Literature review on surveys investigating the acceptance of automated vehicles

Author(s):
Becker, Felix; Axhausen, Kay W.

Publication date:
2017-11

Permanent link:
https://doi.org/10.3929/ethz-b-000185937

Originally published in:
Transportation 44(6), https://doi.org/10.1007/s11116-017-9808-9

Literature review on surveys investigating the acceptance of autonomous vehicles

Date of submission: 2017-03-14

Felix Becker
IVT, ETH Zürich,
CH-8093 Zürich
phone: +41-44-633 32 79
fax: +41-44-633 10 57
e-mail: felix.becker@ivt.baug.ethz.ch
Orcid: 0000-0003-3287-7870

Kay W. Axhausen
IVT, ETH Zürich,
CH-8093 Zürich
phone: +41-44-633 32 79
fax: +41-44-633 10 57
e-mail: axhausen@ivt.baug.ethz.ch
Orcid: 0000-0003-3331-1318

Words: 4311 words + 6 tables = 5811 word equivalents

ABSTRACT

Due to the potential of autonomous vehicles to offer a multitude of advantages to the travelers and therefore influence their daily routines, it is essential to monitor the public's opinion on this particular technological development. The goal of a number of surveys in recent years was therefore not only to elicit the general acceptance of the technology, but to additionally explore when, how and why respondents were inclined to make us of it. This is the first literature review on surveys regarding autonomous vehicles with the intention to investigate the various methods currently being applied and the conclusions they lead to. In addition to comparing the general results in terms of the distributions of the response variables, the surveyed explanatory variables are categorized and analyzed according to their influence in different experiments. Based on these investigations, this review identifies research gaps that can be addressed in future experiments.

INTRODUCTION

The launch of self-driving cars promises to solve many problems for today's travelers, who operate vehicles in often unpleasant and tiring traffic situations. Providing the opportunity to focus on different tasks while traveling more safely through fewer traffic jams with the aid of Vehicle-to-Vehicle and Vehicle-to-Infrastructure communication technologies *(1, 2)* and/or special lanes *(3)* should represent a transport mode preferable to existing alternatives. However, the biggest advantages accrue to those currently without a driver's license, be it due to health conditions or age. This group of people, many of whom rely on public transport in remote areas, could be offered independent and individual transport solutions. Taking into account numerous benefits to travelers and assuming that the price for either renting or buying a self-driving car does not restrict the technology to a small proportion of the population *(4)*, the main obstacle that remains - from a customer's perspective - is trusting the technology. A number of studies reviewed in this work have thus asked respondents about how likely they would be to use the technology and tried linking answers to concerns, attitudes, demographics and current behavior. Thinking further ahead, a subset of the studies have differentiated between different types of usage, whether a private AV, shared autonomous vehicle (SAV), or pooled autonomous vehicle (PAV). While a private AV is shared among household members, the other two options can be considered on-demand services on non-fixed routes. As opposed to SAVs, also denoted as taxi-AVs, pooled autonomous vehicles pick up other passengers during the trip, which may cause detours (ridesharing). It is also essential to evaluate willingness to pay for new services and for which purposes - and when - respondents choose to switch from existing alternatives. Although an increasing number of surveys are being conducted, this work aims at providing an overview of different customer demand dimensions currently being investigated and survey methods employed. Second, results affected by explanatory variables' influence are compared to detect similarities and differences. To the best of the authors' knowledge, this is the first literature review on studies dealing with the acceptance of autonomous vehicles.

After presenting selection criteria and the reviewing process in section 3, scope and methods of the considered experiments are compared in section 4. Comparison of the surveyed literature follows in section 5. A summary of findings and identified research gaps are presented in section 6.

METHODOLOGY

As the earliest surveys on autonomous vehicles are from 2012, the studies were not selected according to a specific time frame and all publication types were included to create a broad overview. Due to the substantial impact of SAE-Level 4 and 5 autonomous vehicles *(5, CHF)* that allow for empty rides and do not require a driver's license, studies focusing on vehicles of lower automation levels are excluded and the review is restricted to studies published in English.

