Acceptance of Shared Autonomous Vehicles: A Literature Review of stated choice experiments

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This paper : "Acceptance of Shared Autonomous Vehicles: A Literature Review of stated choice experiments" (Benoît Lécureux [1], Adrien Bonnet [2], Ouassim Manout [1], Jaâfar Berrada [2], and Louafi Bouzouina [1,3]) has been accepted for Transport Research Arena (Lisbon 2022) and will be published in the conference proceedings.

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Acceptance of Shared Autonomous Vehicles: A Literature Review of stated choice experiments

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Abstract

Automated mobility has always conveyed fantasies about its ability to meet future mobility needs and challenges. If research is still debating the when, where and how of this mobility disruption, there seems to be a consensus on its advent. Meanwhile, the investigation of the demand for this mobility is of critical importance. Stated preference surveys are a common and powerful tool to foresee this demand. This paper tackles the question of the acceptance of shared autonomous vehicles (SAVs) by reviewing most significant published papers on travel demand and travel surveys for SAVs. Given the recent developments in the last three years, the paper updates and complements previous literature reviews.

In contrast with previous research, this paper shows that the impact of various factors on the intention to use SAVs is still controversial. This includes age, gender, income or car ownership. We identify most consensual and controversial effects and correspondingly suggest future research tracks to address some the identified gaps.

Keywords: Shared Autonomous vehicles, Acceptance, Discrete choice, Mode choice, Stated preferences, Attitudes, Literature review

Declarations:

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1 Introduction

Shared autonomous vehicles (SAVs) are likely to impact existing mobility services and induce new mobility practices (Narayanan et al. 2020). However, 10 years after the publication of the first papers on the acceptance of autonomous vehicles (AVs), considerable uncertainty still surround the adoption and use of SAVs. In this research, we address the following question: *did researchers reach a consensus on SAVs' acceptance factors?* We assume that despite the abundant literature on AVs, the study of its acceptance factors is, to some degree, still speculative and a consensus on their nature and magnitude is yet to be reached. The aim of this paper is to compare most studied AV acceptance factors in the economic literature and to investigate whether a scientific consensus has been reached or not and what future research is still needed to reach a consensus.

There have been two major literature reviews on the acceptance of AVs (Becker et al. 2017; Gkartzonikas et al. 2019). Both reviews focus on survey methodologies and explanatory variables of AV acceptance. In particular, Gkartzonikas et al. (2019) review stated-preferences (SP) for AVs by including attitudes. Their review highlights the lack of well-established theories that account for attitudinal dimensions.

In this paper, we update the state of the art on the acceptance of autonomous mobility services by reviewing most significant papers on this subject. 65% of the reviewed papers were published after 2019, i.e. the publication year of the latest literature review on AVs' acceptance. Most importantly, this review evaluates the degree of consensus on the effect of various SAVs' acceptance factors. Unlike Becker et al. (2017) and Gkartzonikas et al. (2019), our review focuses on SAVs and especially on three types: (1) autonomous shuttles or buses (AS) that operate like conventional buses; (2) robo-taxis (RT); and (3) ride-sharing robo-taxis (RS RT). The focus on SAVs is motivated by the fact that AVs are most likely to be first introduced in shared mobility services (Narayanan et al. 2020). We also address some of the limitations identified by Gkartzonikas et al. (2019) and discuss most used theoretical models in psychology that consider the acceptance of the AV technology.

2 Methodology

The literature review is based on a systematic search of relevant papers using Google Scholar, Scopus, Web of Science and a list of keywords, including *"autonomous vehicles, shared autonomous vehicles, stated preferences, methodology, determinants, attitudes, acceptance"* and their most common synonyms following the methodology of Wee et al. (2016). The backward and forward snowballing strategy is used to identify most significant papers on the subject. The selection criteria are: papers published in peer-reviewed journals; papers that include, but are not limited to: autonomous buses, autonomous shuttles, robo-taxis or shared robo-taxis; papers that are empirical and that examine the travel mode choice of SAVs; papers that use the choice experiment method for their data collection. This selection resulted in 29 papers. Most of these papers were published after the last literature review by Gkartzonikas et al. (2019).

