A Literature Review on Surveys for Autonomous Vehicles

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ABSTRACT

This paper provides a structured overview of studies published in peer reviewed journals, conference proceedings and technical reports on surveys for autonomous vehicles from 2012 onward. The different items and descriptions of the studies are summarized and hence, the different methodologies and study objectives are presented. In particular, the reviewed studies are classified into categories about the procedure of adopting autonomous vehicles (AVs), likelihood of adopting AVs, perception of technology and operations, preferred modes of AVs operations, behavioral characteristics and perceptions, willingness-to-pay for AVs, and perceived benefits of AVs. In addition, the key findings of some representative studies, research gaps and concluding remarks are provided. This paper can be of interest to both the research community and industry contemplating the deployment of autonomous vehicles.

INTRODUCTION

Nowadays, technology is altering both vehicles and transportation systems. Specifically, there is a rising interest in autonomous vehicles related to rapid technological developments. Various research studies are currently being undertaken that examine potential impacts of the wide implementation of autonomous vehicles on the transportation system. Behavioral experimental studies in form of surveys have examined the general acceptance of the technological advances and also, explored which factors, and to what extent influence people's decisions towards autonomous vehicles. The objective of this paper is to provide a comprehensive review of the literature about behavioral experiments (surveys) of autonomous vehicles. The surveys are categorized based on their respective methodology, target population, categories of questions included and their results. The rationale on the selected categorization of the literature is provided in the methodology section, followed by a few examples of studies per category. Lastly, some research gaps are identified and discussed in the conclusions section.

METHODOLOGY

This paper critically reviews the current literature on surveys conducted for autonomous vehicles and every publication of such behavioral experimental studies has been taken into account. The majority of studies included questions on Level 4 full self-driving automation vehicles, as defined by NHTSA (NHTSA, 2013) – *"the vehicle that is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available*

for control at any time during the trip. This includes both occupied and unoccupied vehicles". Additionally, some studies included questions on Level 3 limited self-driving automation vehicles, as defined by NHTSA – *"vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time."*

Table 1 provides an overview of the studies that were reviewed as part of this paper. Information is provided for each study about the study period (year that the survey was conducted), the publication year, the location of where the survey was distributed, the target population, number of responses, and the distribution method. As it can be seen in Table 1, some surveys targeted a general population of a region, a country or even countries, some others targeted a specific group of people (for example, drivers), whereas other studies involved focus groups of transportation experts.

Table 1: Summary of Selected Studies from Literature on Surveys for Autonomous Vehicles

Authors	**Year**	**Study Period**	**Location**	**Target Population**	**Distribution Method**	**Number of Responses**
Bansal et al. (a)	2016	2014	Austin, TX	general population	online	347
Bansal & Kockelman (b)	2016	2016	US	general population	online	2,167
Begg	2014	2012	London, UK	transportation experts	online	3500
Brown et al.	2014	2014	19 countries	general population	online	23,000
Casley et al.	2013	2013	Worcester, MA	Students and people older than 60 years old	online	107
Continental	2015	2015	US, Germany, Japan, China	Vehicle owners, transp. experts	focus groups, online	4,100
Daziano et al.	2017	2014	US	general population	online	1,260
Haboucha et al.	2017	2014	Israel, USA, Canada	general population	online	721
Hohenberger et al.	2016	2014	Germany	general population	online	1,603

Howard & Dai	2014	2013	Berkeley, CA	general population	paper based (survey & video)	107
Ipsos Mori	2014	2014	UK	general population	online	1,000
Krueger et al.	2016	2015	Australia	general population	online	435
Kyriakidis et al.	2015	2014	109 countries	general population	online	4,886
Payre et al.	2014	2013	France	general population	interview, paper based, online	347
Power (a)	2012	2012	US	vehicle owners	online	17,400
Power (b)	2013	2013	US	vehicle owners	online	>15,000
Schoettle & Sivak (a)	2014	2014	US, UK, Canada	general population	online	1,596
Schoettle & Sivak (b)	2014	2014	US, UK, Canada	general population	online	1533
Seapine Software	2014	2014	US	general population	online	2038
Shin et al.	2015	2012	South Korea	general population	online	675
Silberg et al.	2013	2012-2013	CA, IL, NJ	vehicle owners	10 focus groups	32
Underwood et al.	2014	2014	USA	transportation experts	online	217
Vallet	2013	2013	USA	vehicle owners	online	2000
Young	2014	2014	US	vehicle owners	online - follow up	15,171
Zmud et al.	2016	2015	Austin, TX	general population	online	556

Table 2 provides a summary of the studies' objective and the methodology adopted in each study. Specifically, more than half of the reviewed studies only reported a descriptive analysis of the survey results. The rest of the reviewed studies conducted some sort of econometric analysis.

