Predicting the use of automated vehicles. [First results from the pilot survey]

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Abstract

The immediate advantages of the introduction of fully automated vehicles (AVs) can already be foreseen today: Travelling in AVs is likely to be more comfortable than in current vehicles and the safety on the roads will be improved by removing the possibility of human error. Furthermore, a driver's license will not be a requirement anymore for affordable and quick door-to-door transportation services. This Stated-Choice survey aims to answer the questions for which types of trips and purposes people will use automated vehicles and how they will adjust their mobility tools such as public transport travelcards and the number of cars the household owns. Next to the currently available modes car, bike, and traditional public transport, respondents have the opportunity to choose among different services of automated vehicles. The attribute levels are pivoted around the real values of the respondents' regular trips in order to increase the realism of the choice tasks. Using additional attitudinal questions, hybrid choice models will be used to explain the traveler's anticipated behavior.

1 Introduction

In order to assess which role automated vehicles will play in the future transport system, it is crucial to continuously investigate whether the public can imagine to fully trust the technology and for which purposes travelers will use them. The survey presented in this paper is supposed to provide answers to these questions for the canton of Zurich. It includes pivot design mode choice experiments, the choice of portfolios of mobility tools once automated vehicles are available, and questions based on attitudinal constructs that are linked to automated vehicles.

Within this work, it is only referred to vehicles of SAE automation levels four and five (SAE International, 2014). This means that the vehicle is capable of performing empty rides and that the passengers are not required to take over the steering. It is furthermore distinguished between private automated vehicles, shared automated vehicles (SAVs), and pooled automated vehicles (PAVs). Private automated vehicles are shared among the household members, while the latter two cases are on-demand services on non-fixed routes. While the service of SAVs is in general similar to a current taxi, PAVs pick up other passengers during the trip, which lowers the price yet may cause detours.

The methods and results of other studies investigating the acceptance of autonomous vehicles are summarized by Becker and Axhausen (2016). Due to the novelty of the field the approaches are heterogeneous and few studies have focused on exactly the same issues as the survey described below. By listing and comparing the results regarding different response and explanatory variables, for example the general intention to use autonomous vehicles, the willingness to pay for them, or the effects of sociodemographic variables, common findings were extracted from the literature however. Automated vehicles are most popular among men, young people, and people who live in urban environments. Furthermore, people who currently own a vehicle with advanced driver assistance systems have a positive attitude towards their introduction. The technology would also preferably be used in monotonous driving situations.

Krueger et al. (2016) conducted a pivot design mode choice experiment, with the alternatives currently chosen mode, SAV, and PAV. The new automated alternatives were chosen in about 28% of the choice situations. In the Austin sample of Bansal et al. (2016) 41% of the respondents would use an SAV once a week at a price of 1 USD per mile. Zmud et al. (2016) conducted an general online survey and subsequently invited respondents that were open towards the innovation to interviews, in order to investigate travel behavior changes. In this sample, 23% of the respondents would reduce the number of vehicles in the household.

The scenario of the survey is depicted in Section 2, while the survey itself is described in Section 3. Section 4 deals with the recruitment strategy including the response behavior in

the Pre-Test. Section 5 shows the first results of the Pre-Test, while Section 6 provides the conclusion and the changes considered for the main study.

2 Scenario description

Specific attention was paid to create coherent scenarios that take into account the interests and projections of the current market players in the field of automated vehicles.

In line with the opinion of Trent Victor, the senior technical leader of crash avoidance at Volvo, it is assumed that SAE level three vehicles will play a minor role, since it is difficult to expect distracted passengers to take over in a dangerous situation (SAE International, 2014; Golson, 2016). As mentioned previously, the concept of shared and pooled automated vehicles further benefits considerably if the vehicles are allowed to perform empty rides. For these reasons, the scenarios only cover vehicles with SAE automation levels four and five. In the introduction to AVs in the survey, it is furthermore mentioned that AVs will only become available once they have proven that they are substantially safer than human drivers. In addition, respondents are told that they will not be responsible for any crashes the vehicle is involved in. Since the respondents of the sample of Kyriakidis et al. (2015) were mostly concerned about hacking, it is stated that its probability is considered low for the assumed vehicles and that the vehicles can operate independently from central servers.