3 Results

3.1 Review of survey methodologies

We analyze and classify the selected papers according to: survey administration type, survey area, survey design and the type of discrete choice model. 90% of the reviewed surveys are conducted

online. The average number of respondents is 1,140 (min 106 - max 4,625). 55% of case studies are conducted in urban areas and 26% on a national level. The remaining part (19%) are difficult to classify or don't specify the survey area. Little attention has been paid to the acceptance of SAVs in rural and suburban areas. Regarding the choice experiments, SAVs are often compared to: private AVs (15 papers), private conventional cars (12), public transport (9), cycling (10), walking (9), regular taxi (1), carpooling (2) or airplane (1). Regarding the experimental design of choice experiments, the mean number of attributes per each travel alternative is 3 (min 2 - max 6). Given the novelty of the subject and the absence of reliable knowledge, 48% of the surveys rely on the straightforward orthogonal design, 29% on the Bayesian design, and 19% on the efficient design (Walker et al. 2018). The used discrete choice models are: mixed logit (39% of papers), multinomial logit (28%), ordered models (17%), hybrid model (11%).

In the following section, we first review the influence of the most studied acceptance factors (control variables). Second, we analyze and comment on four sets of variables of interest. Finally, we discuss the specific case of psychosocial factors.

3.2 Control variables

Gender (reference male): is controlled almost systematically in the reviewed papers with 27 occurrences. The effect of gender on the intention to use the three types of SAVs is not consensual: 11 papers find a positive effect of being male, 11 papers find a non-significant effect and 5 other papers find a negative effect.

Age (reference old): is one of the most studied variables in this review with 25 papers including it. It is most often negatively associated with the intention to use RTs or RS RTs. 12 papers find a negative effect, 8 papers find no significant effect and 5 others find a positive effect of age (being old) on the intention to use RTs or RS RTs. The effect of age on the intention to use AS using choice experiments is yet to be studied.

Trip cost: is controlled in 22 papers and has a systematically negative effect on the intention to use SAVs.

Travel time: has systematically a significant negative effect on the intention to use SAVs. The only study that reports a positive effect is Haboucha et al. (2017). The authors find that SAVs' travel time is positively perceived by potential users due to the fact that those who make longer trips tend to favor AVs over other alternatives.

Income: is examined in 17 of the reviewed papers. 9 of these find no significant effect of income on the intention to use SAVs. 7 papers find a positive effect of high income and only 1 study shows a negative effect.

Waiting time: is controlled for in 16 studies with almost always a negative effect. Only Kontar et al. (2021) did not find a significant effect of this variable on the intention to use SAVs. The authors explain this finding by the fact that the waiting times of the choice experiment were too low to influence mode choice.

Household size: is studied in 13 papers. It has often a non-significant effect (8 out of 13) on the intention to use RTs and RS RTs. In 3 and 2 papers, the size of households has a positive, negative effect, respectively.

Car ownership: car dependency has a negative impact on the intention to use the RTs or RS RTs (7/11 papers). The other 4 papers show no significant effect.

Education (ref. high education): is included in 10 out of 29 papers. It has often a positive effect, i.e. a high level of education tends to increase the intention to use SAVs (8 of 10 papers). The other 2 papers show no significant effect.

Residential location (ref. urban area): is included in 9 papers. In 2 papers this variable has a positive effect. In 4 papers, it has a negative effect. In the rest of paper (3), it has no significant effect.

Driving license (ref. own a license): is included in 9 papers. It has a non-significant effect in 5 papers and a negative effect in 3 papers and a positive one in 1 paper.

Trip purpose: is studied in 8 papers. The intention to use SAVs is higher for commuting than for leisure or shopping (4 papers out of 8). In 3 papers, no significant effect for the trip purpose is found. Only Guo et al. (2021) find a negative effect of the commuting trip purpose. This might be explained by the fact that commuters prefer modes that are reliable.

Access/egress time: are studied in only 3 papers and they systematically have a negative effect on the intention to use all forms of SAVs.

It is noteworthy that for most control variables, there is little or no data on their effect on the acceptance of autonomous shuttles. Most research focuses on the case of robot-taxis.

3.3 Factors of the intention to use SAVs

4 dimensions are often presented as key drivers of the adoption of SAVs. Attitudes, benefits of SAVs, preference for shared and flexible services and current mode choice.

Attitudes

Becker et al. (2017) and Gkartzonikas et al. (2019) consider attitudes as key drivers of the adoption of SAVs. Four of them were identified as primary factors : environmental concerns, safety and trust in AVs, tech-savviness and passion for driving.

