along the route, as well as at fixed stops.
	C. Stops flexible in an area	Service vehicle deviates from its route to desired location.
	D. Door-to-door	Service vehicle goes wherever it is requested. There is no route to deviate from.
Approach	A. Conventional	Designated vehicles and drivers. Clear division of roles between drivers and travellers.
	B. Sharing	No designated vehicles or drivers. Everyone can provide service.

We included regular bus services and private cars in this matrix to emphasise that ATS fall between private cars and conventional public bus services (Bakker, 1999). The lower the transport mode in Table 1, the greater its flexibility, as indicated by the arrow on the left. The defined service types are the following seven:

- **Dial-a-ride:** Similar to a regular bus service, but service only calls at the fixed checkpoints when the service is requested beforehand.
- **Stopflex:** Stopflex services can have both fixed stops and flexible stops along the pre-defined route (instead of only fixed stops). Because it is not required to book the service, service vehicles will not deviate from the pre-defined route.
- **Routeflex:** Routeflex services depart at fixed departure times, serve pre-defined stops in a pre-defined order and follow a pre-determined route. Depending on the demand, it is possible to deviate from the route. Therefore, routeflex services operate with fixed stops and flexible stops in the service area (including door-to-door).

- **Stop hopper:** Stop hopper services transport passengers between fixed checkpoints. There are no pre-defined routes, and services only operate when they are requested. Based on the total demand and the requested departure and arrival times of all passengers, routes are determined and driven.
- **Collective taxi:** Services provide door-to-door transport upon request, like regular taxis. Main difference is that the trips are shared with other users, possibly leading to a longer travel times and greater deviations of departure and arrival times (larger windows).
- **Ride-sharing:** These services make it possible for end users to arrange the sharing of car trips, so that more people travel in the same car. With ride-sharing services, a customer can be a passenger one moment, and a driver or service provider the next.
- **Car-sharing:** These services offer cars that can be rented for short periods. Car-sharing services (also called car clubs) allow travellers to find a nearby car via an app or website and allow travellers to pick up and drop off the cars at any available public parking space within the service area.

Table 2. Categorisation matrix

		Service aspects and alternatives used as categorisation criteria													
		Route			Scheduling			OD-service				Booking		Approach	
Flexibility	**Service types**	A.	B.*	C.	A.	B.*	C.	A.	B.	C.	D.	A.	B.	A.	B.
Not flexible	Regular bus	X			X			X				X		X	
↓	Dial-a-ride	X			X			X					X	X	
	Stopflex	X			X			X	X			X		X	
	Routeflex		X			X		X		X	X	X		X	
	Stop hopper			X		X		X					X	X	
	Collective taxi			X		X	X				X		X	X	
	Ride-sharing			X		X			X	X	X		X		X
Flexible	Car-sharing			X			X				X		X		X
	Private car			X			X				X	X			X

****Semi-flexible routing and scheduling can also mean that consultation or compromises are needed***
The alternatives A, B, C and D for each aspect refer to the alternative as explained in the text. See also Table 1.

Table 1 contains the aspects and criteria considered for the categorisation. For each criterion, a brief explanation is presented in the rightmost column of the table. A letter (A, B, C or D) is assigned to each criterion as well. These letters are used in Table 2 to refer to each criterion.

2.3. *Trip and user characteristics*

Various researchers have found that a variety of trip and user characteristics co-determine travel behaviour. Jain et al. (2017) reviewed a large number of papers and studies to identify the impact of socio-economic variables and trip characteristics on travel behaviour and end user preferences that influence the use of ATS. For example, age and gender – e.g. under or over retirement age – have significant effects on the use of demand-responsive or adaptive transport systems (Wang et al., 2015). Weckström et al. (2018) highlighted several differences by income group in the reasons for using, discontinuing or not using the Kutsuplus demand-responsive transport service, which operated in Helsinki from 2012 to 2015. In addition, land use variables also influence the uptake of ATS. For example, Lee et al. (2015) examined the willingness of ridesharing commuters to use ridesharing services, based on socio-economic and attitudinal parameters of travel and land use, and concluded that having a rural workplace correlated with more ridesharing and a greater willingness to use ridesharing services.

Finally, numerous studies have found that travel mode choice is affected by travel-related attitudes. Anable (2005), for example, showed that having a positive attitude towards the environment discourages car use. There is also an effect of attitude towards a travel mode on mode choice (see e.g., Heinen et al. (2011); La Paix Puello and Geurs (2015); Olde Kalter and Geurs (2016); Molin et al. (2016)). De Vos (2018) concluded that attitudes towards a certain mode are significantly more positive for respondents using that mode. However, about half of the respondents in his sample, mostly public transport users, were not using their preferred travel mode. In the literature, there is very little information on the attitudinal variables and the uptake of ATS. A recent stated choice experiment on Mobility-as-a-Service (MaaS) in Sydney did, however, highlight that infrequent car users are the most likely adopters of MaaS offerings, and car non-users the least likely ones (Ho et al., 2018).

To explore the influence of service attributes and service aspects on the potential uptake of ATS, we developed a categorisation of ATS, ranging from dial-a-ride to ride- and car-sharing services, based on service aspects that are missing in existing categorisations. In addition, the potential uptake of ATS depends on traveller- and trip-related variables, spatial characteristics and attitudinal variables. The role of attitudes towards travel modes is understudied and so we included it in our empirical analysis.

