Public Perception of Automated Driving Systems and Modleing of User Acceptance

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ABSTRACT
The objectives of this study were firstly to understand public perception of Automated Driving Systems (ADSs) and secondly to develop acceptance models of users' intentions to use fully ADSs, including both personally-owned fully ADSs and shared-use fully ADSs. This study consisted of two phases, including focus group studies and online surveys. In Phase 1, through 7 focus group discussions, public perception regarding factors influencing technology acceptance was investigated. Participants' perspectives on various questions of ADS implementations were also explored, including (1) education and training, (2) consumer incentives, (3) shared-use fully ADSs, (4) data privacy and ownership, and (5) liability and insurance. After identifying the critical factors influencing acceptance of fully ADSs from the focus group discussions, we designed two questionnaires and conducted two online surveys. The goal of the online surveys was to verify the hypothesized framework of acceptance model for both personally-owned fully ADSs and shared-use fully ADSs. Our study shows that the factors of safety, trust, compatibility, and perceived usefulness had significant contribution to intention to use for both personally-owned fully ADS and shared-use fully ADS. However, there were noticeable differences between the models for the two fully ADS concepts. In the model for personally-owned fully ADS, safety, trust, and compatibility played a more meaingful role while perceived ease of use had less significant impact on intention to use, as compared with the acceptance model for shared-use fully ADS.

Keywords: personally-owned fully automated driving system, shared-use fully automated driving system, user acceptance of fully automated driving system

INTRODUCTION

While road transportation is an essential service in society, the burden of traffic accidents and traffic congestion is immense. The NHTSA reported that 37,461 people lost their lives in traffic accidents on the US roadways in the year of 2016. The data showed two consecutive years of growth in highway fatalities. According to NHTSA human errors accounted for more than 90% of traffic accidents. At the same time, the U.S. ranked as the most traffic-congested developed nation in the world, according to INRIX 2017 Global Traffic Scorecard (http://www.inrix.com/). On average, Americans spent an average of 41 hours a year stuck in traffic during peak travel time in 2017. In many cities in California, the situation is much worse. For example, Los Angeles and San Francisco were found as first and fifth congested cities in the world respectively in 2017. Researchers argued that fully automated driving systems (ADSs) have the potential to resolve some of the current transportation challenges and to improve road safety and efficiency (*1-3*). The extent of these benefits will depend on successful deployment and widespread adoption of fully ADSs, which in turn are heavily affected by public perception. Howard and Dai (*4*) identified many other challenges of fully ADSs that are yet to be addressed, such as liability issues, security, and control of the systems.

In addition to public perception, legislation and policy domains are also complicating issues that will affect consumer adoption. Policy questions regarding liability, privacy, licensing, security, and insurance regulations remain mostly unanswered (*5*). Although individual states in the U.S. have been advancing ADS legislation (*6*), federal regulations have not yet been put in place for fully ADSs beyond testing purposes on public roads. Nevertheless, auto manufacturers are continuing their effort and investment in the development of ADSs. Several auto manufacturers have introduced level-2 and plus automation into the market, such as Tesla's Autopilot, Audi's AI traffic jam pilot, General Motors' super cruise and Mercedes Benzes' Drive Pilot. In addition, tech companies like Google and Uber are developing fully ADSs and experimenting with their vehicles on the public roads. In light of these advancements in ADS development, there is a strong need for policymakers to address the policy concerns and facilitate the technology development.

The objectives of this study were to understand public perception of ADSs, and to develop an acceptance model that can help understand user intentions to accept and use fully ADSs. We adopt an innovative and integrated framework of user acceptance model for fully ADSs. We divide the study into two phases, which included: (1) focus group discussions and (2) online surveys. Relevant public perception regarding ADS implementation that were investigated in this study include: (1) education and training; (2) consumer incentives; (3) shared-use fully ADSs; (4) data privacy and ownership, and (5) liability and insurance. Two forms of fully ADSs, including personally-owned fully ADSs and shared-use fully ADSs are studied. Findings of this study offer guidelines that can help public agencies to better address the alignment and synergy of public policies with the trend of ADSs to benefit road users as well as the general public.

LITRATURE REVIEW

Fully ADSs are one of the most innovative and fundamentally disruptive changes in transportation. This technology has the potential to resolve or mitigate the current transportation problems, which include but are not limited to traffic accident, congestion, energy consumption, and pollution (*1-3*). However, one of the unknow challenges for widespread adoption of fully ADSs is public perception (*4*). There are various studies which investigated public perception regarding fully ADSs. The study, which surveyed 5000 individuals in 109 countries, found that responders believed that diving with fully ADS would be easier than manual while partially ADSs would be more difficult (*7*). Software hacking and misuse, legal issues, and safety were found as their concerns. The other international study included more than 1,500 persons' opinion from the U.S., the U.K., and Australia found that responders had a positive opinion and high expectations regarding the fully ADSs (*8*). They identified security and privacy, learning to interact with fully ADSs, vehicle performance in poor weather as their concerns. The case study at the University of California at Berkeley investigated the local public perception. After surveying 107 individuals, they found that the most attractive features of fully ADSs were safety, amenities like multitasking, and convenience, while the least features of them were liability, costs, and vehicle control. However, different approaches, data sources, and variables of the available studies made it difficult to compare results. Additionally, most of the available research used qualitative research methods such as survey while there was a lack of quantitative research methods such as focus group in literature (*9*).