Heterogeneous publication types included in a broad literature review require a combination of database queries in Web of Science *(6)* and Sciencedirect *(7)* and backward, as well as forward, snowballing. For different queries, the words *autonomous* and *self-driving*, as well as *car* and *vehicle* were treated as synonyms in combination with the phrases *survey, acceptance, willingness to pay, travel behavior, interview, behavioral experiment, mode choice*, and *stated preferences*. Consistent with the backward snowballing technique, it was recursively investigated whether references of resulting articles contained further experiments. Furthermore, other articles were examined for references to the obtained literature (forward snowballing). This procedure allowed for the inclusion of private and academic reports, despite the fact that the search originated

TABLE 1 Meta-information of the considered surveys

Author(s), Reference	Year of Publication	Type	Method	Location	Nr. respondents
Bansal, Kockelman, & Singh *(8)*	2016	PRJ	Online survey	Austin, TX	347
Krueger, Rashidi, & Rose *(9)*	2016	PRJ	Online survey - mode choice SP	Australia	435
Kyriakidis, Happee & De Winter *(10)*	2015	PRJ	Online survey	109 countries	4886
Payre, Cestac, & Delhomme *(11)*	2014	PRJ	Interview/ Paper-based/ Online survey	France	5/45/421
Bansal, & Kockelman *(12)*	2016	Conference paper	Online Survey	US	2167
Howard, & Dai *(13)*	2014	Conference paper	Paper-based survey	Berkeley, CA	107
Rödel, Stadler, Meschtscherjakov, & Tscheligi *(14)*	2014	Conference proceedings	Online survey	Salzburg, AT	336
Brown et al. (Deloitte) *(15)*	2014	Report	Not found	19 countries	23000
Continental *(16, 17)*	2013	Report	Not found	Germany/ US/ Japan/ China	Not found
Ipsos Mori *(18)*	2014	Report	Interviews	United Kingdom	1001
J.D. Power *(19)*	2012	Report	Not found	U.S.	17400
Schoettle & Sivak *(20)*	2015	Report	Online survey	U.S.	505
Schoettle & Sivak *(21)*	2014	Report	Online survey	US, UK, Australia	1533
Seapine Software *(22)*	2014	Report	Online survey	US	2039
Silberg et al. (KPMG) *(3)*	2013	Report	Focus groups	US cities	32
Zmud, Sener, & Wagner *(23)*	2016	Report	Online survey/ Interview	Austin, TX	556/44

from scientific databases. After synthesizing meta data, studies were categorized according to type of experiment, included response variables and explanatory variables. As main response variables, level of acceptance, modal split, willingness to pay and choice between owning an AV and using a taxi service were identified. Literature related to induced travel and relocation behavior is still at an early stage and very heterogeneous. Similarly, explanatory variables used were categorized according to the groups' demographics, current behavior, attitudes and trip characteristics. Subsequently, the studies' results were compared on how they related to the variable's influence. The level of significance was set to 5% for all studies.

COMPARISON OF SCOPES AND METHODOLOGIES

As can be inferred from table 1, the majority of the experiments were conducted as online surveys to derive statistically valid results about perceptions of autonomous vehicles. Unlike other studies, Krueger, Rashidi, and Rose *(9)* selected a Stated-Preferences Mode Choice survey, allowing them to compare new alternatives with the currently chosen travel mode in specific situations. Although Payre, Cestac, and Delhomme *(11)* also used an online survey to infer the results to the general population with a sufficient sample size, they conducted interviews and paper-based surveys prior to this step, to elicit different public motivations and concerns. In contrast, Zmud, Sener, and Wagner *(23)* gathered general information through an online survey and subsequently conducted interviews with respondents open to the new development. This was motivated by the desire to analyze respondents' travel behavior changes, which would be difficult in an online survey. With the goal of broadly investigating attitudes, motivations and fears, Silberg et al. *(3)* asked 32 respondents within focus groups about their opinions; they specified the target was not to derive statistically valid results from the experiment.

Focusing on specific studies' goals, it is emphasized that acceptance of the new technology was interpreted and surveyed from extremely varied directions. This is in accordance with the broad definition provided by Adell *(24)*:

> The degree to which an individual intends to use a system and, when available, to incorporate the system in his/her driving

Although Ipsos Mori *(18)* asked respondents whether they regarded the technology as important and Continental *(17)* queried whether respondents would welcome the technology, every other study listed in table 1 posed a question that could be linked to the definition above. Bansal, Kockelman, and Singh *(8)* differentiated by frequency of the technology's use, assuming shared autonomous vehicles (SAVs) and Krueger, Rashidi, and Rose *(9)* conducted a mode choice survey where the current alternative, SAVs and pooled autonomous vehicles (PAVs) were available. In contrast, Kyriakidis, Happee, and De Winter*(10)*, Payre, Cestac, and Delhomme*(11)*, Zmud, Sener, and Wagner *(23)*, and Roedel et al. *(14)* let the respondents rate the acceptance of the technology on a scale. The question arose whether it matters when respondents are given the opportunity to choose between existing alternatives and new technology *(20, 14, 10, 12, 9)* or not.