3. SURVEY AND CHOICE EXPERIMENT

The data collection consisted of an online survey, which contained questions about socioeconomic characteristics, attitudes, revealed preference, as well as a stated choice experiment. As the focus was on transport services that were mostly new to the respondents, the revealed preference (RP) scope was limited. Choice experiments are useful to obtain information about preferences of respondents that cannot be obtained by looking at the RP part (Kjaer, 2005). In a stated choice (SC) experiment, which uses hypothetical choice alternatives, the respondents do not have to be current end users of existing ATS.

In the RP survey, we queried the respondents about the travel time, travel costs, travel distance, travel purpose, etc. of their most recent trip. The SC experiment was made up of eight choice cards. The respondents were asked to choose one alternative out of two or more alternatives in multiple different hypothetical choice situations. The values for the service attributes (levels) of the alternatives were different for each choice situation.

Table 3 shows the attribute levels we used to compose each alternative. As can be seen, unrealistic combinations, such as an alternative offering door-to-door transport with a fixed schedule, did not occur. To make the choice situation more realistic, the travel time and travel costs attributes were based on the reported (RP) trip time and costs. This is called pivot design, which introduces realism in the choice context (Ortúzar and Willumsen, 2011). The state of the art of behavioural science aspects of transport research has moved to promoting designs that are pivoted around the knowledge base of travellers (Hensher and Rose, 2007). Applications include Train and Wilson (2008) and (Hensher and Rose, 2007). In the present study, these pivot levels were based on the statistical distribution of the values and introduced enough variation in the sampled (RP) values. Similar implementations of pivot design have shown that the levels applied to a choice task differ depending on the range of attribute levels as well as on the number of levels for each attribute (Hensher, 2004).

The RP values of travel time were pivoted by +/-15% and +/-30%. For the travel costs, we estimated a base level for the alternatives according to the travel distance and public transport fare in the Netherlands. In addition, by using the pivots of +/-20% and +/-40%, we introduced significant travel cost differences between the alternatives within a choice set. Fig. 1 shows an example of a choice card.

Table 3. Adaptive Transport Service types and their attribute levels used in the discrete choice experiment

Alternatives	Stopflex (SF)	Collective taxi (CT)	Ride-sharing (RS)[1]	Car-sharing (CS)
Attributes	Fixed stops Along the route	Door-to-door	Along the route Door-to-door	Door-to-door
Schedule	Fixed schedule Demand responsive	Demand-responsive Unscheduled	Demand-responsive Unscheduled	Unscheduled
Departure and arrival time window	Large time window Small time window No time window	Large time window Small time window No time window	Large time window Small time window No time window	No time window
Travel time	R + 30% R + 15% R +/- 0% R - 15% R - 30%	R + 30% R + 15% R +/- 0% R - 15% R - 30%	R + 30% R + 15% R +/- 0% R - 15% R - 30%	R + 30% R + 15% R +/- 0% R - 15% R - 30%
Travel costs	BF + 40% BF + 20% BF + /- 0% BF - 20% BF - 40%	BF + 40% BF + 20% BF +/- 0% BF - 20% BF - 40%	BF + 40% BF + 20% BF +/- 0% BF - 20% BF - 40%	BF + 40% BF + 20% BF +/- 0% BF - 20% BF - 40%

For the sake of simplicity and because of time constraints, we chose to include a limited number of alternatives per choice situation; the SC experiment consisted of no more than eight choice situations for each respondent. To reduce complexity of the choice cards, we included four alternatives in the choice set, namely three service types which were defined earlier (collective taxi, ride-sharing and car-sharing) and one service type (called stopflex) which consists of the remaining service types. In addition, a no-choice alternative was included to allow respondents to indicate that they would not make the trip by any of the three alternatives or that they would prefer a different transport alternative.

Respondents were asked to indicate the level of agreement (varying from strongly disagree, disagree, neutral, agree and strongly disagree) with nine statements (*attitudinal questionnaire*). These statements tested their attitude towards service types and service characteristics. Examples of the statements we used are the following:

- *"Availability of public transport is important, regardless of the costs for transport company or government."*
- *"Having to book a transport service is negative, because it comes at the expense of the possibility to travel spontaneously."*
- *"I perceive sharing a service as negative, because it comes at the expense of the travel*

[1] *The people who share a ride or a car usually do not know each other.*

time.”