Policies and regulations could address these public concerns for facilitating the emerging technology adoption to benefit road users and the society as a whole. Some U.S. states have adopted regulations, but federal policy has not been fully implemented. Fagnant and Kockelman (*5*) identified licensing and certification, liability, insurance, security, and privacy as policy barriers to implementation. Moreover, all these enhancements in fully ADSs regulations should be consistent in all states to avoid overregulation and incompatible requirement issues which would make it impossible to operate across the states (*1*). There were research gaps in public policies in state, federal and international level and their impacts on public acceptance of ADSs, which prompted this study to explore public perception regarding ADS deployment.

Since the technology of fully ADSs is under development and not fully accessible to the public, some researchers have resorted to studies on the perception of partially ADS end-users to help evaluate certain issues related to fully ADS user. Some recent studies investigated the perception of partially ADS end-users by using different methodologies (*10-12*). A naturalistic study, which based on the author's driving experience with partial automation, revealed the situation awareness and the technology interaction challenges (*11*). One other study, which was based on online survey, investigated end-users experience and attitude toward partial automation failures. It was found that although automation failures were common, end-users who had high driving and computer experience did not perceive the failures as risks (*10*). In an interview-based study, which conducted with 20 Tesla end-users, drivers' behavior adoption was investigated. The authors highlighted end-users' positive attitude and their trust in the technology (*12*). All the mentioned studies pointed out the importance of technology acceptance and the factors influencing end-users' behavior, which need further research (*10-13*).

There have been limited research on acceptance of fully ADSs followed a theoretical or conceptual model of acceptance and use (*9*). Moreover, a various network of factors may affect user's decision whether to use ADSs (*14*). Conceptual models have been developed to address technology acceptance, starting with an extended Technology Acceptance Model (TAM) (*15*). This theory explained user acceptance and intention to use. TAM determines two beliefs to impact user's intention to use: (1) perceived usefulness, which reflects user's belief regarding how using an information technology will enhance his or her performance, and (2) perceived ease of use, which explains user's belief regarding how using an information technology will be free of effort. Gazizadeh et. al. (*16*) extended TAM to better reflect automation acceptance and added compatibility and trust factors to the model. Compatibility reflects the technology's consistency with the possible user's values and past experiences and needs. Trust reflects the user's beliefs regarding the system capability to complete its primary functions. Another factor that should not be neglected in driving environment is safety. Osswald et. al. (*17*) advocated safety as an important factor for acceptance models related to driving environment. They believed that perceived accident risk and risk of violence were related to feelings of safety and defined it as "individual believes that using a system will affect his or her well-being." On the other hand, Choi and Ji (*18*) who constructed a model for trust and its relation to automation acceptance found that perceived risk was a major factor linked to trust. They considered perceived risk as the self-reflective character of perceiving a situation as hazardous. Therefore, by jointly considering the safety definition by Osswald et. al., and the negative relationship between trust and perceived risk by Choi and Ji, safety and trust should have the positive relationship. The aforementioned studies included some of the important constructs for acceptance of fully ADS in their models. In this study, we included constructs suggested by previous studies and aimed to validate their relationships through online surveys for both personally-owned fully ADS and shared-use fully ADS concepts.

METHODOLOGY AND RESULTS OF PHASE ONE: FOCUS GROUP

Methodology of Phase One: Focus Group

The overall objectives of this study are to understand user acceptance and their expectation regarding ADS implementation from users' viewpoint. Specifically, the goals of the focus group study are to identify the important factors influencing user acceptance and to understand public perception regarding the following five domains: (1) education and training; (2) consumer incentives; (3) liability and insurance; (4) data privacy and data ownership; and (5) shared-use fully ADS.

Participants

Seven focus groups were conducted. Each group consisted of 6 to 12 participants. The total number of participants in all seven groups is 59. Each participant received a minimum compensation of 20 dollars. The background of participants in each group varies. The goal was to recruit participants that could offer a broad range of different perspectives from all walks of potential end-users of fully ADSs. These groups differed in terms of transportation needs, household income and existing knowledge of ADSs. Some characteristics of the groups are highlighted below.

(1) The first group consists of elderly drivers, 65 or older.
(2) The second group represents researchers who work in the transportation and/or automated vehicle area.
(3) The third group comprises transportation professionals from a government agency, who work on various transportation problems on the daily basis.
(4) The fourth group includes college students.
(5) The fifth group participants are Silicon Valley professionals.
(6) The sixth and seventh groups include representatives of insurance professionals from one major insurance company in the US.

Procedures

Each focus group took place at a location that was convenient for all participants in that group. At the beginning, participants were given a brief introduction of the study, including the purpose and the procedure of the study. After the introduction, participants were asked to read and sign an informed consent form. Then participants were asked to fill out a demographic information form, including questions such as age, gender, education level, driving experience, income, level of education and ADS experience. After completion of the demographic information form, participants were shown a 5-minute long presentation introducing different levels of automation, definition of fully ADSs and exemplar prototypes of both personally-owned and shared-use fully ADSs. Afterwards, the moderator posed questions regarding fully ADSs, one topic after another, and led the group in discussions to share their opinions, interact with other participants and build upon the ideas of one another. The discussion duration of each topic was controlled to be within 10 minutes. Audio recording was made throughout the discussion. Besides the lead moderator, two other moderators participated in the focus group study, controlling the presentation of slides, pace of discussions, and making notes of the discussion. For each group, four to six topics were covered within one and a half hours approximately.