Assuming that a part of the population is willing to use autonomous vehicles, the question arises; how much are consumers willing to pay for them? While Krueger, Rashidi, and Rose *(9)* estimated a mixed logit model in WTP-space allowing for alternative specific value-of-time estimates, Bansal, Kockelman, and Singh *(8)* asked for the frequency of use dependent on the price per mile of an SAV. In the remaining experiments, willingness to pay for a premium feature allowing for full autonomy was evaluated, either directly or within ranges *(8, 10, 12, 19, 21, 3)*. Two studies also incorporated the choice between owning a self-driving vehicle, or using one within SAV and PAV services. In both studies, respondents were asked directly, either within focus groups *(3)*, or in face-to-face interviews *(23)*.

The scope of experiments conducted in table 1 was, however, not only to determine the overall level of acceptance or willingness to pay, but also to link explanatory variables to respondents' opinions. Every study incorporated socio-demographic variables into the questionnaire or as part of the interview. Interestingly, the studies of Kyriakidis *(10)*, Brown et al., *(15)*, Continental *(16)*, and Schoettle et al. *(21)* were conducted in multiple countries and therefore allowed for the analysis of cross-national differences, although it should be noted that only Continental and Schoettle et al. claim to use representative samples. Information on weighting procedures was not found for the remaining studies.

Nevertheless, Zmud, Sener, and Wagner *(23)* summarize that, in previous studies, attitudes often wield more influence on technology adoption than socio-demographic variables. Kyriakidis, Happee, and De Winter *(10)* thus included an additional 10-item version of the Big Five Inventory personality test *(25)*. In contrast, the main emphasis of studies from Payre, Cestac, and Delhomme *(11)* and Rödel et al. *(14)* was linking attitudes to intention to use autonomous vehicles. As an example, Payre, Cestac, and Delhomme used the Locus of Control (LOC), defined as the extent to which a person believes he/she can control events that effect him/her *(26)* and the driving-related-sensation-seeking scale (DRSS) (*(27, 28)* as citepd in *(11)*). It should further be noted that both Zmud, Sener, and Wagner *(23)* and Rödel et al. *(14)* make use of the Car Technology Acceptance Model *(29)*, which extends the Unified Theory of Acceptance and Use of Technology (UTAUT) model *(30)* to technology acceptance of car-related information systems. Another possibility is to link the intention to use autonomous vehicles to respondents'

TABLE 2 Results - Response Variables

Author(s), Reference	Year of Pub.	General Opinion/ Intention to use	Mode Choice	WTP	Ownership vs SAV/PAV
Bansal, Kockelman, & Singh *(8)*	2016	41% would use an SAV once a week at a price of 1 USD per mile		7253 USD	Both analyzed, no direct comparison
Krueger, Rashidi, & Rose *(9)*	2016		28.46% of trips SAV/PAV vs current mode		
Kyriakidis, Happee & De Winter *(10)*	2015	Enjoyable mean 3.49/5		Median between 3001 and 5000 USD	
Payre, Cestac, & Delhomme *(11)*	2014	68.1% above 4 (7 Lickert) on custom acceptability scale			
Bansal, & Kockelman *(12)*	2016	54,4% as useful; 58.4% scared; 40% for everyday trips		5857 USD	
Howard & Dai*(13)*	2014	40% buying or equipping; 45% would not use an AV-Taxi on a monthly basis			Both analyzed, no direct comparison
Rödel, Stadler, Meschtscherjakov, & Tscheligi *(14)*	2014	3.04/6 Behavioral intention to use the system			
Brown et al. (Deloitte) *(15)*	2014	Graph differentiating by 6 countries			
Continental *(16, 17)*	2013	Welcome technology: 79% China, 61% Japan, 53% Germany, 41% US		2900 EUR Freeway Driving (Germany)	
Ipsos Mori *(18)*	2014	18% regard the technology as important			
J.D. Power *(19)*	2012	37% would like to buy		20% would buy at a price of 3000 USD	
Schoettle & Sivak *(20)*	2015	15.6% prefer full automation			
Schoettle & Sivak *(21)*	2014	Positive impression: 61.9% Australia, 56.3% U.S., 52.2% U.K.		75th percentile 1880 USD	
Seapine Software *(22)*	2014	88% worried			
Silberg et al. (KPMG) *(3)*	2013			Median 4500 USD	50% would give up second car
Zmud, Sener, & Wagner *(23)*	2016	50% of sample intention for everyday use			59% prefer private AV over SAV; 23% want to reduce vehicle ownership