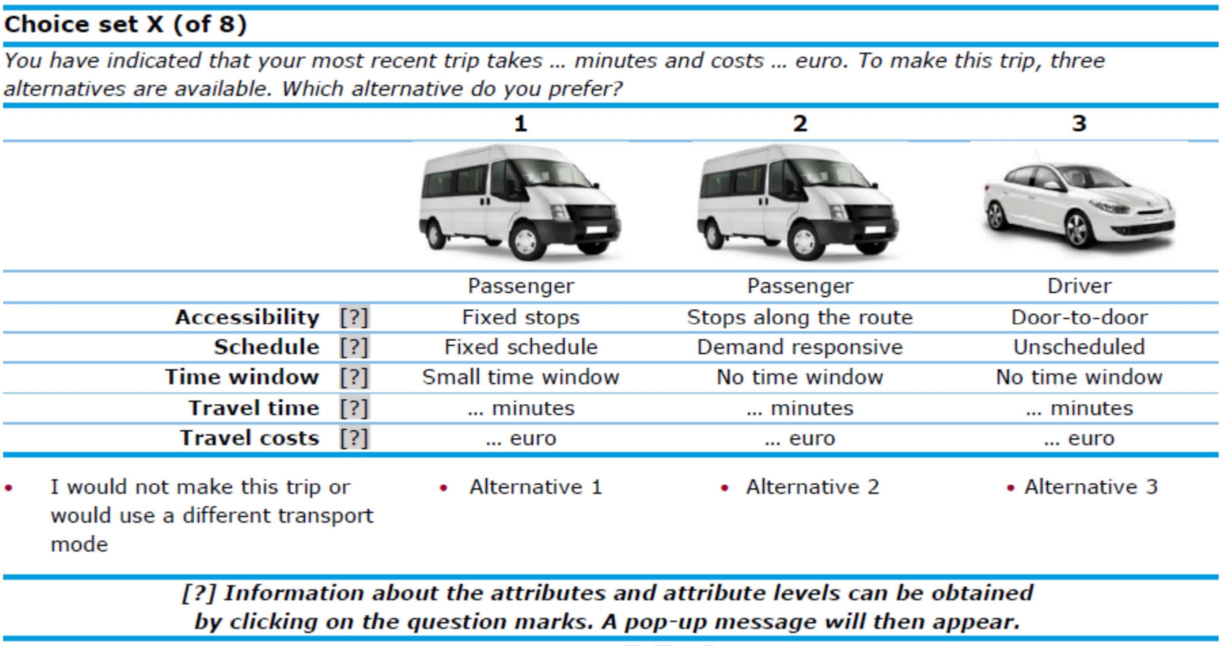

Fig. 1. Example of a choice card in the stated choice experiment

4. CASE STUDY AREA, DATA AND STATISTICS

The case study area is the Province of Overijssel in the Netherlands. Overijssel is located in the central-eastern region of the country, and has over one million inhabitants. More than half of the population lives in low-density and rural areas, and approximately one third of the population lives in three medium-sized cities (Enschede, Zwolle and Deventer, with each more than 100 thousand inhabitants). It is one of the provinces in the Netherlands struggling with providing efficient and high-quality public transport alternatives.

Several ATS services operate in the study area (as well as elsewhere in the Netherlands). The country has a long tradition with community-based public transport in rural areas. There are almost 200 dial-a-ride and neighbourhood bus associations across the Netherlands in which public transport operators and local citizens collaborate in providing mini-bus transport services on fixed routes and timetables. Also, municipalities in the Netherlands have legal responsibilities for providing transport for individuals with disabilities and/or specific needs, and special taxi services (*Regiotaxi*) operate across the Netherlands (de Jong et al, 2011). An overview of ATS services available in the Netherlands can be found in te Morsche (2017).

We used a mixed-mode method to recruit respondents. The largest share of the respondents came from an access panel comprising about 1,900 residents in the Province of Overijssel. In total, 443 members of this panel completed the survey. Secondly, public transport operator *Keolis Netherlands* displayed a message or call to action on the screens in its buses in the Twente part of the Province of Overijssel to recruit additional public transport users and put up posters in buses that had no screens. On several days, travellers were actively encouraged to participate in the survey. Thirdly, to recruit an additional number of older respondents, respondent were recruited at the main hospital in the largest city in the province, Enschede. Flyers were handed to potential respondents on three different days and at two different locations. The distribution of the survey took place over three weeks.

In total 567 respondents completed the online survey; we used the results for 454 respondents in our analysis. Unrealistic observations for the revealed data (e.g. extreme values of distance, costs and travel time) were excluded (20 respondents). Furthermore, 113 respondents were excluded because they chose the no-option for all choice situations. These respondents apparently found the transport alternatives not realistic or attractive at all or were unable to make a decision.

Table 4 shows the sample segments that can be distinguished based on traveller- and trip-related variables and the distribution of the choices made by the respondents in these segments[2]. Our sample is compared with data from the Dutch National Travel Survey (OViN) for the years 2012, 2013 and 2014 of Statistics Netherlands (2017). For most variables, the composition of the OViN data of the Province of Overijssel is shown. Column 4 shows the ratio that indicates the difference between the sample and the OViN data. The sample characteristics correspond fairly well with those of the OViN data, for most of the variables. Our sample does overrepresent older and unemployed/retired people and underrepresents multiple-person households with children. To address these problems with the representativeness of the sample, we estimated the models with weighting factors for each respondent[3].

Table 4. Descriptive statistics on sample and choice behaviour

		Sample composition (n=454)		OViN	Ratio	No-choosers (n=93)	Choice behaviour				
Variables	**Segments**	**Freq.**	**%**	**%**		**%**	**SF**	**CT**	**RS**	**CS**	**NO**
Gender	Male	256	56%	53%	0.94	54%	18%	23%	30%	55%	23%
	Female	198	44%	47%	1.08	46%	21%	30%	30%	59%	15%
Age	Under 25	52	11%	11%	0.96	17%	26%	27%	27%	46%	15%
	25-44	73	16%	32%	1.99	43%	20%	24%	26%	62%	22%
	45-64	170	37%	39%	1.04	17%	19%	26%	29%	57%	21%
	65 and older	159	35%	19%	0.54	22%	16%	26%	34%	57%	18%
Cars in household	0 cars	55	12%	7%	0.58	5%	25%	36%	29%	43%	11%
	1 car	288	63%	52%	0.82	56%	18%	24%	31%	58%	19%
	2 or more cars	111	24%	41%	1.68	38%	18%	27%	27%	59%	23%
Driving licence	Yes	414	91%	90%	0.99	5%	18%	25%	30%	59%	20%
	No	40	9%	10%	1.14	95%	27%	35%	29%	36%	11%
Household structure	One-person household	89	20%	11%	0.56	21%	20%	26%	29%	57%	18%
	Multiple-person, no children	234	52%	25%	0.49	54%	17%	27%	32%	56%	19%
	Multiple-person, children	119	26%	58%	2.21	23%	21%	23%	26%	60%	21%
	Other	12	3%	6%	2.27	1%	28%	30%	35%	33%	6%
Position in labour market	Working full-time	139	31%	28%	0.91	33%	19%	25%	27%	62%	21%
	Working part-time	80	18%	16%	0.91	17%	21%	27%	28%	57%	18%
	Student	44	10%	19%	1.96	3%	27%	28%	26%	42%	16%
	Unemployed/retired	173	38%	19%	0.5	44%	16%	26%	34%	56%	19%