Table 2: Summary of Studies According to their Objective and Methodology

Authors	Year	Study Objective	Methodology
Bansal et al. (a)	2016	• Estimate the average willingness-to-pay for fully and partial automated vehicles. • Estimate adoption rates of shared autonomous vehicles using different pricing scenarios.	• Multivariate ordered probit models.
Bansal & Kockelman (b)	2016	• Develop a framework to forecast long term adoption levels of connected and autonomous vehicles. • Estimate adoption rates of shared autonomous vehicles using different pricing scenarios.	• Multinomial logit models to determine the probabilities of annual decisions to buy, sell or replace a vehicle. • Different simulation scenarios for long term adoption.
Begg	2014	• Understand expectations and concerns on advanced vehicle technologies in London, UK.	• Descriptive analysis.
Brown et al.	2014	• Estimate people's preferences on autonomous vehicles in different markets around the world.	• Descriptive analysis.
Casley et al.	2013	• Identify the key influences that might impact the desirability of autonomous vehicles (related to cost, safety, legislation, productivity, efficiency, and environment).	• Descriptive analysis. • Factor analysis to test six research hypotheses.
Continental	2015	• Understand the acceptance of	• Descriptive analysis.

		autonomous vehicles in different countries and whether the technology is welcome.	
Daziano et al.	2017	• Estimate the willingness-to-pay for fully and partial automated vehicles.	• Conditional logit models. • Parametric and semi-parametric logit models.
Haboucha et al.	2017	• Understand what motivates the intention to use autonomous vehicles. • Estimate long term decision mode choices.	• Confirmatory factor analysis. • Logit Kernel model with panel effects.
Hohenberger et al.	2016	• Estimate the willingness to use autonomous vehicles. • Identify potential differences among gender or age groups.	• Conceptual moderated mediation model. • Ordinary least squares.
Howard & Dai	2014	• Investigate people's attitudes towards autonomous vehicles.	• Descriptive analysis.
Ipsos Mori	2014	• Investigate awareness and attitudes on autonomous vehicles. • Perceptions of potential concerns and benefits.	• Descriptive analysis.
Krueger et al.	2016	• Identify characteristics of potential users who may adopt the use of shared autonomous vehicles. • Elicit willingness-to-pay measures for service attributes (travel time, waiting time, and fares).	• Mixed logit model.

Kyriakidis et al.	2015	• Examine user acceptance, risks, and willingness-to-pay towards fully and partial automated vehicles in different countries.	• Descriptive analysis.
Payre et al.	2014	• Explore to what extent drivers are willing to accept the use of autonomous vehicles. • Investigate and link attitudes to the intention to use autonomous vehicles.	• Confirmatory factor analysis. • Hierarchical linear regression.
Power (a)	2012	• Estimate willingness-to-pay for autonomous vehicles.	• Descriptive analysis.
Power (b)	2013	• Estimate willingness-to-pay for autonomous vehicles.	• Descriptive analysis.
Schoettle & Sivak (a)	2014	• Investigate public opinion towards emerging technologies in different countries.	• Descriptive analysis.
Schoettle & Sivak (b)	2014	• Understand the perceptions towards autonomous vehicles in different countries. • Estimate willingness-to-pay for autonomous vehicles.	• Descriptive analysis.
Seapine Software	2014	• Examine concerns towards the emergence of autonomous vehicles.	• Descriptive analysis.
Shin et al.	2015	• Explore consumer preferences for alternative fuel types of advanced vehicle technologies.	• Multiple discrete-continuous probit model of vehicle type choice. • Multinomial probit model of smart

			vehicle choice and option valuation.
Silberg et al.	2013	• Investigate the decision to purchase autonomous vehicles.	• Descriptive analysis.
Underwood et al.	2014	• Explore people's opinion on future emergence of autonomous vehicles. • Identify research and policy changes on autonomous vehicles.	• Descriptive analysis.
Vallet	2013	• Investigate the willingness to purchase autonomous vehicles.	• Descriptive analysis.
Young	2014	• Estimate willingness-to-pay for autonomous vehicles.	• Descriptive analysis.
Zmud et al.	2016	• Investigate the intention to use autonomous vehicles and the factors that are associated with it. • Explore potential benefits and concerns towards autonomous vehicles.	• Descriptive analysis.

