Survey of Bicyclists and Pedestrians towards Autonomous Vehicles

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ABSTRACT

An important first step towards the widespread adoption of autonomous vehicles (AVs) is understanding public opinions, sentiments, and perceptions. In recent years, there have been many studies about the public perception of AVs. There are prospective challenges to the adoption of AVs concerning pedestrians and bicyclists that require additional attention. The present study examines survey data collected by a non-profit organization named BikePGH located in Pittsburgh, Pennsylvania. This study used Chi Squared tests and multiple correspondence analysis (MCA) to identify the response patterns of participants and sort the responses into several clusters. This study developed six different clusters from the responses of the participants. There are groups of people who are very receptive to the AV technologies, and some are vehemently opposing the inclusion of AVs on the roadways. The results show that participants with real-world experience involving AV interactions have higher expectations and interest than the participants with no prior experience. The findings also show that participants who think there are no safety potentials for AVs are also against the proving ground of AVs in Pittsburgh. The authors anticipate that these results will provide a significant contribution to the policies related to safe interactions between AVs and non-motorists.

Keywords: Autonomous vehicles, pedestrians, bicyclists, perception, multiple correspondence analysis.

INTRODUCTION

In recent years, the advent of autonomous vehicles (AVs) has gained worldwide attention. Emerging technologies have transformed the transportation system, particularly in regard to safety and mobility. Full automation level AVs can handle different traffic conditions without human input reducing the number of crashes caused by human errors. The widespread implementation of AVs will also reduce traffic congestion and air pollution. It is important to understand end-user's knowledge of and attitude towards AVs to ensure that consumers are aware of these many benefits.

Non-motorized traffic fatalities are on the rise. In 2016, pedestrian fatalities made up 16 percent (5,987) of all traffic fatalities, and bicyclist fatalities made up 2.3 percent (852) of all traffic fatalities *(1, 2).* In crashes involving a vehicle and a non-motorized roadway user, the non-motorized user is more likely to be killed or injured. In recent news, an AV was in full automation mode when a crash occurred and resulted in a pedestrian fatality, but studies have shown that AVs will make roadways safer. This incident gained international media attention and has brought forth potential safety concerns in unexplored research areas such as the interactions between the AVs and non-motorized users such as pedestrians and bicyclists on the roadways.

This study applied Chi Squared tests and multiple correspondence analysis (MCA) to public survey data collected by BikePGH in Pittsburgh, Pennsylvania, in order to describe and visually explore complex associations among responses. Conventional survey analysis methods limit the understanding of occurrence phenomena in a complex questionnaire survey, and the interpretation and conclusions are restricted to broad generalities. This study showed that there is great value in confining the analysis to smaller clusters to gain knowledge about participants' response patterns towards AVs with while considering whether they previously had any interaction with AVs as non-motorized users like pedestrians and bicyclists.

LITERATURE REVIEW

Large-scale testing of AVs on private and public roads are currently being implemented in several countries. However, these technologies are not universally accepted. To successfully penetrate the marketplace, AV technologies need to not only overcome technological challenges but also social barriers. Many studies have explored consumers' opinions, public insight, and the potential adaptation of AV technologies (*3*-*7*).

Through survey analysis, Schoettle and Sivak (*8*) evaluated public opinion regarding AV technology in three English-speaking countries (the U.S., the U.K., and Australia). The results indicated that females express more concern in comparison to males. Also, most of the respondents expressed interest in having this technology in their vehicle, but a majority of them were unwilling to pay additional costs. A case study by Howard and Dai (*9*) assessed public attitudes regarding AVs by utilizing the responses of 107 adopters in Berkeley, California. An evaluation of the vehicle characteristics that people liked and disliked was conducted, and the participants also expressed how they envisioned the inclusion of the technology. The positive attitudes are associated with potential safety improvements from AVs, finding right parking spots, and multitasking while driving. On the other hand, people were also concerned with liability, the cost of the vehicles, and losing control. Men have been found to be more concerned with liability and less concerned with control than women. Choi et al. (*10*) analyzed the user's adoption perspective of the AVs as well as investigated what factors result in people's trust in an AV. The findings show that perceived usefulness and trust are significant determinants of intention for using self-driving cars. Moreover, it is found that three constructs—system transparency, technical competence, and situation management—have positive impacts on trust. In addition, Kyriakidis et al. (*11*) investigated user acceptance, attitudes, and willingness to buy partially, highly, and fully automated vehicles. They used a 63-question Internet-based survey which led to 5,000 responses from 109 countries. On average, results indicated that respondents found manual driving the most enjoyable mode of driving. Additionally, respondents were mostly concerned with software hacking/misuse, legal issues, and safety.