current behavior, especially their current type of car, considering distinctions between the included advanced driver assistance systems *(3, 14, 10, 21, 23, 9)*, or whether the car is considered a premium vehicle or not *(19)*. Furthermore Krueger, Rashidi, and Rose *(9)* distinguished among modality style clusters based on use frequency of different transport modes, whereas Bansal, Kockelman, and Singh *(8)* surveyed whether the driver mostly drives on his or her own.

Furthermore, it was suggested that trip characteristics play an important role in the acceptance of autonomous vehicles *(16, 3, 8, 12, 9)*, which are considered especially attractive in monotonous driving conditions, e.g. on highways and in traffic jams.

COMPARISON OF RESULTS

The result section is divided into two parts. First, general response variables results are compared and second, the studies' conclusions on effects of explanatory variables are contrasted.

Summary statistics of the response variables' distributions are outlined in table 2, indicating that general opinion or intention to use the technology varies substantially among the studies. In the earliest study considered (2012), 37% of the US respondents "definitely " or "probably would" buy the technology *(19)*. Two years later however, only 18% of the respondents in a UK sample regarded the development as important *(18)*. Interestingly, the numbers are closer to each other in the latest US experiments. In the Bansal and Kockelman sample *(12)*, 40% of the respondents wanted to use a private autonomous vehicle for everyday use, while in the Austin sample of Zmud, Sener, and Wagner *(23)*, this figure rose to 50%. In addition, 41% in the Austin sample of Bansal, Kockelman, and Singh *(8)* would use an SAV weekly at a competitive price of 1 USD per mile. In the only mode choice experiment, 28.46% of the decisions referred to the new alternatives SAV/PAV *(9)*.

The elicitepd willingness to pay for adding autonomous capabilities to one's own vehicle is similar among the studies. Except for early studies from J.D. Power *(19)* and Schoettle and Sivak *(21)* in 2012 and 2014, the median, or mean, willingness to pay ranged from the lowest level of US$ 3,001 in the interval provided by Kyriakidis, Happee, and De Winter *(10)* and US$ 7,253 in the Bansal, Kockelman, and Singh study *(8)*. However, one should note that Kyriakidis et al. *(10)* surveyed multiple countries without factoring in economic purchasing power, while the sample of Bansal et al. *(8)* is representative for Austin, Texas. It can further be stated that Schoettle et al. *(21)*, as well as Kyriakidis et al. *(10)*, kept the introductory segments for autonomous vehicles short. In contrast, the Bansal et al. survey *(8)* made the respondents aware of different types of services, multiple benefits and introduced the consideration that the respondents might choose to relocate in the long term.

The results of studies that compare the decision to buy an autonomous vehicles or use it as a taxi service (see also *(31)*) indicate that this aspect should be analyzed on the household level. While few respondents would fully rely on taxi services, 50% of the respondents in the Silberg et al study would give up the household's second car *(3)*. 23% would reduce vehicle ownership in the sample of Zmud, Sener, and Wagner *(23)*.

In table 3, socio-demographic variables' effects on the opinion about autonomous vehicles are summarized for the studies. In terms of gender, the summary in table 3 suggests that men are more open to the technology than women. The only study contradicting this trend is Silberg et al. *(3)*, whose results were based on the opinions of 32 participants. It should also be noted that acceptance of self-driving was measured on a scale from 1 to 10 and that medians between the genders differed by only 0.75 at the end of the experiment.