[2] The income variable in the survey was optional, which resulted in a high percentage of incomplete responses.
[3] It is important to note that weights do not affect the estimated parameters but the aggregated probabilities.

	Other	18	4%	14%	3.53	3%	18%	19%	33%	56%	21%
Income	Unknown	102	22%			16%	20%	27%	29%	60%	17%
	Less than €1900	81	18%			14%	19%	26%	30%	49%	22%
	€1900 - €2700	119	26%			31%	19%	26%	27%	55%	23%
	€2700 - €5400	86	19%			26%	18%	27%	32%	59%	18%
	€5400 or more	66	15%			14%	20%	23%	34%	58%	15%
Urbanisation	Unknown	17	4%			3%	19%	21%	39%	50%	13%
	Very strongly urban	5	1%			0%	29%	27%	17%	60%	18%
	Strongly urban	187	41%	38%	0.92	39%	19%	27%	30%	54%	19%
	Moderate urban	90	20%	16%	0.81	16%	19%	23%	30%	58%	20%
	Little urban	99	22%	34%	1.56	28%	18%	25%	28%	62%	21%
	Not urban	56	12%	11%	0.89	14%	21%	29%	30%	55%	16%
Vehicle used	Car	306	67%			80%	16%	25%	31%	60%	21%
	Public Transport	142	31%			20%	24%	27%	28%	50%	16%
	Other	6	1%			0%	24%	50%	28%	50%	6%
Trip purpose	Work/business	149	33%	19%	0.58	24%	20%	26%	26%	61%	20%
	Social/recreational	198	44%	52%	1.19	49%	18%	27%	31%	55%	18%
	Education	31	7%	12%	1.76	3%	26%	24%	24%	44%	21%
	Doctor's appointment	32	7%	3%	0.43	7%	16%	21%	35%	64%	19%
	Other	44	10%	14%	1.44	16%	14%	25%	36%	53%	20%
Trip frequency	4 or more days a week	106	23%			27%	20%	25%	26%	61%	21%
	1 to 3 days a week	145	32%			26%	19%	26%	31%	58%	19%
	1 to 3 days a month	91	20%			17%	19%	25%	29%	53%	22%
	6 to 11 days a year	55	12%			14%	20%	24%	36%	54%	14%
	5 or less days a year	57	13%			17%	16%	31%	31%	54%	20%

Percentages for choices indicate how often alternative was chosen when the alternative was available
SF = Stopflex; CT = Collective taxi; RS = Ride-sharing; CS = Car-sharing; NO = No-option

The characteristics of the group of no-choosers differ from the other respondents'. For all choice situations, these respondents would choose to use an alternative that was not included; this is the so-called no-option (Louviere et al., 2000). As Table 4 shows, having a driving licence and owning a car was important for the no-choosers. This may indicate that that no-choosers preferred to use their own car instead of another (public) transport mode. In the remainder of this paper, the group of no-choosers is not taken into account.

Table 4 also indicates that the respondents seemed to prefer flexible alternatives. The same can be concluded based on the alternatives that the respondents selected in the choice situations. The alternatives stopflex and collective taxi were chosen by 19.0% and 26.1%, respectively, whereas the alternatives ride sharing and car-sharing were chosen by 30.0% and 56.6% of the respondents, respectively.

The most striking differences can be observed in the variables *driving licence*, *gender*, *vehicle used* and *number of cars in household*. For example, car-sharing and the no-option were far less attractive to respondents without driving licence. This makes sense as travellers would need a driving licence to be able to use car-sharing. Not having a driving licence therefore can be expected to have a negative influence on the utility of car-sharing. The descriptive statistics of the sample show that people using public transport tended to choose the alternatives car-sharing and-/or ride-sharing. People already using a car for their trips chose ride-sharing, car-sharing and the no-option more often than people who were using public transport.

4.1 Factor analysis

We used the outcomes of the attitudinal questionnaire to conduct a factor analysis, because it is likely that that the respondents responded similarly to the various statements. Therefore, multiple observed variables have similar patterns of response because they are all associated with a latent or unobserved variable (Rahn, 2017). In this study, variables that were not directly measured (so-called covering components) could represent a general attitude. We found three covering components through the factor analysis:

1. *Perception of public transport in general*,

2. *Attitude towards conventional public transport*, and

3. *Perception of modern ATS services* (such as car-sharing and ride-sharing).