KEY FINDINGS

Each behavioral experimental study had a different objective, included different categories of questions targeting a different sample (general population or transportation experts) in different countries. As such, the behavioral experimental studies were classified into categories based on the study objective. The categories that were used are studies about: a) the process of the adoption of autonomous vehicles, b) the likelihood of autonomous vehicle adoption, c) the perceptions of various aspects of technology and operation of autonomous vehicles, d) the level of awareness and general attitudes on autonomous vehicles, e) the preferred modes of the operation on autonomous vehicles, f) behavioral characteristics and perceptions of autonomous vehicles, g) the willingness-to-pay for fully autonomous vehicles, and h) the perceived benefits of autonomous vehicles. Additionally, Table 3 provides information on the classification of all the reviewed studies by the study objective.

Table 3: Classification of Reviewed Studies According to the Study Objective

Authors	**Year**	Process of adoption of Avs	Likelihood of adoption of Avs	Perception of technology and operations	Level of awareness and attitudes on Avs	Preferred modes of AVs operation	Behavioral characteristics and perceptions	Willingness-to-pay for AVs	Perceived benefits/concerns of AVs
Bansal et al. (a)	2016			x			x	x	x
Bansal & Kockelman (b)	2016			x			x	x	
Begg	2014	x	x						
Brown et al.	2014						x		
Casley et al.	2013			x			x		x
Continental	2015	x	x						x
Daziano et al.	2017							x	x
Haboucha et al.	2017				x	x	x		
Hohenberger et al.	2016				x		x		
Howard & Dai	2014			x			x	x	x
Ipsos Mori	2014						x		
Krueger et al.	2016				x	x	x		
Kyriakidis et al.	2015			x	x		x	x	
Payre et al.	2014				x	x	x	x	
Power (a)	2012				x	x	x	x	
Power (b)	2013				x	x	x	x	
Schoettle & Sivak (a)	2014			x	x		x	x	x
Schoettle &	2014			x	x		x	x	x

Sivak (b)									
Seapine Software	2014			x					x
Shin et al.	2015			x				x	
Silberg et al.	2013	x	x						
Underwood et al.	2014	x	x						
Vallet	2013	x	x						x
Young	2014				x	x	x	x	
Zmud et al.	2016				x		x		x

The first category includes studies about the process of the adoption of autonomous vehicles, where different scenarios of market adoption and penetration were introduced to the survey participants. For example, Silberg et al. (2013) developed a survey which targeted focus groups in California, New Jersey and Illinois asking their opinion on autonomous vehicles by developing different scenarios and business models for diffusion of autonomous vehicles in transportation systems. It was found that the respondents were more interested in adopting autonomous vehicles when they were provided incentives like having designated lanes for autonomous vehicles. Additionally, people older than 60 years old and people between 18 and 25 years old stated the highest willingness-to-pay. Furthermore, according to the technical report by Vallet (2013), more than half of the respondents were interested in purchasing an autonomous vehicle and also, approximately 25% of the respondents would allow their children to ride one.

In the second category, Begg et al. (2014) developed a survey about the likelihood of autonomous vehicles adoption targeting a cross-section of transportation experts in London, U.K. to ascertain their perception on whether and how soon the respondents would expect autonomous vehicles to become a reality. In the survey, 35% of the respondents stated that Level 2 autonomous vehicles would be on the UK roads by 2025, around 28% stated that Level 3 autonomous vehicles would be on public roads by 2040, and almost 25% stated that road safety would improve with the implementation of autonomous vehicles.

Furthermore, one study that is included in the category of perceptions of various aspects of technology and operation on autonomous vehicles (third category) developed an online survey of 1,533 respondents in the UK, US and Australia (Schoettle et al., 2014). This study investigated the familiarity of respondents with autonomous vehicles, the benefits and concerns about the emergence of autonomous vehicles, the interest in owning one, and people's willingness-to-pay. It was found that 66% of respondents were aware of autonomous vehicles before the survey, 72% expected increases in fuel economy, 43% expected increases in travel time savings, and more than half of the respondents did not want to pay more for advanced technologies and features installed on autonomous vehicles. Additionally, according to Seapine Software study, it was found that approximately 88% of the respondents were concerned on riding AVs, 79% were

worried about equipment failures, 59% were concerned on liability issues and 52% about hacking issues.

Turning to the level of awareness and general attitudes on autonomous vehicles, Kyriakidis et al. (2015) conducted a survey of 4,886 people in 109 countries using a crowd-sourcing internet survey. That study investigated acceptability, concerns and willingness-to-pay for all level of autonomous vehicles. It was concluded that respondents with higher vehicle-miles-traveled (VMT) and who used cruise control in their personal vehicles were more likely to pay more for an autonomous vehicle. Also, 20% of the respondents stated that they would be willing to pay $7,000 more for a Level 4 fully autonomous vehicle and 69% stated that autonomous vehicles could gain around 50% market share by 2050.