Results of Phase One: Focus Group

After each focus group, the research team held a debriefing session to reflect upon all the specifics of the discussion. Categories for coding of the participants' statements were aligned with the factors in the proposed technology acceptance model.

The mean age of all participants is 45.29 (SD=16.35). They are relatively highly educated (91%) and approximately 60% have some ADS experience. Additionally, almost half of them (54%) consider themselves as late or laggard technology adaptor.

Table 1 shows the coding scheme and percentage of occurrence of feedbacks in each topic. The counts and percentages of various feedbacks in each topic are provided for descriptive purposes.

TABLE 1 Coding Scheme and Percentage of Feedbacks

Technology acceptance		**Education and training**		**Incentives**	
• Safety	19 (35.85%)	*Whether need training for using fully ADS?*		Need incentives	16 (50.00%)
• Benefits	11 (20.75%)	• Need training	34 (68%)	Not need incentives	7 (21.88%)
• Vehicle Control and Compatibility	7 (13.21%)	• Not need training	16 (32%)	Built-in incentives	5 (15.63%)
• Trust	6 (11.32%)	*Whether training should be mandatory or optional?*		Depends…	4 (12.50%)
• Ease of use	4 (7.55%)	• Mandatory	5 (35.71%)		
• Cost	3 (5.66%)	• Optional	9 (64.29%)		

• Convenience	2 (3.77%)				
• Share with others	1 (1.89%)				
Liability and insurance		**Data privacy and ownership**		**Shared-use fully ADS**	
Is insurance needed?		*Overall perception of data privacy issue*		*Expected experience*	
• Need insurance	24 (72.73%)	• Issue exists in various domains		• Clean and comfortable	
• Not need insurance	5 (15.15%)	• Data for product support		• Fast response from the dispatch center	
• Built-in insurance	4 (12.12%)	• Personal data		• Designated route or door-to-door services	
Who is responsible for an accident?		• Don't know value of the data		• Option of not sharing with others	
• OEM	8 (50.00%)	*Data ownership and other rights*		• Emergency response	
• Owner	6 (37.50%)	• To share	14 (50.00%)	• ADA Compliance	
• Both	1 (6.25%)	• To own	9 (32.14%)	*Likes and dislikes*	
• Programmer	1 (6.25%)	• No personal data	4 (14.29%)	• Likes	13 (46.43%)
How to define the responsibility in case of accidents?		• Only to know	1 (3.57%)	• Dislikes	15 (53.57%)
• Technology to detect pedestrian	4 (36.36%)	*Usage of data and privacy concerns*		*Approaches to enhance safety*	
• New law system	4 (36.36%)	• No commercial use	10 (55.56%)	• Cameras	11 (40.74%)
• Use data	3 (27.27%)	• To improve technology	7 (38.89%)	• Identification	8 (29.63%)
		• Don't care	1 (5.56%)	• Options	5 (18.52%)

• Others	3 (11.11%)

Technology Acceptance

The following question was asked: "What are the factors that will have influence on your acceptance of the fully automated driving system?" This topic was discussed within 4 groups: the elder-driver group, the researcher group, the Silicon Valley professional group and one of the insurance professional groups. In total, there are 53 statements about factors that influence technology acceptance. Each factor and statements are summarized as follows:

- **Safety:** The most mentioned factor that influenced participants' acceptance of the fully ADS was safety. Participants elaborated on safety as (1) "*being safer than me as a driver", (2) "not hurting other road-users", (3) "not involving in fatal crashes", (4) "being able to deal with emergency situations", and (5) "being able to function on improperly maintained roads"*. Participants thought that the fully ADSs should be well-tested and examined by a third-party rather than by the manufacturer.
- **Benefits and usefulness:** The expected benefits and usefulness could be divided into three categories: (1) saving time and effort for something else instead of fighting in the traffic, (2) being comfortable, and (3) presenting a good social image of the owner.
- **Option of vehicle control and compatibility:** Participants wanted to occasionally have control of the vehicle and enjoy driving themselves. Participants also deemed it necessary to take over vehicle control at certain conditions. As for shared-use fully ADSs, participants expected the driving style to be compatible with a manually driven vehicle. It was expected to not take longer time to arrive a destination, even though the driving style of the fully ADSs might be too conservative. Participants also expressed that with shared-use fully ADSs, they would't be able to keep the personal belongings inside of the vehicle, which would be inconvenient for families with kids.
- **Trust:** The most salient reason that participants wouldn't trust fully ADSs was cyber security and computer glitches. Participants had the concern that computer wouldn't be able to always function as supposed to. In case of the computer malfunction, the consequence would be much more severe for fully ADSs. Some participants mentioned that they would build the trust of fully ADSs gradually by starting with using ADAS (Advanced driver assistance system). Some participants also mentioned that they would like to build their trust in a system based on other people's experience with fully ADSs.
- **Other factors:** Ease of use, cost, convenience, and option of sharing with others. Participants expected the fully ADSs to be as easy as a regular vehicle, easy and intuitive to communicate with, and responsive in emergency situations. Participants expressed the concern of how much the fully ADSs would cost. Affordability was an important factor that would influence user acceptance. Regarding shared-use fully ADS, participants expressed the concern of convenience and reluctance of sharing with others. One example was *"(I am) not comfortable to share with other people at the same time. Don't want to be distracted while doing some work."*

Education and Training

For this topic, several questions were asked, including "Do you think training for using fully ADSs is needed?" "What kind of training is preferred?" "What would you like to learn?" This topic was discussed in all seven groups. Overall, training was considered needed but optional as commented by most of the participants. Multiple approaches of training material should be available, to accommodate people's preference and needs in different situations. Training of safety precautions and instructions of what to do during emergency situations were deemed as critical.