Assessing age of the respondents as a factor, only Roedel et al. *(14)* observed a stronger intention to use autonomous vehicles with an increasing age. The authors justified this by citing the physical limitations that prohibit older people from driving. Six other studies conclude that younger people are more open to the introduction of autonomous vehicles. Interestingly Bansal, Kockelman, and Singh *(8)* observed a significant negative effect when respondents were asked about willingness to pay, yet saw no significant effect if the adoption time relative to the one of the friends is being regressed on. This raises the issue of whether older people are simply not inclined to be innovative, but will use the technology after a critical diffusion point.

Bansal, Kockelman, and Singh *(8)*, as well as Kyriakidis, Happee, and De Winter *(10)* observed a significant positive relationship between willingness to pay for an autonomous feature and income of the respondents, as would be expected. Because people with higher incomes have more money available with which to experiment, the idea that those people buy the technology at an earlier time is also plausible *(8)*. Respondents with lower incomes could

TABLE 3 Effects of socio-demographic variables

Predictor	Effect on Opinion	Dependent variable	Source	Comments
Gender	Positive - Male	Intention to use; Concern	Schoettle & Sivak *(20)*	Men less concerned
		Concern	Schoettle & Sivak *(21)*	Men less concerned
		WTP for Ownership	Kyriakidis, Happee & De Winter *(10)*	Significant correlation
		WTP for Ownership, Adoption timing	Bansal, Kockelman, & Singh *(8)*	
		Acceptance, intention to use	Payre, Cestac, & Delhomme *(11)*	
			Rödel, Stadler, Meschtscherjakov, & Tscheligi *(14)*	
		Intention to use	J.D. Power *(19)*	No comments on significance
		Intention to use	Zmud, Sener, & Wagner *(23)*	
		Regard as important	Ipsos Mori *(18)*	
	Positive - Female	Intention to use	Silberg et al. (KPMG) *(3)*	No comments on significance
	Not sign.	Concern	Seapine Software *(22)*	
		WTP for Ownership	Bansal, Kockelman, & Singh *(8)*	
		Mode Choice	Krueger, Rashidi, & Rose *(9)*	
Age	Positive	Intention to use	Rödel, Stadler, Meschtscherjakov, & Tscheligi *(14)*	
	Negative	WTP for Ownership	Bansal, Kockelman, & Singh *(8)*	
		Concern	Schoettle & Sivak *(20)*	Young respondents less concerned
		Regard as important	Ipsos Mori *(18)*	
		Being worried	Seapine Software *(22)*	Young respondents less worried; Chi-Square-Test conducted based on information in report
		Intention to use	J.D. Power *(19)*	No comments on significance
		Intention to use; Concern	Schoettle & Sivak *(21)*	Young respondents less concerned
	Not sign.	Intention to use	Payre, Cestac, & Delhomme *(11)*	
		Intention to use	Zmud, Sener, & Wagner *(23)*	
		Adoption timing	Bansal, Kockelman, & Singh *(8)*	
		Mode Choice	Krueger, Rashidi, & Rose *(9)*	except for 24-29 vs 30-49 years old for PAV
Income	Positive	WTP for Ownership; Adoption timing	Bansal, Kockelman, & Singh *(8)*	
		WTP for Ownership	Kyriakidis, Happee & De Winter *(10)*	Significant correlation
	Not sign.	Intention to use	Schoettle & Sivak *(20)*	Surveyed but not reported
		Intention to use	Zmud, Sener, & Wagner *(23)*	
Education	Not sign.	Intention to use	Zmud, Sener, & Wagner *(23)*	
Children	Negative	Intention to use	Zmud, Sener, & Wagner *(23)*	BIN in household
	Not sign.	WTP for Ownership	Bansal, Kockelman, & Singh *(8)*	Number of children
	Not sign.	Mode Choice	Krueger, Rashidi, & Rose *(9)*	BIN in household

also be accustomed to waiting for new technology to spread and become cheaper. However, none of the studies showed that income had a significant effect on intentions to use the new technology.