Bansal et al. (*12*) proposed a new simulation-based fleet evolution framework to predict Americans' long-term (year 2015–2045) adoption levels of AV technologies in eight scenarios based on 5% and 10% annual drops in technology prices; 0%, 5%, and 10% annual increments in Americans' willingness to pay (WTP); as well as changes in government regulations. "Overall results indicate that without a rise in most people's WTP, or policies which promote or require technologies, or unusually rapid reductions in technology costs, it is unlikely that the U.S. light-duty vehicle fleet's technology mix will be anywhere near homogeneous by the year 2045." For advancing future research regarding the travel behavior effects of AVs, Krueger et al. (*13*) identified the characteristics of costumers who are likely to adopt these vehicles services and evaluated their willingness to pay additional measures for service attributes. The results of the study showed that service characteristics such as travel cost, travel time, and waiting time could be critical determinants of AV use and the users' acceptance of them. This adaptation may vary among individuals in different demographic groups; for example, young people and individuals with multimodal travel patterns may be more likely to adopt AVs.

Daziano et al. (*14*) utilized data from a nationwide online panel of 1,260 individuals who responded to a vehicle-purchase discrete choice experiment focusing on energy efficiency and autonomous features. The purpose of their study was to properly estimate individuals' willingness to pay for AVs. The overall results of their analyses suggested that the average household is willing "to pay approximately \$3,500 for partial automation and \$4,900 for full automation." Menon (*15*) examined the potential market segments of AV consumers and revealed the factors which influence their adoption or non-adoption of AVs. The findings showed that the effect of relinquishing household vehicles varies among single- and multi-vehicle households with various triggers such as socio-demographics, current travel characteristics, crash severities, and vehicle purchase histories.

Lee et al. (*16*) investigated the responses from a national sample of 1,765 adults in the U.S. to identify the main influences of the acceptance of AVs and to determine how age and other characteristics are related to perceptions and attitudes regarding AVs. The study outcome indicated negative effects of age on perceptions of a self-driving car, interest in using it, and behavioral intentions to use one when it becomes available. Moreover, experiential characteristics which are associated with age, such as experiences with, knowledge of, and trust toward technology in general, have been found to have a significant impact on how people felt regarding AVs.

Bansal and Kockelman (*17*) also surveyed 1,088 people in Texas to determine their opinions regarding smart vehicle technologies and related decisions considering the respondents' demographics, built-environment attributes, travel patterns, and crash histories. The findings suggest that more experienced licensed drivers and older people are less willing to pay (WTP) for all new vehicle technologies. The authors mentioned that these findings can predict the long-term adoption of AVs technologies and contribute to transportation planners to understand the characteristics of regions with high or low future-year CAV adoption levels. In a follow-up study, Bansal and Kockelman (*18*) conducted an internet-based survey asking 347 Austinites about their perceptions on smart-car technologies. The results concluded that respondents consider fewer crashes as the primary benefit of self-driving cars and equipment failure as their top concern. Hulse et al. (*19*) surveyed nearly 1,000 individuals on their perceptions, particularly regarding safety and acceptance of self-driving cars. The findings showed that AVs are perceived as a "somewhat low risk" form of transportation, and there was little opposition to their use on public roads. These vehicles were also perceived as riskier than existing autonomous trains. Gender, age, and risk-taking features were found to have various relationships with the perceived risk of different vehicle types and general attitudes towards these cars. For example, men and younger adults expressed greater acceptance.

Canis (*20*) found that 30 percent of survey participants expressed reluctance in buying an AV. The study also reported that more than half of U.S. drivers "feel less safe at the prospect of sharing the road with a self-driving vehicle." By using two natural language processing (NLP) tools, Das et al. (*21*) evaluated people's attitudes toward AVs and the existing polarities regarding content and automation level to perform knowledge discovery from a bag of approximately seven million words from a large number of YouTube videos. They found that the public is engaging more with AVs technologies than in the past, and they also found that as the automation level increases, as does the possible perception of safety. Finally, they concluded that positive sentiments towards AVs are more common than negative, uncertain, or litigious sentiments. Penmetsa et al. (*22*) examined survey data collected by BikePGH and revealed that respondents with direct experience of interaction with AVs reported significantly higher expectations of their safety advantages than respondents with no AV interaction experience.