Environmental concerns are tested in 5 papers (out of 27). This attitude positively influences the intention to use SAVs in 80% of the cases. Pro-environment concerns positively influence the intention to use RTs in 3 out 4 papers, and RS RTs in 1 paper. Yap et al. (2016) note that attitude toward AV sustainability is the most important attitudinal factor of the intention to use AVs as a last mile service. This finding is in contradiction with other findings showing that security concerns are the most impactful (Nazari et al. 2018). It should be noted that in Yap et al. (2016), the AV sustainability latent construct is defined by only two items. For Webb et al. (2019), the influence of the environmental attitude can be amplified if information on SAV's environmental benefits is provided. Haboucha et al. (2017) find a contextual effect of the environmental attitude on the use of AVs. The authors reveal that the effect of environmental attitudes on SAVs' acceptance is significant in Israel, but not in the USA. Nazari et al. (2018) find a correlation between green travel patterns and socio-demographic variables. This correlation is positive for young men with high education and negative for rich people and those with children.

Security/safety concerns and trust are studied in a total of 5 papers each. Safety concerns influence negatively the intention to use SAVs in 100% of the cases, while trust in AVs influences it positively. As regards the different types of SAVs, safety concerns are studied in the case of RTs, RS RTs and AS in 2, 2 and 1 paper out 5, respectively. Trust in AVs is tested for RTs, RS RTs and AS in 3, 1 and 1 paper, respectively. Nazari et al. (2018) confirm that safety concerns are a primary factor to the adoption of SAVs that is more important, for example, than being interested in Mobility On Demand (MOD) or having a green travel pattern. Yap et al. (2016) also identify safety as a major attitudinal determinant of the intention to use SAVs. Smith et al. (2019) argue that the main safety concern is related to system tampering that might compromise the safety of passengers. Nevertheless, Lavieri et al. (2019) find that despite the importance of privacy in the acceptance of RS RTs, delays associated with sharing a ride (due to detours for example) are more detrimental to their use than sharing a ride with strangers.

Pro-technology attitudes are studied in 5 papers. They positively influence the intention to use SAVs in 100% of the cases. Pro-technology attitudes have been tested for RTs, RS RTs and AS in 2, 1 and 2 papers, respectively. S. Wang et al. (2020) and Haboucha et al. (2017) find that those with high interest in technology are more likely to use AVs. Wicki et al. (2019) decomposes interest in technology as acceptance, competence and control. Acceptance is highly significant and positive whereas competence and control are not (Wicki et al. 2019). Winter et al. (2019) confirm this finding in the case of AS.

Passion for driving is studied in 3 papers. It does not influence the intention to use RTs in 66% of the cases (2 out 3 papers) and influences it negatively in 1 case. This attitude was not studied in the case of AS. Gkartzonikas et al. (2019) find that driver are more likely to prefer greater control of their vehicle and less likely to use an AV. Becker et al. (2017) suggest to interact passion for driving with traffic conditions as drivers might be interested in being chauffeured in traffic jams. S. Wang et al. (2020) note no significant relationship between driving enjoyment and attitudes towards AVs, and suggest that the benefits of driving are balanced by the perceived benefits of AVs.

Benefits

Perceived benefits of AVs are explored in 3 papers. These benefits include reducing driver fatigue, environmental-friendliness, increased accessibility of travel for non-drivers and traffic regulation. They positively influence the intention to use SAVs in 100% of the cases. They are studied in the case of RTs and RS RTs in 2 and 1 paper, respectively. The effect of perceived benefits is often assessed at a national level through online surveys (S. Wang et al. 2020; Wu et al. 2020). In the USA and China, the perceived benefits of SAVs are found to positively impact their acceptance over the purchase of a private AVs. Gkartzonikas et al. (2019) note that safety benefits of AVs are widely expected. Due to its reduced perceived usefulness, Winter et al. (2019) find a negative effect of the presence of a steward on board of AS, despite the increased safety brought by this presence.

Preferences for shared and flexible services

Preference for shared services is tested in 1 paper. It positively influences the intention to use SAVs (Webb et al. 2019). People who already use public transport/ride-sharing are more likely to accept to use SAVs.

Interest for Mobility-On-Demand (MOD) is tested in 2 papers. It positively influences the intention to use SAVs in 100% of the cases. It is tested for RTs, and RS RTs (1 paper each). In a study including, among others, private AVs and SAVs (Nazari et al. 2018), interest in MOD is positively associated with the intention to use SAVs for commuting. In another research, Winter et al. (2019) show that public transit users have a higher intention to use regular autonomous shuttle services than on-demand autonomous services, due to the extra effort involved by MOD planning.