Attitudinal variables' effects on opinions about autonomous vehicles are outlined in table 4. Studies incorporating information and awareness of the new technology unequivocally conclude that it has a positive effect on opinion. Should researchers decide against a thorough introduction to the topic, it is worthwhile to survey the current knowledge about the technology. Payre, Cestac, and Delhomme *(11)* noticed that drivers seeking "sensation or adventure" are more inclined to use autonomous vehicles. The authors are, however, unable to distinguish between adventure and mere novelty. They also suggest that drivers primarily seeking novelty might be

TABLE 4 Effects of attitudinal variables

Predictor	Effect on Opinion	Dependent variable	Source	Comments
Technology awareness	Positive	Adoption timing	Bansal, Kockelman, & Singh *(8)*	Have heard of Google car
		Intention to use	Silberg et al. (KPMG) *(3)*	No comments on significance
		Intention to use	Schoettle & Sivak *(21)*	Have heard of autonomous vehicles
Locus of Control	Not sign.	Intention to use	Payre, Cestac, & Delhomme *(11)*	
Sensation Seeking	Positive	Intention to use	Payre, Cestac, & Delhomme *(11)*	Driving-related sensation-seeking scale (DRSS)
Personality Test (Big Five Inventory - 10 items)	Not sign.	Driving in AVs enjoyable, driving in AVs is easier than manual driving, worries about data transmission, concerns about software hacking	Kyriakidis, Happee & De Winter *(10)*	"Not substantially predictive" - Spearman correlation between -0.1 and 0.1
Passion for Driving	Negative	Intention to use	Silberg et al. (KPMG) *(3)*	No comments on significance
		Regard as important	Ipsos Mori *(18)*	
Acceptance of advanced driving systems	Positive	Acceeptance	Continental *(16)*	No numbers provided
Data privacy concerns	Negative	Intention to use	Zmud, Sener, & Wagner *(23)*	

TABLE 5 Effects of the current behavior

Predictor	Effect on Opinion	Dependent variable	Source	Comments
Mileage	Positive	WTP for Ownership	Kyriakidis, Happee & De Winter *(10)*	Annual VMT
	Not sign.	Intention to use	Rödel, Stadler, Meschtscherjakov, & Tscheligi *(14)*	Driving Frequency
		WTP for Ownership; Adoption timing	Bansal, Kockelman, & Singh *(8)*	Annual VMT
Car Sharing	Not sign.	WTP for Ownership	Bansal, Kockelman, & Singh *(8)*	Experience with Car Sharing
	Positive	Mode Choice; PAV	Krueger, Rashidi, & Rose *(9)*	Currently Use Car Sharing
Current Vehicle: Autonomy Level	Positive	Intention to use	Silberg et al. (KPMG) *(3)*	No comments on significance
		Intention to use	Rödel, Stadler, Meschtscherjakov, & Tscheligi *(14)*	Experience with Advanced Driver Assistance Systems
		Intention to use	Schoettle & Sivak *(21)*	
		Intention to use	Zmud, Sener, & Wagner *(23)*	
		WTP for Ownership	Kyriakidis, Happee & De Winter *(10)*	Currently in possession of car with ACC
Current Vehicle: Premium	Positive	Intention to use	J.D. Power *(19)*	At a price of 3000 USD
Car Availability	Not sign.	Mode Choice	Krueger, Rashidi, & Rose *(9)*	
Using multiple modes	Positive	Mode Choice	Krueger, Rashidi, & Rose *(9)*	
Number of past crash experiences	Positive	WTP for Ownership, Adoption timing	Bansal, Kockelman, & Singh *(8)*	

bored after an adaption time as the driving task becomes obsolete.

Variables related to respondents' current mobility behavior are depicted in table 5. While the picture for current mileage and car sharing experience is not clear, every study that surveyed the current vehicle's level of autonomy observed a positive correlation with the opinion about self-driving vehicles. Not only are these respondents open to new technological developments, but they have already gained experience in using and trusting systems that assume partial responsibility for driving. Krueger, Rashidi, and Rose *(9)* clustered the respondents by their current modal split and could show that those who use multiple modes are more likely to choose

TABLE 6 Effects of the trip characteristics

Predictor	Effect on opinion	Dependent variable	Source	Comments
Population density	Positive	Intention to use	J.D. Power *(19)*	Urban areas; No comments on significance; Price of 3000 USD
		Adoption timing	Bansal, Kockelman, & Singh *(8)*	Urban areas
Trip purpose	Mostly Not sign.	Mode Choice	Krueger, Rashidi, & Rose *(9)*	
Trip distance	No effect	Intention to use	Bansal, & Kockelman *(12)*	Approximately the same proportion of respondents would not use AVs for short-distance (<=50 miles) and long-distance trips
On highways and in cong. traffic	Positive	Intention to use	Continental *(16)* Bansal, Kockelman, & Singh *(8)*	
Special lanes for AVs	Positive	Intention to use	Silberg et al. (KPMG) *(3)*	no comments on significance

the new alternatives SAV and PAV. It should also be pointed out that a significant positive effect was observed for the number of crashes a person has been involved in *(8)*.