In elderly group, we discussed weather they think special training was needed for elderly drivers. Participants gave feedback, which applied not only to elderly drivers but also to all driver groups because *"... This has high consequences to it…."*. However, "*... they (the manufacturers) are not going to be able to anticipate everything which are going to go wrong and they're going to adjust it*."

Consumer Incentives

For incentive, the question was asked "Do you think incentive is needed for people who buy a personally-owned fully ADSs and for people who use shared fully ADSs?" This topic was discussed in all seven groups. Most participants agreed on providing incentive to shared-use fully ADSs as it would help to reduce the number of vehicles on the road and make traffic flow faster. Format of incentive for shared-use fully ADSs could be either dedicated lane or lower price. Whether giving incentive to personally-owned fully ADSs should (1) depend on the benefits that it would contribute to the society and (2) be market driven.

Shared-Use Fully ADSs

Three questions were asked (1) "What experience do you expect while riding in shared-use fully ADSs?" (2) "What aspects do you like and dislike about shared-use fully ADSs?" and (3) "What approaches could make you feel safe to ride in shared-use fully ADSs?" This topic was discussed in six groups except for one of the two insurance professional groups. Participants expected the shared-use fully ADSs service to be clean, comfortable and responsive. They understood the potential advantages of using shared fully ADSs, but they also had various concerns regarding safety, sanitation, efficiency and privacy. Participants proposed different approaches in order to make it safe while riding in shared-use fully ADSs with other passengers. However, each aforementioned approach would need to be further investigated in order to make them really work.

Data Privacy and Ownership

For this topic, participants were asked "Who should own the data of fully ADSs, the vehicle manufacturer or the owner?" This topic was discussed in all seven groups. Each comment on this topic was coded along three dimensions: (1) participants' overall perception of data privacy issue, (2) ownership, right to share, right to access and right to know, and (3) usage of data and privacy concerns. Participants had privacy concern if personal data were collected in fully ADSs. However, they didn't necessarily have the knowledge to protect their data privacy. Most participants wanted ownership of the data. At the same time, they were willing to share the data with the manufacturer for the purpose of improving safety of the technology. Most participants didn't like their data to be used for other commercial purposes.

Liability and Insurance

For liability and insurance, participants were asked two questions: (1) "Do you think insurance is needed for fully ADSs?" and (2) "Who should be responsible in case of accident?" For the 2nd question, participants further commented on how to define the responsibility of an accident. This topic was discussed in all seven groups. The comments were coded along three dimensions of (1) whether insurance would be needed, (2) who should be responsible for an accident, and (3) how to define the responsibility. Most participants thought that insurance would still be needed for personally-owned fully ADS in order to protect themselves as the vehicle owner. In case an accident happened to the fully ADS, most participants thought that the manufacturer should take more responsibility than the owner. However, the vehicle owners would be responsible for maintaining the vehicle at the proper working condition. In order to avoid malicious intentions at fully ADS, there should be techniques such as a black-box or cameras to record the operational data in order to clearly define the responsibility of accidents.

METHODOLOGY AND RESULTS OF PHASE TWO: ONLINE SURVEYS

Methodology of Phase Two: Online Surveys

The objective of the online surveys was to identify the significant factors which would impact intention to use fully ADSs and the relationships among the factors. SurveyMonkey's Audience tool was used to target and recruit drivers who are 18 years and older and live in the state of California.

Procedures

The data were collected from two separate questionnaires, one for personally-owned fully ADS model and the other one for shared-use fully ADS model. In the personally-owned fully ADSs questionnaire, respondents firstly provided their demographic and background information. Then they were required to watch a two-minute video. The video had three main objectives: (1) to introduce the different levels of ADSs (SAE Automation Levels (*19*)); (2) to introduce level 5 automation (fully ADS) and its capabilities; and (3) to show a prototype of personally-owned fully ADSs introduced by Volvo car corporation (*20*). After watching the video, respondents rated 34 items regarding acceptance of personally-owned fully ADSs.

In the shared-use fully ADS questionnaire, after answering the demographic and background questions, the respondents were required to watch a 3-minute video. The video included information regarding (1) level 5 automation (fully ADSs) and its capabilities, (2) definition of shared-use fully ADSs and its capabilities, and (3) two prototypes of shared-use fully ADSs introduced by Waymo (*21*) and Group Renault (*22*). Then respondents rated 33 items regarding acceptance of shared-use fully ADSs.