Current mode choice

Experience of carsharing is explored in 8 papers. In 5 of them, it positively influences the intention to use SAVs. In the case of RS RTs, 2 papers (out of 2) find a positive influence on the intention to use this service. This proportion is 3 out of 6 for RTs. Experience of carsharing is not tested for AS. Zhou et al. (2020), Kontar et al. (2021), Krueger et al. (2016), and S. Wang et al. (2020) find a positive impact of prior carsharing experience on the intention to use SAVs. It is also easier to share a ride if respondents know the person they share the ride with (Abe 2021). Bansal et al. (2016) find a significant and negative relationship between carsharing experience and the intention to use SAVs. This is due to the unwillingness of carsharing users to pay more for an equivalent service with AVs.

Experience of public transport (PT) is explored in 6 papers. In 3 of them, it positively influences the intention to use SAVs. In the case of RTs, 2 experiments out of 3 find a positive influence on the

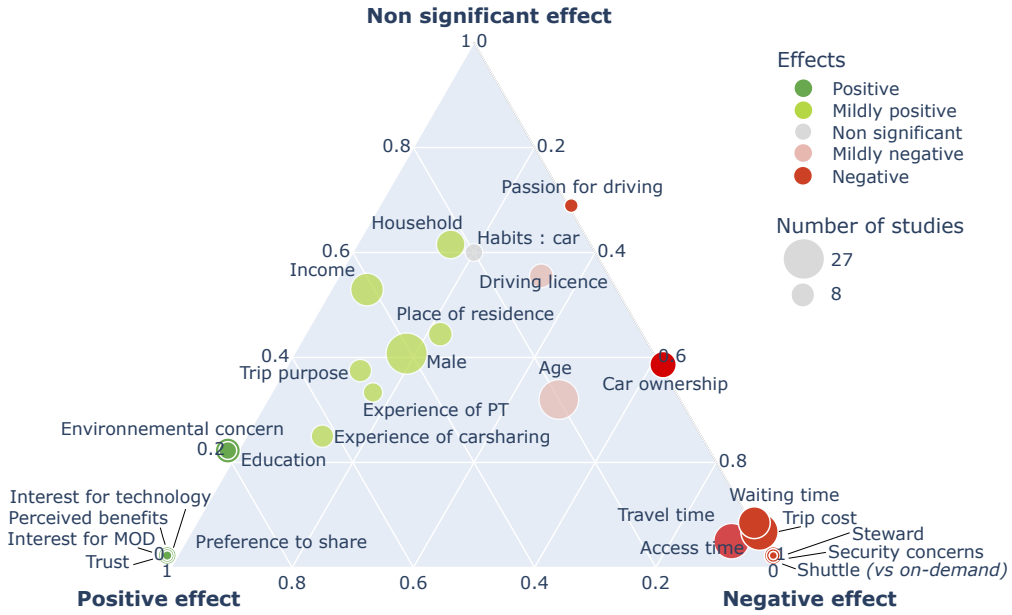

Figure 1: Research consensus on the effect of SAVs' acceptance factors. The colors are defined following equation 1

intention to use this service. This proportion is 1 out of 2 for RS RTs. Experience with, or regular use of PT in general has a positive impact on the intention to use AVs (Krueger et al. 2016; Steck et al. 2018; S. Wang et al. 2020). Winter et al. (2019) find that experience of PT is non-significant in the case of AS. In addition, the possession of a PT subscription has a positive effect on the intention to use SAVs. Kontar et al. (2021) suggest, however, that those who frequently use PT are significantly less likely to choose an AV, while K. Wang et al. (2019) find that individuals who reside in neighborhoods with adequate public transit services may be less likely to participate in a SAV system for daily commuting.

Car as the main travel mode is tested in 5 papers. It has mostly a non-significant effect (3 papers out of 5). It's found to have a positive effect on the intention to use RTs in 1 paper out of 2, and a negative effect on the intention to use RS RTs in 1 paper out of 3. Unlike Gkartzonikas et al. (2019) who assume that frequent drivers are more likely to prefer control of the vehicle, Kontar et al. (2021), Krueger et al. (2016), and K. Wang et al. (2019) find that driving control is non-significant for SAVs' adoption in metropolitan areas. Etzioni et al. (2020) determine in a cross national survey that car usage makes respondents more reluctant toward AV services in general.