Two studies concluded that residents of urban areas are more inclined to use self-driving cars. While J.D. Power *(19)* focused on the willingness to buy an AV, Bansal, Kockelman, and Singh *(8)* investigated the adoption time for SAVs. With residents of rural areas expecting long waiting times and high travel costs for long distance trips, it is plausible that a taxi service is more appealing to urban dwellers. Furthermore, Continental *(16)* and Bansal, Kockelman, and Singh *(8)* found that respondents prefer to use the technology in monotonous driving situations, such as on highways and in congested traffic.

CONCLUSION AND OUTLOOK

Despite the fact that this technology is currently not available to the public and that its specific launch date is still unclear, a few trends can be identified by reviewing experiments whose results have been published. It seems to be most popular among young people and in urban environments; men, as well as those currently owning a vehicle with advanced driver assistance systems, tend to be most positive about using the technology. A similar effect was observed for potential users already in contact with news about the technology, which, unsurprisingly, would preferably be used in monotonous driving situations.

With many studies investigating a number of different response variables and predictors simultaneously, future experiments might focus on special dimensions of demand or classes of predictors. As an example, it should be emphasized that in the experiments of Zmud, Sener, and Wagner *(23)*, some respondents expressed concern about safety aspects, while others mentioned increased safety as one of the autonomous vehicle benefits. Although it is difficult to quantify, it would therefore be interesting to investigate the relationship between safety level and segment of the population that intends to use AVs. As the drivers would not be in control of the vehicle anymore, it is hypothesized that the crash rates or miles per casualty should be substantially lower than in today's cars.

In spite of the fact that the ownership vs. taxi-service decision has been addressed in two experiments *(3, 23)*, further insights into this decision on the household level are necessary. Next to choosing the appropriate decision unit, it is also essential to precisely examine which factors play a role in the (family) decision process. Respondents' statements in the *(3)* study led to the conclusion that detailed travel plans and costs could cause a bias towards rational decisions. When addressing willingness to pay for adding the technology to a private car, it is interesting to note that reported means are mostly below anticipated costs, which range from $7,000 to $10,000 in 2025, but above the costs predicted for 2035, expected to be about $3,000 *(32)*. Given these numbers, it is obvious that experiments combining cost predictions with diffusion theory for private AVs have the potential to provide further insights into private autonomous vehicles' adoption curve .

Although the passion for driving *(3, 18)* and traffic conditions *(16, 8, 3)* have already been included in some experiments, it may be expedient to interact both in future experiments. Because even passionate drivers could enjoy being chauffeured in an autonomous vehicle on their daily commute slowed by traffic jams, the passion for driving might be restricted to certain road and traffic conditions.

The studies of Zmud, Sener, and Wagner *(23)* and Bansal, Kockelman and Singh *(8)* did not reveal substantial travel behavior changes caused by the introduction of the autonomous vehicle. Zmud, Sener and Wagner observed an increase only for long distance trips, but no changes in the daily routines, routes, or activities. In the Bansal, Kockelman, and Singh sample, 74% did not consider relocating with the new technology at hand. Nonetheless, increased comfort and the opportunity to perform tasks other than driving could have substantial impacts in the long run. It is possible that experiments focusing solely on this issue, in line with detailed scenarios, could lead to different results.

REFERENCES

1. Tientrakool, P., Y. C. Ho and N. F. Maxemchuk (2011) Highway Capacity Benefits from Using Vehicle-to-Vehicle Communication and Sensors for Collision Avoidance, paper presented at the *Vehicular Technology Conference (VTC Fall), 2011 IEEE*, ISBN 1090-3038.

2. Friedrich, B. (2015) *Verkehrliche Wirkung autonomer Fahrzeuge*, 331–350, Springer Berlin Heidelberg, Berlin, Heidelberg, ISBN 978-3-662-45854-9.

3. Silberg, G., M. Manassa, K. Everhart, D. Subramanian, M. Corley, H. Fraser, V. Sinha and A. W. Ready (2013) Self-Driving Cars: Are we Ready?, *Technical Report*, KPMG.