Research Model

To assess user acceptance of personally-owned fully ADSs and shared-use fully ADSs, an extended Technology Acceptance Model (TAM) was developed in this study. TAM was frequently used to predict individual adoption and use of new information technologies in literature (*14 & 17*). Considering TAM, which takes into account perceived usefulness (PU) and perceived ease of use (PEoU) as the core of the proposed model, three constructs including safety (SA), trust (TR), and compatibility (CO) are hypothesized to impact the core based on related studies (*14, 16, 17, 18 & 23*). Moreover, findings of focus groups also highlight the importance of SA, TR, and CO on behavioral intention to use (BIU). We defined SA as the degree to which an individual believes that using ADSs will affect his/her well-being. TR is defined as the degree to which an individual believes that using ADSs will affect his/her well-being. Moreover, CO is defined as the degree to which an individual believes driving/riding with ADSs is perceived as being consistent with existing experience. With the TAM model as a core, SA, TR, and CO are proposed to affect PU, together with PEoU, influence BIU. SA, PU, PEoU are proposed to affect BIU directly. TR influence SA, and CO impacts TR. The strength of the proposed relationships in the model and the robustness of the model in predicting behavioral intention to use of personally-owned fully ADSs and shared-use fully ADSs are tested.

Develop Instrument Measures

The proposed constructs were measured with multiple items, which were adapted from existing studies (*9, 14-18 & 23*) and were updated based on the findings from the focus group discussion. The items were modified to increase internal consistency and to allow the comprehension of the effect of personally-owned fully ADSs and shared-use fully ADSs. All of the items were rated with a 7-point Likert scale from 1 (extremely disagree) to 7 (extremely agree) (see Table 2).

TABLE 2 Items Used in Personally-owned Fully ADS Acceptance Model (Model 1) and Shared-use Fully ADS Acceptance Model (Model 2)

Models	Constructs	Items	
Model 1	Behavioral Intention to Use (BIU)	BUI1	Assuming I have access to a personally-owned fully Automated Driving System, I intend to use it.
		BUI2	I expect that I will use a personally-owned fully Automated Driving System in the future.
		BUI3	If a personally-owned fully Automated Driving System is available, I plan to use it in future.
Model 1	Perceived Ease of Use (PEoU)	PEoU1	Learning to use a personally-owned fully Automated Driving System would be easy for me.
		PEoU2	I would easily understand how to interact with a personally-owned fully Automated Driving system.
		PEoU3	I would be able to quickly interact with a personally-owned fully Automated Driving System.
		PEoU4	I would easily become skillful at using a personally-owned fully Automated Driving System.
Model 1	Perceived Usefulness (PU)	PU1	Using a personally-owned fully Automated Driving System would allow me to reach my destinations more quickly.
		PU2	A personally-owned fully Automated Driving System would perform some driving tasks better than I can.
		PU3	A personally-owned fully Automated Driving System would increase my productivity (e.g., have time to do some work) during my travel.
		PU4	A personally-owned fully Automated Driving System would make my trip less stressful.
		PU5	A personally-owned fully automated vehicle would reduce my fuel consumption.
		PU6	I would like to use a personally-owned fully Automated Driving System because it's cutting-edge technology.
Model 1	Trust (TR)	TR1	A personally-owned fully Automated Driving System would provide adequate, effective, and responsive help.

Models	**Constructs**	**Items**	
		TR2	A personally-owned fully Automated Driving System would handle driving tasks without any human intervention.
		TR3	A personally-owned fully Automated Driving System would be free of errors or accidents.
		TR4	A personally-owned fully Automated Driving System would be predictable and reliable.
Model 1	Compatibility (CO)	CO1	I expect that a personally-owned fully Automated Driving System will drive the same way as I do.
		CO2	A personally-owned fully Automated Driving System would be able to select a route in the same way that I do.
		CO3	A f personally-owned fully Automated Driving System would drive in the way that I would expect as a passenger.
Model 1	Safety (SA)	SA1	A personally-owned fully Automated Driving System would decrease the risk of an accident.
		SA2	A personally-owned fully Automated Driving System would make proper decisions and take actions faster than some drivers.
		SA3	I would feel safer if I could take over control of a personally-owned fully Automated Driving System when it is necessary.
		SA4	In emergency situations, a personally-owned fully Automated Driving System would protect passengers' lives and safety.
Model 2	Behavioral Intention to Use (BIU)	BUI1	Assuming I have access to a shared-use fully Automated Driving System, I intend to use it.
		BUI2	I expect that I will use a shared-use fully Automated Driving System in the future.
		BUI3	If a shared-use fully Automated Driving System is available, I plan to use it in future.
Model 2	Perceived Ease of Use (PEoU)	PEoU1	Learning to use a fully Automated Driving System would be easy for me.
		PEoU2	I would easily understand how to interact with a shared-use fully Automated Driving system.
		PEoU3	I would be able to quickly interact with a shared-use fully Automated Driving System.
		PEoU4	I would easily become skillful at using a shared-use fully Automated Driving System.
Model 2	Trust (TR)	TR1	A shared-use fully Automated Driving System would be free of errors or accidents.
		TR2	A shared-use fully Automated Driving System would handle driving tasks without any human intervention.
		TR3	A shared-use fully Automated Driving System would be predictable and reliable.
		TR4	A shared-use fully Automated Driving System would provide adequate, effective, and responsive help.
Model 2	Compatibility (CO)	CO1	A shared-use fully Automated Driving System would fit well with my preferred mode of transportation.
		CO2	A shared-use fully Automated Driving System would be as clean as my personal car.