Furthermore, it is crucial to define whether respondents are given the ability to buy and use private automated vehicles or request AVs on demand (or both). In addition, it is considered important to take temporal dependencies into account. If travelers are already used to requesting SAVs or PAVs, the market potential for privately owned AVs could be smaller compared to a simultaneous introduction (and vice versa). Given that fewer vehicles will be needed to meet the transport demand within fleet solutions, it is interesting to note that car manufacturers like BMW Group (2016) and Ford (Ross, 2016) are planning to introduce fleets of shared AVs prior to selling AVs to private customers. The plans of Google point towards the same direction (Urmson, 2016). For this reason, two main scenarios are distinguished:

- Scenario 1: Fleets of shared and pooled AVs are available. Mass transit services are the same as today.
- Scenario 2: Scenario 1 has been present for three years, private customers can now buy automated vehicles.

Of course, it can be expected that mass transit operators will adjust their service and operations

after AVs have been introduced. However, talks with Swiss transit operators lead to the conclusion that substantial changes like the automation of currently existing lines are currently not considered even for the distant future.

In order to account for people that tend to adopt new technologies only once they have shown to be safe over a certain time frame, the two scenarios above each contain two sub-scenarios in the survey: Adoption two weeks after market introduction and one year afterwards. The respondents are furthermore informed that they can request SAVs and PAVs via a smartphone app and via their telephone. The payments are handled electronically.

3 Survey description

The survey is separated in three stages. The first stage deals with the respondents' sociodemographics, their mobility tools, as well as two regular itineraries. Furthermore the respondents are asked how they would change their mobility tool ownership given scenario one (SAVs and PAVs are available). In the second stage, respondents fill out a mode choice questionnaire, which encompasses currently available modes as well as the alternatives SAV, PAV and an SAV feeder service for trains. The attribute levels are based on the two regular itineraries. The availability of the modes is based on the information provided in stage one. Subsequently, the respondents are asked to fill out items with attitudinal statements. The last part of stage two consists of the adjusted mobility tool ownership portfolio given that private automated vehicles as well as SAVs and PAVs are available. In the third stage of the survey, respondents are again asked to choose among modes in different scenarios.

3.1 First stage

The questions regarding the sociodemographics include age, income, sex, household size and type, educational background, employment situation, and the income. The levels and categories are based on the Swiss Mikrocensus (Bundesamt für Statistik (BFS) and Bundesamt für Raumentwicklung (ARE), 2010). As mentioned previously, the respondents are also asked about the mobility tools of the household. In addition to the number and type of cars in the household, the survey includes questions regarding the public transport season tickets of all household members. The parking situation at home is elicited too. For the two regular itineraries, the starting and end locations and times, as well as the frequency are asked. In addition, respondents provide information on the parking availability and the number of people that join for the itinerary. The latter is elicited because the costs for public transport refer to ticket prices

for one person while the marginal costs for cars and SAVs are zero up to a certain number of people. The current mode choice is further distinguished by the weather forecast.

The next section of the first stage consists of the introduction of the concept of automated vehicles. The description includes the aspects mentioned in section 2. Furthermore, a link and a QR-code to a video of the Mercedes F015[1] are provided. The video was chosen, because it shows an AV in motion and an interior design that has made use of the benefits of AVs.

Finally, respondents are asked the same questions about mobility tool ownership in the household given that SAVs and PAVs are available. The price levels are varied among respondents: SAV - 35,55,75 Rappen per vehicle kilometer, PAV - 20,30,40 Rappen per passenger kilometer. The base levels 55 Rappen for SAV and 30 Rappen for PAV are based on an extensive cost analysis which was carried out previously by the authors and colleagues (Bösch et al., 2017). The analysis tries to cover the full set of transit operators' types of expenses, uses current cost estimates of the technology, and includes occupancy rates of simulations of fleets of automated vehicles, such as (OECD - International Transport Forum, 2015).

3.2 Second stage

The second stage of the survey starts with the introduction to AVs and continues with the mode choice experiment. The possible alternatives are: Current public transport, walk, bike, current car, shared AVs, and pooled AVs. If the current public transport connection involves a train, train with an SAV feeder is added to the list of alternatives. The alternatives car and bike are dependent on the current mobility tools of the respondents.