Based on the attitudinal questions in the survey, the correlation between each statement and the corresponding factor, we calculated scores for each respondent and component. These factor scores indicate the attitude of a respondent towards one of the components and were used in the model estimation process. We tested how attitudes influence the potential uptake of an ATS. Table 5 shows the results of the factor analysis; the rotated method was varimax. Communalities show the extent to which a variable explains behavior. Factor scores explain the level of contribution of one variable to each factor. The number of factors and variables were selected based on the communalities, factor scores and percentage of variance explained.

Table 5. Factor scores from factor analysis

	Component		
Variable	**Attitude towards sharing transport**	**Attitude towards conventional transport services**	**Attitude towards public transport in general**
S1 Availability of public transport is important, regardless of the costs for transport company or government ***(attitude towards availability)***	-0.065	0.114	**0.779**
S2 Having to book a transport service is negative, because it comes at the expense of the possibility to travel spontaneously ***(perception of booking)***	-0.103	**0.680**	0.167
S3 I perceive sharing a service as negative, because it comes at the expense of the travel time ***(statement on travel time)***	-0.172	**0.802**	-0.082
S4 I perceive sharing a service as negative because it comes at the expense of my privacy ***(statement on privacy)***	-0.150	**0.759**	-0.077
S5 I like to use public transport services because the driver can offer me assistance when I need it ***(need for assistance)***	0.110	-0.095	**0.743**
S6 A shared car or car-sharing service would be an attractive alternative to make the trip I described ***(attitude towards car-sharing*)**	**0.582**	-0.189	0.206
S7 A ride-sharing service would be an attractive alternative to make the trip I described ***(attitude towards ride-sharing)***	**0.833**	-0.086	-0.040
S9 I think that sharing a ride, as is the case with ride-sharing services, is safe ***(attitude towards safety of ride-sharing)***	**0.793**	-0.146	-0.049
S8 I like to share my own trips and would therefore like to share my own ride with a ride-sharing service ***(attitude towards sharing own ride)***	**0.772**	-0.120	0.002

5. MODEL ESTIMATION

The estimated choice model contains six alternatives: Stopflex (2), collective taxi (1), ride sharing (1), ride sharing (2)[4], car-sharing and no-choice. Three of the six alternatives, plus the no-choice, were shown in the experiment.

5.1. Analytical framework

According to Khan (2007), when confronted with alternative travel modes, consumers will make decisions "on the basis of the terms upon which the different travel modes are offered, i.e. the travel times, costs and other service attributes of the competing alternative traveling modes" and an individual will select the mode which maximises his or her *utility*. The utility of a certain transport mode for an individual is a measure for the attractiveness or potential uptake of the mode for a specific trip. For each mode, the utility can be formed from the weighted sum of the service attributes of the alternative (Train, 2002), as expressed by Eq. 1:

$$U_{mi} = \beta_1 x_{mi1} + \beta_1 x_{mi2} + \ldots + \beta_k x_{mik} \qquad \textbf{\textit{Eq. 1}}$$

U_{mi}	is the utility for mode *m* for individual *i;*
$x_{mi1}, \ldots, x_{mik}$	are *k* numbers of level-of-service attributes for mode *m* for individual *i*; and
$\beta_1, \ldots, \beta_k$	are *k* numbers of coefficients (or relative importance of each level-of-service attribute). The sign (+ or -) indicates whether the attribute contributes positive or negative to the mode's alternative.

The probability that individual *i* will choose alternative *m* can be calculated by comparing the utility of alternative *m* with the total utility of all available alternatives (N). This is shown in Eq. 2.

$$P_{mi} = \frac{e^{U_{mi}}}{\sum e^{U_{Ni}}} \qquad \textbf{\textit{Eq. 2}}$$

The models estimate the likelihood of observing the choices made by respondents and a higher value for the likelihood indicates a better model estimation (Louviere et al., 2000). This is called the *maximum likelihood estimation.* The likelihood ratio test measures how the model with the estimated values for the betas performs relative to the model, in which all betas are equal to zero.

An advantage of using a mixed logit (ML) model in analysing choice experiments is that it includes panel effects (repeated choices of the same respondent) and considers the correlation across respondents. ML models are the integrals of standard probabilities over a density of parameters (Train, 2002):

[4] *There are two different types of ride-sharing based on the attribute combinations (RS 1 and RS 2. Since the experiment did not use labels, we referred to alternatives 1, 2 and 3, and did not offer the respondents a choice set with two ride sharing (RS) options, but only used this distinction in the modelling work).*

$$P_{mi}= \int L_{mi}(\beta)f(\beta)d\beta \qquad \textit{Eq. 3}$$

$f(\beta)$ is a density function; and
$L_{mi}(\beta)$ is the logit probability evaluated at parameters β:

$$L_{mi}(\beta)= \frac{e^{V_{mi}(\beta)}}{\sum e^{V_{Ni}(\beta)}} \qquad \textit{Eq. 4}$$

$V_{mi}(\beta)$ is a portion of the utility that depends on parameter β.

When the utility is linear with β, $V_{mi}(\beta) = \beta' x_{mi}$, the mixed logit probability becomes:

$$P_{mi}= \int \frac{e^{\beta' x_{mi}}}{\sum e^{\beta' x_{Ni}}} f(\beta)d\beta \qquad \textit{Eq. 5}$$

As there is no closed form for the integral in Eq. 5, simulation is needed to estimate the parameters. According to Train (2002), 125 to 250 draws are desirable. To account for panel effects, we added error components to the utility functions in Biogeme.