Models	Constructs	Items	
		CO3	A shared-use fully Automated Driving System would drive in the way that I would expect as a passenger.
Model 2	Safety (SA)	SA1	I would feel safe if I use a shared-use fully Automated Driving System service.
		SA2	In highly hazardous situations, a shared-use fully Automated Driving System would protect passengers' lives and safety.
		SA3	A shared-use fully Automated Driving System would make proper decisions and take actions faster than drivers.
		SA4	I would not feel safe using a shared-use fully Automated Driving System in a dangerous neighborhood.

Results of Phase Two: Online Surveys

In order to validate the proposed models for both personally-owned fully ADSs and shared-use fully ADSs, we took the following four steps: (1) analyzing respondents' demographic and background information, (2) analyzing reliability of the models, (3) analyzing fitness of the measured models and convergent validity by performing Confirmatory Factor Analysis (CFA), and (4) analyzing structural relationships by performing Structural Equation Modeling (SEM).

Demographic and Background Information

For the personally-owned fully ADS questionnaire, approximately 67% of the respondents have a college degree, and 46.8% think of themselves as late technology adapters. The majority of them earn more than 50K per year (62.9%). Driving is the most common mode of their commute (87.7%). They have environmental concerns (67.7%). They all have extensive driving experience (mean=26.94 years). Respondents were asked about their ADS experience.

In the questionnaires the following systems were listed as examples of ADS: Blind Spot Warning System, Cruise Control, Adaptive Cruise Control, Forward Collusion Warning System, Lane Departure Warning System, Autopilot, Traffic Jam Assist, Super Cruise, and Driver Pilot. Respondents were asked about experience with any other ADSs which were not listed above. About 64.2% of them have had some ADS experience. Their ADS experience has a mean of 5.23 years but varies significantly with a standard deviation of 8.65 years.

For the shared-use fully ADS questionnaire, 60.4% of the respondents report that they have a college degree and almost half of them think of themselves as late technology adapters (48.0%). Driving is their regular commute mode (86.8%). More than half of them earn more than 50K per year (58%). They are all experienced drivers (mean = 23.62 years) and 75.6% of them have some ADS experience (mean = 6.72 and std= 10.49). Sixty percent of the respondents have environmental concerns.

Reliability of Constructs

Coefficient alpha is used to validate the internal consistency and the value of which at 0.7 or higher is recommended *(24)*. Coefficient alpha for constructs in the personally-owned fully ADS model is between 0.83 and 0.95. For Safety items (Cronbach's alpha= 0.83), a more detailed analysis shows that dropping Item SA3 increases the reliability (Cronbach's alpha= 0.90). Item S3 states that "I would feel safer if I could take over control of the fully Automated Driving System when it is necessary".

For shared-use fully ADS model, the coefficient alpha for all constructs exceeds 0.75 except for Safety (Cronbach's alpha= 0.59). By dropping one of the Safety items (Item SA4: “I would not feel safe using a shared-use fully Automated Driving System in a dangerous neighborhood”), the coefficient alpha increases to 0.85.

Fitness of the Measured Models and Convergent Validity

Confirmatory factor analysis (CFA) is performed using Lavaan package in R studio. According to Harlow (*24*), non significant χ^2 is preferred. However, with a big sample size, usually χ^2 is significant. χ^2/df should be less than 3. Comparative fit index (CFI) ranges from 0 to 1, where 0.95 or higher is preferred. Hu and Bentler *(25)* suggested that CFI values around 0.9 were acceptable. Moreover, regarding root means square error of approximation (RMSEA), Harlow *(24)* mentioned that values of 0.05, 0.08, 0.1 could be considered as indications of good, fair and acceptable fit, respectively. For personally-owned model, χ^2/df = 2.40, RMSEA=0.067, and CFI=0.958, which shows a good fit. Regarding shared-use fully ADS, a combination of χ^2/df = 2.85, RMSEA=0.080, and CFI=0.910 is considered as an acceptable model.

After checking the model fitness, convergent validity is examined by a standard criterion recommended by Harlow *(24).* All factor loadings should be significant. Values of 0.5, 0.3, and 0.1, can be considered as indications of good, fair and acceptable loadings. As a result, all factor loadings for both models are above 0.50 which can be indicated as good.

The Fitness of the Structural Model

We follow Harlow’s *(24)* recommendation regarding the macro-level interpretation and micro-level interpretation for Structural Equation Modeling (SEM). At the macro-level, the recommendations are: (1) Chi-square/degree of freedom (χ^2/df), wherein the value of χ^2/df should be below the cut-off of 3.0, (2) RMSEA, wherein the RMSEA values of 0.05, 0.08, 0.1 can be considered as indications of good, fair, and acceptable fit, (3) R^2 which is suggested as a good measure of effect size (ES) wherein the values of 0.26, 0.13, 0.02, can be considered as indications of large, medium, and small, and (4) CFI 0.95 or higher is preferred. It is worth noting that Hu and Bentler *(25)* suggested that values around 0.9 were acceptable. As a result, personally-owned fully ADS model shows a good fit (χ^2/df=2.27, RMSEA=0.067, R^2=0.911, CFI=0.952). Additionally, shared-use fully ADS model indicates an acceptable fit (χ^2/df =2.80, RMSEA=0.079, R^2=0.770, and CFI =0.911).