The attributes in the experiment are: Total travel time, travel time in main mode, travel time in feeder, waiting time, access and egress time, number of transfers, headway, and variable costs. The base level of the attributes refer to the current travel times and prices. Travel times are extracted from the Google Maps API [2]. The levels are 66%, 100%, and 133% of the base level. The travel time for SAVs corresponds to car travel times. The base level of PAVs is 30% above. The ticket prices for public transport were extracted manually from the SBB website [3]. Public transport season tickets are taken into account for the ticket price calculations of public transport. If the respondent has annual season ticket, the price stays 0. The variable costs per car kilometer correspond the calculations of the Swiss touring club TCS Touring Club Schweiz (2009) and amount to 26.18 Rappen per kilometer. Parking costs are added if provided in the previous stage.

[1] https://www.youtube.com/watch?v=P781CuUoQUA
[2] https://developers.google.com/maps/?hl=de
[3] https://www.sbb.ch/

The waiting times of 3.5 minutes for SAVs and 4 minutes for PAVs are based on the calculations of the OECD - International Transport Forum (2015). The order of the alternatives changes among respondents. The latter are required to choose exactly one mode.

In addition, the choice situations include scenario variables. As indicated previously, it is distinguished between two different adoption stages: The fleet is introduced two weeks and one year ago. Furthermore the weather has levels sunny and 20°C as well as rainy and 5°C. The available mobility tools change after the eighth choice situation to the anticipated portfolio in the era of a fleet of autonomous vehicles. Furthermore, respondents are asked to choose modes for the two itineraries provided.

An exemplary choice situation is depicted in Fig. 1. The scenario variables are located on the top of the page. The respondents are furthermore informed which alternatives are automated and which alternative they choose most frequently.

The following section in the survey consists of items of different attitudinal constructs, which are assumed to influence the acceptance and frequency of use of autonomous vehicles. While the Car Technology Acceptance Model of Osswald et al. (2012) captures the opinion towards the technology in general, the Driving Related Sensation Seeking Scale of Delhomme and France (2002) takes into account whether the respondent regards driving a car as enjoyable rather than as a burden. In addition, the lifestyle typology of Otte (2005), in which respondents are classified along the dimensions modernity and financial capability is supposed to provide further insights regarding the link of general attitudes to the acceptance of AVs. Finally, the respondents are asked about their trust in strangers according to the scale of Gächter et al. (2004), which is assumed to partly explain a possible negative mindset towards pooled autonomous vehicle services.

At the end of stage two, the respondents are asked to update their portfolio of mobility tools once private autonomous vehicles are available.

The third stage only consists of mode choice experiments, which include private automated vehicles.

4 Recruitment and response behavior

It is the goal of the survey to investigate the effects of automated vehicles both in cities, agglomerations, and on the countryside. Since the survey is paper-based and public transport subscriptions vary among cantons in Switzerland, the target population are inhabitants of the

Figure 1: Exemplary mode choice situation

Flotte eingeführt	Wetter	Mobilitätswerkzeuge	Angegebener Weg
Vor zwei Wochen	**20°C**	Auto, Halbtax	Arbeitsweg

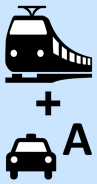
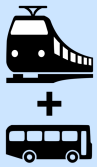
	Autonom		Autonom	Autonom	Bisher gewählt
					
Hauptverkehrsmittel	**Zug**	**Zug**	**Pooled-Service**	**Taxi-Service**	**Derzeitiges Auto**
Zubringer	Autonomer Taxi-Service	Bus / Tram			
Gesamtreisezeit	**00:56 h**	**00:52 h**	**00:34 h**	**00:40 h**	**00:45 h**
davon Fahrzeit in Hauptverkehrsmittel	00:30 h	00:18 h	00:30 h	00:35 h	
davon Fahrzeit in Zubringer	00:25 h	00:16 h			
davon Gesamtwartezeit	00:01 h	00:04 h	00:04 h	00:05 h	
davon Zugangs- und Abgangszeit		00:14 h			
Anzahl Umsteigen	**1**	**1**			
Takt	**00:18 h**	**00:18 h**			
Variable Kosten	**8 CHF**	**7 CHF**	**12 CHF**	**20 CHF**	**18 CHF**
Ihre Auswahl	☐	☐	☐	☐	☐