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

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

6. Thomson Reuters (2016) Web of Science, `https://apps.webofknowledge.com/WOS{_}GeneralSearch{_}input.do?product=WOS{&}search{_}mode=GeneralSearch{&}SID=R1VXWEiOGN9EjIBbtZB{&}preferencesSaved=`.

7. Elsevier (2016) Sciencedirect, `http://www.sciencedirect.com/`.

8. 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, ISSN 0968090X.

9. Krueger, R., T. H. Rashidi and J. M. Rose (2016) Preferences for shared autonomous vehicles, *Transportation Research Part C: Emerging Technologies*, **69**, 343–355, ISSN 0968090X.

10. 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, ISSN 13698478.

11. Payre, W., J. Cestac and P. Delhomme (2014) Intention to use a fully automated car: Attitudes and a priori acceptability, *Transportation Research Part F: Traffic Psychology and Behaviour*, **27** (PB) 252–263, ISSN 13698478.

12. Bansal, P. and K. M. Kockelman (2016) Forecasting Americans' Long-Term Adoption of Connected and Autonomous Vehicle Technologies, paper presented at the *95th Annual Meeting of the Transportation Research Board*.

13. Howard, D. and D. Dai (2014) Public Perceptions of Self-driving Cars: The Case of Berkeley, California, paper presented at the *93rd Annual Meeting of the Transportation Research Board*, ISBN 9780857290847.

14. Rödel, C., S. Stadler, A. Meschtscherjakov and M. Tscheligi (2014) Towards Autonomous Cars: The Effect of Autonomy Levels on Acceptance and User Experience, paper presented at the *Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '14, 11:1—-11:8, New York, NY, USA, ISBN 978-1-4503-3212-5.

15. Brown, B., M. Drew, C. Erenguc, M. Hasegawa, R. Hill, S. Schmith and B. Ganula (2014) Global Automotive Consumer Study: The changing nature of mobility - Exploring consumer preferences in key markets around the world, *Technical Report*, Deloitte.

16. Continental (2013) German Motorists Want Automated Freeway Driving, *Technical Report*.

17. Continental (2014) Motorists Worldwide Open to Automated Driving, *Technical Report*.

18. Ipsos MORI (2014) Ipsos MORI Loyalty Automotive Survey, *Technical Report*.

19. J.D. Power (2012) Vehicle Owners Show Willingness to Spend on Automotive Infotainment Features, *Technical Report*, Westlake Village.

20. Schoettle, B. and M. Sivak (2015) Motorists' preferences for different levels of vehicle automation, *Technical Report*, **July**, The University of Michigan Transportation Research Institute.

21. Schoettle, B. and M. Sivak (2014) A survey of public opinion about autonomous and self-driving vehicles in the U.S., the U.K., and Australia, *Technical Report*, The University of Michigan Transportation Research Institute.

22. Seapine Software (2014) Study Finds 88 Percent of Adults Would Be Worried about Riding in a Driverless Car, `http://www.seapine.com/about-us/press-release-full?press=217`.

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

24. Adell, E. (2009) Driver Experience and Acceptance of Driver Support Systems - A Case of Speed Adaptation, Ph.D. Thesis, Lund University.

25. Rammstedt, B. and O. P. John (2007) Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German, *Journal of Research in Personality*, **41** (1) 203–212, ISSN 00926566.

26. Rotter, J. B. (1966) Generalized expectancies for internal versus external control of reinforcement, *Psychological Monographs: General and Applied*, **80** (1) 1–28, ISSN 1098-6596.

27. 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].

28. Taubman, O., M. Mikulincer and A. Iram (1996) The Cognitive, Motivational and Emotional System of Driving, *Technical Report*, Department of Casualties and Road Safety of the Israeli Army, Israel.

29. 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, ISBN 978-1-4503-1751-1.

30. Venkatesh, V., M. G. Morris, G. B. Davis and F. D. Davis (2003) User Acceptance of Information Technology: Toward a Unified View, *MIS Quarterly*, **27** (3) 425–478.

31. Becker, H., F. Ciari and K. W. Axhausen (2016) Comparing Car-Sharing Schemes in Switzerland: User Groups and Usage Patterns, paper presented at the *95th Annual Meeting of the Transportation Research Board (TRB 2016)*, 16–3277.

32. IHS Markit (2014) Self-Driving Cars Moving into the Industry's Driver's Seat, jan 2014, `http://news.ihsmarkit.com/press-release/automotive/self-driving-cars-moving-industrys-drivers-seat`.