Following Harlow’s *(24)* recommendation regarding the micro-level interpretation, two values: (1) z-value for constructs, and (2) the standardized loadings (ß) should be calculated. Regarding the standardized loadings, the recommendation is that loadings with values of 0.5, 0.2, and 0.1 should be considered as large, medium and small loadings.

In Model 1 for personally-owned fully ADS, six path coefficients (z-values) are significant. Figure 1-A illustrates the assessment of the structural model for personally-owned fully ADSs along with standardized path coefficient and R^2 value for constructs. The finding reveals that for personally-owned fully ADS users’ intention to use is influenced by two constructs: PU and SA. Moreover, this finding confirms their intention to use is not affected by PEoU, which means they might know that the system is not easy to handle but they may still have high intention to use it. Interestingly, the other constructs such as SA, TR, and CO also have insignificant relationships with PEoU. However, the two constructs PEoU and SA are significantly influenced by PU. These findings show the strong effect of PU on BIU and weak effect of PEoU on BIU. SA is strongly influenced by TR, which is impacted by CO.

We carry out similar analyses for shared-use fully ADS. Almost the same results as personally-owned fully ADSs are obtained (see Figure 1-B.). The shared-use fully ADS users' intention to use relies on how useful and safe the system is, rather than how easy it is to use. None of the constructs such as SA, TR, and CO have an effect on PEoU. However, the results show the significant effects of PEoU on PU and effect of SA on PU. TR strongly influences SA, while TR is strongly impacted by CO. Figure 1-B depicts the proposed structural model for shared-use fully ADS along with significant path coefficient and R^2 values.

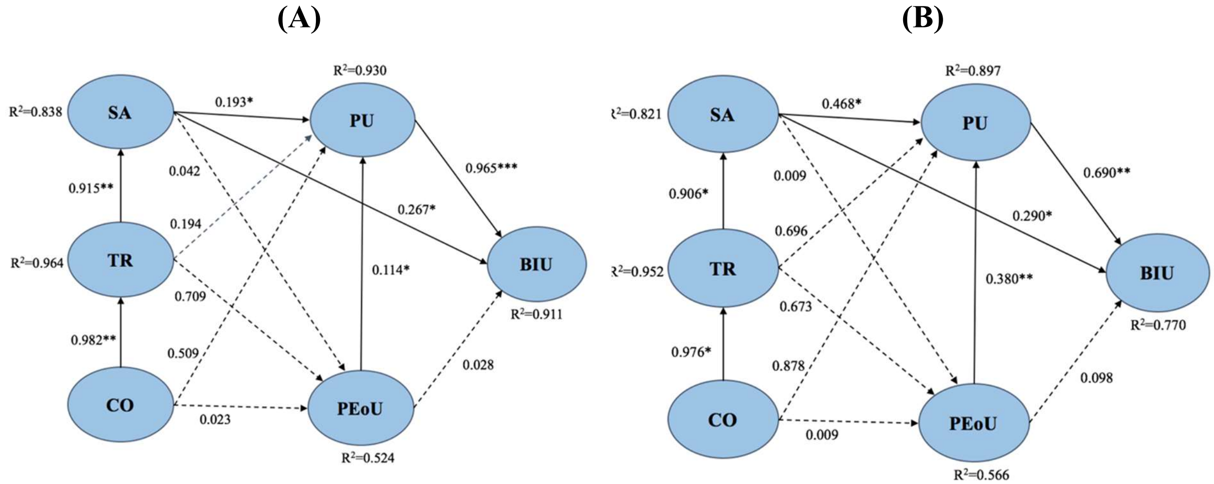

Figure 1 Assessment of the structure models: (A) personally-owned fully ADSs and (B) shared-use fully ADSs, Note: *p<0.05, ** p<0.01, ***p<0.001

DISSCUSION AND CONCLUSION

Public Perception of ADSs Implementation

In the focus group discussion, we explore public perception regarding implementation of fully ADSs. Herein, we suggest some of the public concerns regarding fully ADS implementation should be addressed by formulating corresponding policies. According to the focus group results, participants express the need for training, especially on safety and how to deal with emergency situations. The need for training is not specific to aged users and was more of a general need for all users. Although designing a universal and efficient training for all drivers is a challenging task (*13*), it is necessary to have relevant government policy which leads manufacturers to provide various training methods. This is particularly important since consumers may have different needs due to their age, physical capabilities and interests. The effectiveness of training can be maximized based on these needs.

One of the focus group findings regarding fully ADS implementation is consumer incentives. There will be greater potential benefits that fully ADS adopters share with other road users such as improvement of safety and traffic congestion (*1-3*). Hence, these adopters should be encouraged by some incentives, which include but not limited to (1) HOV lane (or dedicated lane) accessibility (*1 & 3*), (2) facilitative insurance policies (*3*), and (3) financial incentives (*1*).

There are some policy items related with the implementation of shared-use fully ADSs. Those policies address the identified concerns of using shared fully ADSs, which include efficiency, safety, sanitation, privacy, and discrimination.