Access to the service, schedule and *time window* are categorical rather than continuous, hence dummy coding was used for these three attributes. As a result, each attribute level is seen as an individual variable with its own parameter in the utility function of an alternative. Furthermore, it is desirable that the sample composition matches the composition of the population of the Province of Overijssel and the trips made in the province (according to the OViN data). To achieve this, we chose to assign a weighting factor to each of the respondents. The OViN data served as the reference population and looked at socioeconomic and travel-related variables. We selected three variables with relatively high ratios in Table 4 to determine the weighting factor. For each respondent, the factor was calculated on the basis of the product of the ratios for age, household structure and trip purpose. The weighting factor compensates for the over- and underrepresentation of population segments in the sample, while the estimated parameters are not affected. The models were estimated using the BIOGEME extended package (Bierlaire and Fetiarison, 2009)

5.2. Model results

We estimated several models by using all the information obtained so far. For each alternative in the models, an alternative-specific constant (ASC) was included. These constants indicate preferences of respondents that cannot be observed with the included parameters and attributes. The importance of the parameters is systematically tested at the 90% significance level. Four different models were estimated:

1. Generic model with the same betas for each attribute level;
2. Alternative-specific model with different betas for the attribute level per alternative;
3. Alternative-specific model with traveller- and trip-related variables; and
4. Alternative-specific model with traveller- and trip-related variables and travellers' attitudes.

The difference between the generic and alternative-specific models is based on the potential differences in valuation of travel time for different alternatives. The alternative-specific parameters for the attribute levels of access, schedule and time window were not found to be significant. We therefore used generic parameters for these attributes. The difference between

Models 3 and 4 is that they estimate the separate influence of attitudinal variables. Table 6 displays the results of the four models. The analysis of the results mainly focuses on the most comprehensive models (Models 3 and 4).

Table 6: Model results (continues on next page)

	Model 1		Model 2		Model 3		Model 4	
Variable	**Value**	**T-test**	**Value**	**T-test**	**Value**	**T-test**	**Value**	**T-test**
ASC SF[5]	0.00	Fixed	0.00	Fixed	0.00	Fixed	0.00	Fixed
ASC CT	-0.47	-5.26	-0.61	-4.77	-0.55	-2.28	-0.38	-1.76
ASC RS	-0.53	**-5.43**	-0.54	-4.56	0.05	0.25	-0.08	-0.42
ASC CS	1.22	**9.69**	1.49	**7.94**	0.89	**2.95**	0.93	**3.33**
ASC NO	-2.68	**-11.20**	-2.59	**-10.56**	-3.28	**-8.15**	-3.06	**-8.05**
Fixed stops	-1.23	**-15.50**	-1.23	**-15.46**	-1.22	**-15.42**	-1.21	**-15.37**
Stops along the route	0.00	Fixed	0.00	Fixed	0.00	Fixed	0.00	Fixed
Door-to-door	0.41	**5.16**	0.47	**5.79**	0.46	**5.64**	0.45	**5.62**
Fixed schedule/Demand responsive	0.00	Fixed	0.00	Fixed	0.00	Fixed	0.00	Fixed
Unscheduled	0.20	**3.35**	0.23	**3.81**	0.23	**3.72**	0.22	**3.63**
No time window/Small time window	0.00	Fixed	0.00	Fixed	0.00	Fixed	0.00	Fixed
Wide-time window	-0.11	**-2.32**	-0.09	-1.81	-0.10	**-1.96**	-0.10	-2.02
Travel time generic	-0.01	**-4.54**						
Travel time SF (/minute)			0.00	-1.80	0.00	**-2.14**	-0.01	**-2.70**
Travel time CT (/minute)			0.00	0.21	0.00	0.56	0.00	0.24
Travel time RS (/minute)			-0.01	**-5.72**	-0.01	**-5.36**	-0.01	**-5.28**
Travel time CS (/minute)			-0.01	**-2.11**	-0.01	-1.85	-0.01	-1.84
Travel costs generic	-0.02	**-5.13**						
Travel costs SF (/euro)			-0.04	**-5.41**	-0.03	**-4.31**	-0.03	**-4.40**
Travel costs CT (/euro)			-0.05	**-4.16**	-0.05	**-4.41**	-0.05	**-4.22**
Travel costs RS (/euro)			-0.01	-1.22	-0.01	-1.8	-0.01	-1.88
Travel costs CS (/euro)			-0.04	-1.92	-0.03	-1.89	-0.03	-1.57
Being 25-44 years old (CS)					0.76	**3.02**	0.66	**2.71**
No cars in household (CT)					0.44	1.83		
No driving licence (SF)					0.42	**2.26**		
No driving licence (CT)					0.48	**2.42**	0.35	1.78
No driving licence (CS)					-0.82	**-2.39**	-0.88	**-2.66**
No driving licence (NO)					-0.91	-1.83	-1.17	**-2.40**
Being student (SF)					0.45	2.52		
Being unemployed/retired (RS)					-0.32	-1.91		
Being male (RS)					0.22	**2.17**	1.34	4.03
Being male (NO)					1.45	**4.33**		
Multiple-person household without children (SF)					-0.54	**-2.31**		
Multiple-person household without children (RS)					-0.38	-1.83		
Multiple-person household with children (SF)					-0.81	**-3.57**	-0.80	**-3.47**
Multiple-person household with children (CT)					-1.11	**-4.74**	-0.95	**-4.18**
Multiple-person household with children (RS)					-0.90	**-3.64**	-0.95	**-4.72**
Location slightly urban (CS)					0.62	**2.33**	0.56	**2.16**

[5] Note: Bold values show significance at 95% confidence level.