3.4 Results' summary

For each variable, Figure 1 and Table 1 evaluate the consensus degree of the reviewed papers. The consensus degree is measured as equations 1 and 2, where Total(+), Total(-) and Total(NS), are the total number of studies with a positive, negative and non-significant effect.

$$CD = \frac{\max(Total(+); Total(-))}{Total(+) + Total(-)} \tag{1}$$

By design, $0.5 \leq CD \leq 1$. $CD = 1$ indicates a total consensus on the effect of the factor, i.e. either positive or negative effect. CD = 0.5 indicates a no consensus on the effect of the factor, i.e. 50% positive and 50% negative. In between, the consensus is not yet reached. In figure 1 and

table 1, the color of the variables shows the consensus degree. Darkest green, darkest red, indicates the most consensual variables with a positive, negative effect on SAVs' acceptance, respectively ($CD \geq 0.9$). Lightest green, lightest red, indicates a weak consensus with a positive, negative effect, respectively ($0.6 < CD < 0.9$). Gray corresponds to a $CD \leq 0.6$ or non-consensual effect.

The consensus degree is completed by the statistical significance indicator (SI):

$$SI = \frac{Total(NS)}{Total(+) + Total(-) + Total(NS)} \tag{2}$$

We assume that if $SI \leq 0.1$, i.e. less than 10% of studies indicate a non-significant effect, the variable is assumed significant. If $0.1 < SI < 0.5$ the variable is assumed to be moderately significant. If $SI \geq 0.5$ the variable is set to be non-significant.

Table 1: Main results of the literature review. Colors of the column Variables are defined by equation 1. SI column is defined according to equation 2. Non-significant factors/rows are colored in gray.

Variable groups	Variables	Robo Taxi			Ridesharing Robo Taxi			Autonomous Shuttle			Total			Total	SI
Effect direction		(+)	(NS)	(-)	(+)	(NS)	(-)	(+)	(NS)	(-)	(+)	(NS)	(-)		
Control variables	Gender (male)	5	8	4	3	3	1	3			11	11	5	27	*
	Age	5	6	6		2	6				5	8	12	25	*
	Trip cost			12		1	4			5	0	1	21	22	**
	Travel time	1	1	11			3			4	1	1	18	20	**
	Income	4	6	1	2	3		1			7	9	1	17	NS
	Waiting time		1	8			3			4	0	1	15	16	**
	Household	2	5	1	1	3	1				3	8	2	13	NS
	Own a car		4	4			3				0	4	7	11	*
	Education	5	2		2			1			8	2	0	10	*
	Place of residence	1	3	2	2	1					3	4	2	9	NS
	Driving licence		4	2	1	1	1				1	5	3	9	NS
	Trip purpose	3	2		1	1				1	4	3	1	8	*
	Access/Egress time			1			1			1	0	0	3	3	**
Attitudes	Environmental concern	3	1		1						4	1	0	5	*
	Pro-technology	2			1			2			5	0	0	5	**
	Passion for driving		2	1							0	2	1	3	NS
	Security concerns			3			1			1	0	0	5	5	**
	Trust in AV	2			2			1			5	0	0	5	**
Benefits	Perceived benefits of AV	2			1						3	0	0	3	**
	Presence of a steward									1	0	0	1	1	**
Pref. for shared flexible services	Interest for MOD	1			1						2	0	0	2	**
	Prefer to share	1									1	0	0	1	**
	Shuttle (VS on demand)									1	0	0	1	1	**
Current mode choice	Experience of carsharing	3	2	1	2						5	2	1	8	*
	Experience of PT	2		1	1	1			1		3	2	1	6	*
	Main mode: car	1	1			2	1				1	3	1	5	NS

4 Discussion

10 years after the first published papers on the intention to use SAVs, our literature review shows that various factors that are deemed to influence this intention still have a non-consensual effect. In this review, we included factors related to: socio-demographic characteristics of respondents (age, gender, income, to name a few), mode-specific characteristics (travel time, waiting time), contextual characteristics (urban, national), attitudes of respondents (pro-environment, safety concerns, for example), perceived benefits and travel habits. As Gkartzonikas et al. (2019), we find that most studies mainly focus on socio-demographic and travel characteristics. Less attention has been paid to the role of psychosocial factors in the economic literature. We find that the better acceptance of SAVs is among young males, with high income and education (moderate consensus, i.e. $0.6 < CD <$