Table 1: Sample characteristics

	Pre-Test	MZ Zurich 2010
Average age	60	43
Average monthly household income	10800 CHF	7729 CHF
Average number of cars per household	1.43	1.05
Share of respondents with a local season ticket	28.33%	20.18%
Share of respondents with a national season ticket	6.66%	10.44%

canton of Zurich. Addresses including landline numbers were bought from the Schober Schweiz AG [4]. People were first notified by mail that they will be contacted by phone in the upcoming days. In total 256 landline numbers, out of which 37 were invalid, were called since the target sample size for the Pre-Test was reached earlier than anticipated. 194 people could be reached with a maximum number of contact attempts of three. Out of these 194 people, 80 people agreed to participate (41.24%). The incentive levels in the Pre-Test were randomly assigned and amount to 20, 35, and 50 CHF. In total, 62 respondents returned the first stage with the intention to proceed with the study. The sample size of the main study will be calculated based on the asymptotic variance covariance matrix of the Pre-Test (de Bekker-Grob et al., 2015).

The sample characteristics are depicted in table Table 1 and are contrasted to the weighted characteristics of the Swiss Microcensus (Bundesamt für Statistik (BFS) and Bundesamt für Raumentwicklung (ARE), 2010). It is observed, that the average age is substantially higher than in the population. Similar problems can be noted for the monthly household income as well as the number of cars per household, which are likely to be linked to the higher age. It is obvious that the recruiting strategy needs to be adjusted for the main survey. Remedies are explained in section Section 6.

5 First results

Given that only feedback from stage one of the Pre-Test is available, the results section is limited. If fleets of AVs in the form of SAVs and PAVs are available, six out of 62 respondents declared that they would buy a new local season ticket. It was pointed out that the prices of SAVs and PAVs are not affected by the ownership of season tickets. In five of these cases, they declared that the number of cars in the household would decrease simultaneously. In case of the national public transport season ticket, one of four people would decide not to buy it again while three

[4] http://www.schober.ch/

Table 2: Car ownership with and without fleets of automated vehicles

		Number of households		
Price SAV per vehicle kilometer	Price PAV per passenger kilometer	In the sample	With cars	With less cars if SAV/PAV available
35 Rp.	20 Rp.	18	15	7
55 Rp.	30 Rp.	20	18	8
75 Rp.	40 Rp.	22	20	10

respondents would buy a new one. For the latter case, two of the respondents would decrease the number of cars. As can be inferred from Table 2, 25 out of 53 households that own cars would decrease the number of cars in the household. The table also suggests that the respondents did not primarily make this decision based on the price levels of automated vehicles. The car ownership rate per household drops from 1.47 to 0.95 in the sample. The current ownership rate of 1.47 is not equal to the number in Table 1, as respondents that did not provide information on the future number of vehicles were excluded (2).

Based on the itineraries and the anticipated mobility tools it was also possible to evaluate in how many cases SAVs as well as PAVs would be dominant in terms of variable costs and travel times compared to the currently chosen alternative. While the SAV ist only dominant in eight out of 91 trips (3 compared to car, 5 compared to mass transit), the PAV is dominant in 20 trips (8 compared to car, 12 compared to mass transit). The modal split in the sample is: Bike 6, car 58, mass transit 24, walk 3.

6 Conclusion and Outlook

The results of the Pre-Test suggest that people put in question whether they will need the same number of cars as they currently own. Although the number of public transport season tickets increases, it is interesting to observe that the majority of respondents that stated to decrease the number of cars does not buy a new season ticket. In addition, the combination of the respondents' itineraries and extensive cost calculations for fleets of automated vehicles showed that the current transport services can compete in terms of variable costs and travel times.

As described previously, the average age in the sample is substantially higher than the population average. Since the data source does not provide accurate information on the age of the

respondents and is limited to landline numbers, the recruitment strategy needs to be adjusted. It is therefore planned to use data from the register of residents and contact a subpopulation by mail. The latter needs to be oversampled for young respondents. Once the contacted people have received the letter, they have the choice to answer either by link or a reply-paid envelope. Since this strategy is not dependent on a landline connection and the people's presence at home, it is expected that the average age of the sample will decrease.