SF = Stopflex; CT = Collective taxi; RS = Ridesharing; CS = Car-sharing; NO = No-option

	Model 1		Model 2		Model 3		Model 4	
Variable	**Value**	**T-test**	**Value**	**T-test**	**Value**	**T-test**	**Value**	**T-test**
Location not urban (SF)					1.46	**2.96**	1.44	**2.91**
Location not urban (CT)					1.70	**3.40**	1.70	**3.35**
Location not urban (RS)					1.36	**2.79**	1.40	**2.85**
Location not urban (CS)					1.96	**3.21**	1.98	**3.31**
Work/business trip (SF)					0.67	**4.62**	0.52	**3.83**
Work/business trip (CT)					0.50	**3.26**	0.40	**2.68**
Public transport used (SF)					0.26	1.73	0.34	**2.30**
Attitude towards PT in general (SF)							0.45	**4.52**
Attitude towards PT in general (CT)							0.44	**4.17**
Attitude towards PT in general (RS)							0.41	**4.26**
Attitude towards conventional services (SF)							0.27	**4.60**
Attitude towards conventional services (CT)							0.19	**2.95**
Attitude towards conventional services (CS)							-0.24	**2.22**
Attitude towards shared services (RS)							0.23	**4.96**

Goodness of fit	**Model 1**	**Model 2**	**Model 3**	**Model 4**
LL (0)	-5359	-5359	-5359	-5359
LL (β)	-4344	-4331	-4258	-4222
Sample size	3632	3632	3632	3632
*LL ratio test= -2 * (LL (β) - LL (0))*	2031	2056	2202	2273

In general, the ASC of car-sharing indicates a positive base preference for car-sharing (relative to the stopflex alternative). The relatively large ASC of car-sharing (compared with the other ASCs) is likely caused by the fact that car-sharing has fixed attribute levels for *access to the service*, *schedule* and *time window*. Since these attribute levels are fixed, the ASC represents the explanatory power. This leaves only the attributes travel time and travel costs to explain why respondents chose car-sharing. The ASCs of the other alternatives indicate that these alternatives were disfavoured relative to the stopflex alternative. For the no-option, the relatively large value of ASC is probably caused by the absence of service attributes in the utility function of the alternative. Another interesting observation is that the absolute values of the ASCs in Models 3 and 4 are lower than in Models 1 and 2. This means that individuals' behaviour is more accurately captured by including traveller-related variables and the attitudes of respondents.

Most other parameters in the models confirm that attribute levels making alternatives more flexible and demand-responsive have a positive influence on the attractiveness of alternatives. For example, unscheduled transport – providing the possibility to travel whenever you want – is perceived positively. While, a large time window – possibly hindering the possibility to travel spontaneously – is perceived negatively. However, not all attribute levels are found to have a significant influence. Regarding travel time and travel costs, it can be seen that not all parameters are significant, but in general, the values are as expected, - *with the correct sign according to the literature and previous works*. The longer the travel time or the more expensive a trip, the less attractive it becomes.

As can also be seen in Table 6, various traveller- and trip-related variables have a significant influence on the potential uptake of ATS types as well. The first thing that stands out is the considerable importance of the location of the trip's origin and destination. For all alternatives (except the no-option, which is used as reference), a rural location has a positive influence on the attractiveness of the alternatives, consistent with what Davison et al. (2014) found.

By contrast, lack of driving licence has a negative influence on the attractiveness of car-sharing and the no-option, but has a positive influence on the choice for collective taxi. These results are consistent over the four models. In addition, travellers currently using public transport were more likely to choose stopflex. This can be associated with the direct competition between car and demand-responsive services (Ryley et al., 2014) and the importance of existing travel patterns in choosing an ATS (Diana, 2010). Furthermore, male respondents were more likely to choose the no-option. We can link this to previous findings that men travel less frequently by demand-responsive transport than women, if they are below pension age (Wang et al., 2015). Model 3 reveals that being a student is positively correlated with the stopflex alternative, which may imply a preference for traditional bus services as the stopflex alternative resembles regular bus services most closely.

Living in a multiple-person household (with or without children) has a negative influence on one or more alternatives. The *attitudes* of potential travellers are also very important for the potential of ATS. All factors (from the factor analysis) related to people's attitudes towards both modern and conventional services were statistically significant. A positive attitude towards public transport increases the likelihood of using both fixed and flexible stop-based services (e.g. stopflex and ride-sharing). In stop-based services, travellers can get on and off along a route, which is different from a door-to-door service. Having a negative attitude towards conventional public transport influences the use of door-to-door services (e.g. car-sharing and ride-sharing). This result is consistent with the work of Lee et al. (2015), who found that attitudes related to privacy, proximity and driving preferences are relevant for the choice of sharing or not sharing a ride. Furthermore, the model substantially improved after we added the attitudinal factors (see the goodness of fit measures at the bottom of Table 6).

5.3. Application of the results

Table 7 shows the probabilities by different segments, based on the significance level obtained from Model 4. There is a clear influence of traveller-related variables on the average probabilities (market shares) . For example, for people without driving licence, the predicted probability of travel mode choice is considerably different from that of people who did have a driving licence. There are also differences in probabilities according to the vehicle used by the respondents. Public transport users are more willing to use the stop-flex service, and less willing to opt for car-sharing than car users. Habits manifest strongly in these choices. Moreover, these segmented probabilities show the potential market shares according to different target groups.