0.9). These results are partly in line with Becker et al. (2017) since we show that the effect of gender and age is moderately significant ($SI > 0.1$) and moderately consensual (i.e. $0.6 < CD < 0.9$). Trip cost, travel and waiting times have a negative effect on SAVs' acceptance (high consensus, i.e. $CD \geq 0.9$ and high significance, i.e. $SI \leq 0.1$). Educational attainment improves SAVs' acceptance (high consensus, i.e. $CD \geq 0.9$, moderately significant, i.e. $SI > 0.1$). Owning a car or a driving license is negatively associated with the intention to use SAVs (moderate consensus, i.e. $0.6 < CD < 0.9$, moderately significant, i.e. $SI > 0.1$), while experience of carsharing or public transportation increase SAVs' acceptance (moderate consensus, i.e. $0.6 < CD < 0.9$, moderately significant, i.e. $SI > 0.1$). Finally, perceived benefits, technology savviness and trust in SAVs boost the acceptance of SAVs (high consensus, i.e. $CD \geq 0.9$ and high significance, i.e. $SI \leq 0.1$).

The majority of studies focus on RTs and RS RTs. SAVs' acceptance factors have similar effect on both types of RTs (shared or not). This cannot be confirmed in the case of AS due to the scarcity of research on these services (only 18% of reviewed papers).

The lack of consensus or significance on the effect of some important SAVs' acceptance factors may be attributable to various reasons: the nature of study areas, data collection methodologies or statistical models that are different from one study/survey to another. Future research needs to disentangle the effect of differences due to methodological approaches and to spatial/social contexts.

5 The specific case of psychosocial factors

About 30% of reviewed papers explore the effect of psychosocial factors on the intention to use SAVs. Most of these factors relate to attitudes or social norms. 33% of these papers discuss the psychosocial models behind these factors. The identified psychosocial factors are very heterogeneous and, in some cases, are related to concepts which belong to different theories of behavior. Gkartzonikas et al. (2019) and Jing et al. (2020) highlight the need for a clear theoretical framework to produce more robust predictors and demand predictions. A number of recent studies have proposed to fill this gap in the field of psychology.

The most widely used model is the Technology Acceptance Model (TAM) (Davis et al. 1989). The TAM predicts the intention to use a technology based on two factors: perceived ease of use and perceived utility. It is often preferred to other models thanks to its specification parsimony (Jing et al. 2020). Nordhoff, Madigan, et al. (2021) investigate the intention to use AS and find that the constructs of the unified theory of acceptance and use of technology 2 (UTAUT2) model (Venkatesh et al. 2012) are validated by the literature. UTAUT2 adds constructs of different acceptance models: social network influence, facilitating conditions, hedonic motivation, price value and habit.

Other variants of the UTAUT2 model exist: Yuen et al. (2020) study a mix of the theory of planned behavior and UTAUT2. The dimensions of the latter are mediated by attitudes toward SAVs. The constructs of the Theory of Planned Behavior (Ajzen 1991) (attitude, norms, perceived behavioral control) as well as the perceived ease of UTAUT2 are used as predictors of the intention to use SAVs. Nordhoff, Kyriakidis, et al. (2019) also design a multi-level model on automated vehicle acceptance (MAVA) based on the unified theory of acceptance and use of technology 3 (UTAUT3).

6 Conclusion and limitations

Despite the substantial research effort put into the study of autonomous mobility, research devoted to SAVs is still scarce. This literature review focuses on this type of services and updates the state

of knowledge with recent publications. It also reviews the main empirical and theoretical papers in psychology that consider the acceptance of SAVs.

This paper focuses on the factors of the intention to use SAVs. It reviews the methodologies used in discrete choice surveys, survey areas, the statistical models used to analyze the data and their specifications. Some effects seem strongly consensual: travel costs and times, educational attainment. On the other hand, other effects remain controversial and need further research: age, gender, income, car ownership, driving license or preferences of rural households. Despite the scarcity of research on the effect of psychosocial factors in the economic literature, there seem to be a consensus on their importance. Further research on this subject is needed. Future work should integrate psychosocial and economic models to better assess the role of attitudes and other psychosocial constructs in the intention to use SAVs. Finally, more emphasis needs to be put on the intention to use SAVs in rural or suburban areas.

This research is subject to several limitations. This review is based on 29 articles published in the economic literature between 2015 and 2021. Papers that do not use the discrete choice experiment method were not included. Further research could expand this set by integrating other survey methodologies to include new variables and strengthen the validity of the ones included in this research. In order to compare different research studies, simplifications have also been made to harmonize their methodologies. An effort has been made, for example, to make consistent the definition of the variables and their attribute levels for all surveys. This harmonization might introduce a bias in our results.

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