7 References

Bansal, P., K. M. Kockelman and A. Singh (2016) Assessing public opinions of and interest in new vehicle technologies: An Austin perspective, *Transportation Research Part C: Emerging Technologies*, **67**, 1–14.

Becker, F. and K. W. Axhausen (2016) Literature review on behavioral experiments for autonomous vehicles, *Arbeitsberichte Verkehrs- und Raumplanung*.

BMW Group (2016) BMW Group, Intel and Mobileye Team Up to Bring Fully Autonomous Driving to Streets by 2021, `https://www.press.bmwgroup.com/global/article/detail/T0261586EN/bmw-group-intel-and-mobileye-team-up-to-bring-fully-autonomous-driving-language=en`.

Bösch, P. M., F. Becker, H. Becker and K. W. Axhausen (2017) Future Cost Structures and Scenarios with Autonomous Vehicles, *Arbeitsberichte Verkehrs- und Raumplanung*.

Bundesamt für Statistik (BFS) and Bundesamt für Raumentwicklung (ARE) (2010) Mikrozensus Mobilität und Verkehr 2010 - Kurzversion Fragebogen, *Technical Report*.

de Bekker-Grob, E. W., B. Donkers, M. F. Jonker and E. A. Stolk (2015) Sample Size Requirements for Discrete-Choice Experiments in Healthcare: a Practical Guide, *Patient*, **8** (5) 373–384.

Delhomme, P. and I. I. . France (2002) *Croyances des jeunes automobilistes en matière de vitesse : rapport final*, Institut national de recherche sur les transports et leur sécurité, [Arcueil, France].

Gächter, S., B. Herrmann and C. Thöni (2004) Trust, voluntary cooperation, and socio-economic background: Survey and experimental evidence, *Journal of Economic Behavior and Organization*, **55** (4 SPEC.ISS.) 505–531.

Golson, J. (2016) Volvo autonomous car engineer calls Tesla's Autopilot a 'wannabe', apr 2016, `https://www.theverge.com/2016/4/27/11518826/volvo-tesla-autopilot-autonomous-self-driving-car`.

Krueger, R., T. H. Rashidi and J. M. Rose (2016) Preferences for shared autonomous vehicles, *Transportation Research Part C: Emerging Technologies*, **69**, 343–355.

Kyriakidis, M., R. Happee and J. C. F. De Winter (2015) Public opinion on automated driving: Results of an international questionnaire among 5000 respondents, *Transportation Research Part F: Traffic Psychology and Behaviour*, **32**, 127–140.

OECD - International Transport Forum (2015) Urban Mobility System Upgrade: How shared self-driving cars could change city traffic, *Technical Report*, Paris.

Osswald, S., D. Wurhofer, S. Trösterer, E. Beck and M. Tscheligi (2012) Predicting Information Technology Usage in the Car: Towards a Car Technology Acceptance Model, paper presented at the *Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '12, 51–58, New York, NY, USA.

Otte, G. (2005) Entwicklung und Test einer integrativen Typologie der Lebensführung für die Bundesrepublik Deutschland, *Zeitschrift für Soziologie*, **34** (6) 442–467.

Ross, P. E. (2016) Ford: Robotaxis in 2021, Self-Driving Cars for Consumer 2025, sep 2016, `http://spectrum.ieee.org/cars-that-think/transportation/self-driving/ford-robotaxis-in-2021-selfdriving-cars-for-consumer-2025/?utm{_}source=CarsThatThink{&}utm{_}medium=Newsletter{&}utm{_}campaign=CTT09142016`.

SAE International (2014) Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems, Report SAE J3016, *Technical Report*.

Touring Club Schweiz (2009) Kilometerkosten 2009, software.

Urmson, C. (2016) Google Self-Driving Car Project, paper presented at the *South by Southwest (SXSW) 2016*, Austin, Texas, mar 2016.

Zmud, J., I. N. Sener and J. Wagner (2016) Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles, *Technical Report*, Austin.