Our study also reveal that data privacy and ownership is a critical concern. It is not limited to personally-owned fully ADSs or shared-use fully ADSs. Cellphones, GPS and social media are also reported as consumers' concerns regarding data privacy and ownership. Based on the results of the focus group, it appears that participants understand the benefits of sharing ADS data with manufacturers for the purpose of improving safety of the technology. At the same time, they have privacy concerns of sharing the data. Policymakers should address such concerns and make companies legally obligated to protect consumers' privacy. One of the suggested solutions is to require manufacturers to obtain consent from owners of fully ADSs or riders of shared-use fully ADSs for using their data for non-safety purposes.

Another important concern of the participants is liability and insurance of ADSs. Based on the focus group study results, most participants believe that owners will still need insurance to protect themselves from unexpected circumstances. They will also remain responsible for maintaining the vehicle under proper working conditions. On the other hand, the focus group participants believe that most of the responsibilities for accidents will rest on the manufacturers. Thus, policymakers have a critical role in making it clear that in what circumstances owners or the manufacturer should be liable *(7)*. From another aspect, approaches such as the black-box recorder used in the aviation industry or data recording via vehicle' sensors and cameras should be developed and used as evidence to define responsibility in case of accidents.

Acceptance Model for Using ADSs

Impact of Perceived Ease of Use (PEoU)

As a result of online surveys, all four path coefficients relating to PEoU in both models are statistically insignificant. In addition, the R^2 of PEoU (=0.524) is the lowest compared with the other constructs (>0.838). One possible reason is that respondents are already familiar with driving a vehicle or using shared vehicles. Therefore, they assume that it will not be hard for them to use fully ADSs. Moreover, the ease of use in ADSs impacts the usefulness of the system. There are significant paths from PEoU to perceived usefulness (PU) in both models. Therefore, we concur that PEoU should be redefined to convenience of use and benefits of using such technologies following Shin et al. *(26)*. Although this finding is different from the traditional TAM studies, it is in line with some previous studies, which focus on fully ADSs *(18 & 27)*.

Impacts of Safety (SA), Trust (TR) and Compatibility (CO)

According to the focus group discussions, participants most frequently cites safety as the factor that influences their acceptance of the fully ADSs. In addition, safety is found as the significant predictor of behavioral intention to use (BIU), which is in line with previous studies *(9 &17)*. This result highlights the significant influence of safety on users' intention to use both personally-owned fully ADSs and shared-use fully ADSs.

Trust is also stated frequently during the focus group discussions. In the online surveys, a strong relationship exists between safety and trust in both models. This finding demonstrates that users need to trust the personally-owned fully ADSs and shared-use fully ADSs to perceive them as safe. The effect of trust on perceived risk (negative form of safety factor) was also found in a previous study *(18)*.

Another highlighted factor in focus group discussions is compatibility. Through online surveys, we found the strong relationship between trust and compatibility. Previous studies *(14 & 16)* also identified this relationship. This finding is particularly important for car manufacturers. It emphasizes the importance of designing compatible ADS features to help users build trust which will lead users to have intention to use ADSs.

Comparing Acceptance Models for Personally-owned and Shared-Use Fully ADSs

Although both personally-owned and shared-use fully ADSs depict similar acceptance models, there are differences in the importance of the constructs. Considering the level of factors' effect (*p-value*), perceived usefulness, trust and compatibility play more important roles and perceived ease of use plays a less important role in users' intention to use for personally-owned fully ADSs compared with shared-use fully ADSs. These findings may root in responders' knowledge and familiarity regarding the usefulness of the personally-owned ADSs. All survey respondents live in California. Therefore, they are more likely to be exposed to the advertisement of personally-owned ADSs. Additionally, they realize the necessity of such a technology while they suffer from congestion on the daily basis. For example, Los Angeles and San Francisco in California were found to be among the top five congested cities in the world in 2017 according to INRIX 2017 Global Traffic Scorecard. On the other hand, lack of public transportation experience and familiarity may cause this different pattern in acceptance. According to American Public Transportation Association, 45% of American have no access to public transportation (*28*). Moreover, all survey respondents live in California and 87% of them drive for their commute. This finding is important for operators of shared-use fully ADSs to understand the users' perception and design their vehicle in the way that users will not require any new skills or expertise.

Our findings show that safety, usefulness, trust and compatibility are the most critical factors that have influence on users' acceptance of the fully ADSs. For deployment of fully ADSs, public agencies should have policy regarding education and training for the potential consumers for safety purpose, policy to make companies obligated to protect consumers' data privacy, policy to well define the liability between the manufacturer and the users, and policy for incentives in order to promote the technology.

From manufacturers' perceptives, firstly they should make every effort to ensure that the fully ADS are safe and robust in all road conditions. Secondly, they should design different training programs for consumers to learn how to use fully ADSs. Thirdly, they should develop new approaches to clarify responsibilities in case of accidents. Lastly but not the least, they should give access to the consumers of their own data and not use it for other commercial purposes. There are considerable safety concerns related to shared-use fully ADSs, which should be well investigated and resolved before deployment.

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AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: Sanaz Motamedi, Pei Wang, and Ching-Yao Chan; data collection: Sanaz Motamedi, Pei Wang, and Tingting Zhang; analysis and interpretation of results: Sanaz Motamedi and Pei Wang; draft manuscript preparation: Sanaz Motamedi, Pei Wang, and Ching-Yao Chan. All authors reviewed the results and approved the final version of the manuscript.

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