Table 7: Average predicted probability of travel mode choice for sample segments

		Predicted probability of travel mode choice				
Variables	**Segments**	**SF**	**CT**	**RS**	**CS**	**NO**
Gender	Female	0.189	0.135	0.127	0.448	0.1
	Male	0.152	0.12	0.116	0.425	0.187
Age	Younger than 25	0.233	0.168	0.113	0.376	0.11
	25-44	0.15	0.104	0.087	0.526	0.133
	45-64	0.168	0.122	0.118	0.444	0.148
	65 and older	0.156	0.128	0.142	0.404	0.17

Driving licence	No	0.239	0.242	0.142	0.295	0.082
	Yes	0.161	0.115	0.119	0.449	0.155
Household structure	One-person household	0.192	0.154	0.132	0.399	0.123
	Multiple-person, without children	0.167	0.132	0.135	0.41	0.157
	Multiple-person, with children	0.144	0.089	0.084	0.523	0.159
Location	Very strongly urban	0.168	0.118	0.089	0.476	0.149
	Strongly urban	0.178	0.128	0.132	0.39	0.172
	Moderately urban	0.176	0.128	0.126	0.417	0.153
	Slightly urban	0.141	0.103	0.1	0.514	0.142
	Not urban	0.168	0.158	0.107	0.488	0.08
Vehicle used	Car	0.144	0.108	0.126	0.461	0.162
	Public Transport	0.219	0.163	0.109	0.385	0.124
Trip purpose	Work/business	0.192	0.128	0.098	0.452	0.131
	Social/recreational	0.153	0.126	0.133	0.42	0.167
	Education	0.209	0.146	0.106	0.414	0.126
	Doctor's appointment	0.149	0.111	0.133	0.463	0.142

6. CONCLUSIONS AND DISCUSSION

In summary, this paper reports on a review of the concept of ATS, and on how we used survey results including a stated choice experiment to examine the factors influencing the attractiveness and potential uptake of these services. The literature study showed us that a proper categorisation of ATS was still lacking. We extended existing categorisations based on the service aspects and added a distinction between services based on conventional public transport approaches (e.g. pre-booked dial-a-ride approaches) and new shared mobility services.

From the empirical work, it is possible to draw several conclusions. Firstly, various service attributes and variables related to the traveller have a significant influence on the potential uptake of alternatives. For example, fixed stops and large time windows negatively influence potential uptake, whereas door-to-door transport and unscheduled-less transport positively affect potential uptake. Traveller-related variables such as having a driving licence and the level of urbanisation of the location of the trip are the most significant variables for ATS mode choice. In addition, both the attitude towards public transport in general and attitudes towards conventional and modern service types appear to be relevant for ATS mode choice.

Furthermore, our work shows that several service types should be considered when looking to implement ATS. Car-sharing appears to have a high potential uptake across almost all segments of travellers; an exception is the segment of travellers who have no driving licence. With regard to existing public transport services, it could be desirable to convert regular, inflexible bus services into more flexible services by allowing travellers to get on and off the bus wherever they want along the route. Our results show that introducing flexible stops along the route might increase the attractiveness of such a service considerably. Other interventions that make services more flexible, such as minimising the time window for the departure or arrival times, would also have a positive effect. The outcomes of the study are highly useful for (particularly Dutch) public transport authorities and public transport operators as they can use them as input for an exploration of alternatives. Obviously, the potential demand should be balanced against operational costs, which can be particularly challenging in rural areas.

The Province of Overijssel has already used results of our study in the development of a demand-responsive micro transit service (*TwentsFlex*, a combination of dial-a-ride with flexible routes), introduced in the case study area in July 2018.

We can see several directions for future research. Firstly, the choice experiment in this study only considered one overall time attribute and cost attribute, which simplified the results considerably. An important expansion for future research is to design more complex and still easy to understand choice experiments to examine the potential uptake of ATS including a range of attributes for time (e.g. waiting, access/egress) and cost (e.g. fare, subscription fees). Abrantes and Wardman (2011) for example found, in a meta-analysis for the UK, that waiting time and walking time are experienced as 1.7 and 1.65 times the in-vehicle time, respectively. Ho et al. (2018) designed choice experiments reflecting pay-as-you-go and possible MaaS subscriptions, including several cost attributes such as public transport fares, credits and discounts for taxi and Uber services. They found preferences to vary systematically across different types of car user and socio-demographic groups.

Secondly, the choice experiments from our study could be repeated at specific locations where regular public transport is to be reduced or abolished, while taking location-specific variables into account. This would make it possible to include more realistic assumptions for the values of travel time and travel costs per alternative when simulating the predicted probability of travel mode choice. Another option is to examine the role of ATS as access and egress services to public transport stops, specifically in low-urban-density areas. ATS can encourage multimodality and extend the catchment area of public transport stops. In both cases, a more elaborated stated choice experiment could be conducted.

Finally, examining the interaction of ATS with emerging transport services (UberPool, UberPool Express, Lyft etc.) and the integration of ATS in MaaS platforms, in which multiple transport options are made available on a single platform, could also be an interesting avenue.

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- Public transport users were found more likely to use flexible public transport alternatives.
- Car users were found to be more inclined to use car and ride-sharing services.
- Making transport services more flexible may increase their attractiveness considerably.
- Fixed stops and large time windows negatively influence potential acceptance.
- Door-to-door transport and non-scheduled transport positively affect potential uptake.