On a similar note, in the category of preferred modes of the operation on autonomous vehicles, a survey was developed using an online tool in France. 421 drivers were asked about their attitudes and a priori accessibility of autonomous vehicles, as well as their intention to use an autonomous vehicle with a focus on Level 4 fully autonomous vehicle using a scoring system (Payre et al., 2014). It was concluded that 68% of the respondents scored more than 4 out of 7 regarding the acceptability of autonomous vehicles and also, older people were less likely to pay for such technologies while showing more acceptance towards them. As it was found in the study conducted by Haboucha et al. (2017), older people tend to prefer private vehicles than autonomous vehicles. It was found that men in Israel tend to prefer more shared autonomous vehicles than private vehicles or privately-owned autonomous vehicles. Similarly, people with higher level of education than others have a tendency towards autonomous vehicles than private vehicles.

Moreover, a study that is included in the category of behavioral characteristics and perceptions of autonomous vehicles developed an interview-format survey targeting students; for older participants, an online tool was used asking about people's opinion on autonomous vehicles (Casley et al., 2013). A total of 467 responses were obtained regarding the influential features to determine the desirability of autonomous vehicles it was found that safety influenced people's decision by 82%, legal issues/regulatory by 12%, and cost by 7%. Interestingly, 58% of the responses were unfamiliar with current laws regarding testing and operating of autonomous vehicles. Furthermore, Ipsos MORI (2014) indicates that younger people are more likely to adopt these emergent technologies or people living in condensed areas such as metropolitan areas. According to Hohenberger et al. (2016), it was found that emotion and affective reaction towards autonomous vehicles indicate differences across gender towards the willingness to use automated vehicles. Specifically, it was found that men were more likely to anticipate pleasure and not anxiety which is associated with the willingness to use autonomous vehicles.

Turning to studies on willingness-to-pay for autonomous vehicles, Bansal et al. (2016a) conducted a survey in Austin, TX where people indicated that they were willing to pay around $7,000 more on average for a Level 4 autonomous vehicle and around $3,300 more for a Level 3 autonomous vehicle. Moreover, as it is indicated in the study by Daziano et al. (2017), the average U.S. household was willing to pay $3,500 for partial automation and approximately $4,900 for full automation.

In the last category of the perceived benefits of autonomous vehicles, Schoettle et al. (2014b) developed an online survey in the UK, US and Australia with a total of 1596 responses including questions about people's opinion regarding connected-vehicle technologies. It was found that

only 25% of the respondents were aware about autonomous vehicles prior to the survey, 86% expect fewer accidents, 61% expected less distraction for the driver, and 84% of the respondents thought that safety was the most important benefit. Likewise, as it is indicated in Continental Mobility Study (2015), it was found that 60% of the respondents were expected to use AVs in stressful driving scenarios and more than half of them believed that crashes may be prevented due to emergence of autonomous vehicles. Howard et al. (2014) found that 75% of the respondents stated that safety was the most attractive feature of AVs. On another note, around that 70% and 69% of the respondents indicated that liability issues and purchasing cost, respectively are the least attractive features of AVs.

CONCLUDING REMARKS

Behavioral experimental studies have been conducted over the last few years worldwide exploring people's perception towards autonomous vehicles, in attempt to predict the market penetration rate and ascertain people's willingness-to-pay for autonomous vehicles. These studies gauged not only the public perspective on autonomous vehicles but also, the perspective of transportation experts which can provide valuable insights for policy-making. This paper highlights the different categories and objectives of prior surveys on autonomous vehicles, as well as presents the methodology that was adopted and the key findings.

The literature review on surveys for autonomous vehicles revealed that most of the studies have examined the behavioral characteristics, perceptions and attitudes towards autonomous vehicles using descriptive analysis, or some sort of econometric analysis. Interestingly, models of the intention to use autonomous vehicles based on theories, such as the theory of reasoned action (Fishbein et al., 1975) and the theory of planned behavior (Ajzen, 1991), which can relate behavior with attitudes, have not been estimated to date. While some studies investigated the process and likelihood of adopting autonomous vehicles, the questions of their surveys were not based on the theory of diffusion of innovation (Rogers, 1995). Such approach can very simply explain how, why and to what extent an emerging technology like autonomous vehicles can be spread out and as such, it is recommended to be used in future studies.

Both researchers and transportation professionals can benefit from a condensed review of the literature on the public and experts' perceptions of this emerging technology. Researchers can build on the existing work and address the research gaps identified, while transportation professionals contemplating the implementation of autonomous vehicles can benefit from the important insights regarding autonomous vehicle adoption.

Note that this paper on the literature review on behavioral studies on autonomous vehicles consists the current status quo. However, due to the emergent nature of the topic in transportation, the state of the art in this area is rapidly changing as numerous behavioral studies are currently being conducted both in the US and internationally.

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