The current state-of-the-art literature review has several limitations. First, the indications of attitudes are not dependent on the future safe adoption of AVs. Second, the interaction between participants and AVs are unknown in most of the studies. Third, only a few studies investigated the perception of AVs regarding non-motorists such as pedestrians and bicyclists. Fourth, conventional survey analysis methods are limited in interpreting the cooccurrences of the responses. The current study presents a suitable data analysis tool that can identify patterns and associations from a complex survey to understand the perception of roadway users towards the adoption of AVs.

DATA DESCRIPTION

Survey Design and Participants

According to the first edition of the Highway Safety Manual (HSM), approximately 94 percent of crashes occur due to human errors *(23).* The AV companies anticipate that the AV technologies could greatly reduce or eliminate these crashes by removing the human error component in the driving tasks. Irrespective to the automation modes (full automation to partial), AVs promise many potential benefits such as reducing roadway crashes and fatalities, easing traffic congestion, and increasing mobility *(23, 24).* However, AVs can also pose safety and infrastructure challenges for state DOT authorities. DOTs must decide if the current approach to vehicle testing and standards can adequately ensure a safe driving environment. Additionally, there is a need to address how AVs interact with other road users. AVs could require potential infrastructure changes, and regulatory agencies will need to decide what changes to pursue, while also providing for conventional vehicles which will likely remain on the roads for decades. However, many agencies do not have readily available comprehensive plans that will set clear goals on the deployment of AVs on the roadways *(25).*

Since September 2016, AV companies have tested AVs in cities, including Pittsburgh. In 2017, the United States Department of Transportation (USDOT) designated ten AV proving grounds to encourage testing of new technologies, one of which included Pittsburgh, PA. In early 2017, BikePGH designed a survey to see how both BikePGH donor-members and Pittsburgh residents at large feel about sharing the road with AVs as a bicyclist and/or as a pedestrian. BikePGH is a charitable non-profit with a mission to transform "…our streets and communities into vibrant, healthy places by making them safe and accessible for everyone to bike and walk" *(26)*.

The survey asked participants how they felt about being a fellow road user with AVs, either walking or biking. To help policymakers comprehend the complexity of possible futures, the survey was conducted to show that AV technology can bring different marketplace models to the cities and town centers. BikePGH conducted the survey in two parts. First, the survey was limited exclusively to donor-members, yielding 321 responses (out of 2,900) via email. In the second stage, BikePGH allowed the public to participate by promoting it on the BikePGH website, social media channels, and a few news articles. The second stage yielded 798 responses (mostly from people in the Pittsburgh region) for a combined total of 1,119 responses. The major questions are below:

- **InteractBicycle:** Have you interacted with an AV while riding your bicycle on the streets of Pittsburgh?
- **InteractPedestrian:** Have you interacted with an AV while using sidewalks and crosswalks in Pittsburgh?
- **BikePghPosition:** What do you think BikePGH's position on AVs should be?
- **CircumstancesCoded:** Circumstances coded in six categories: AV Safer, Cautious about AV, Negative about AV, No Difference, No Experience, and Others.
- **SafetyHuman:** On a typical day, how safe do you feel using Pittsburgh's streets with human-driven cars?
- **SafetyAV:** On a typical day, how safe do you feel using Pittsburgh's streets with AVs?
- **AVSafetyPotential:** Do you think that AVs have the potential to reduce injuries and fatalities?
- **RegulationTesting:** On public streets, do you think that regulatory authority should come up with regulations regarding how AVs are tested?
- **RegulationSpeed:** On public streets, do you think that regulatory authority should cap the speed limit in which AVs are allowed to operate?
- **RegulationSchoolZone:** On public streets, do you think that regulatory authority should prevent AVs from operating in an active school zone?
- **RegulationShareData:** On public streets, do you think that regulatory authority should... Require companies to share non-personal data with the proper authorities, planning agencies, etc.? (AVs collect lots of useful data for city planners)
- **FeelingsProvingGround:** How do you feel right now about the use of Pittsburgh's public streets as a proving ground for AVs?
- **AdvocacyIssues:** Is this an advocacy issue that BikePGH should dedicate resources to?
- **PayingAttentionAV:** To what extent have you been paying attention to the subject of AVs in the news?
- **FamiliarityTechnoology:** How familiar are you with the technology behind AV?

Exploratory Data Analysis

The research team used the final survey dataset with 321 responses from the BikePGH members (BPG) and 793 responses from the general public (Public) for a total of 1,114 respondents. Due to the missing values, five Public responses were discarded. Table 1 lists the chi-square test values (a convenient test to determine the difference between the dataset attributes) and descriptive statistics of the key variables. The p-values from the chi-square tests indicate that some of the variables are significantly different for two types of participants (BPG and Public).

Among the survey respondents, any interaction with an AV as a pedestrian was higher than BPG participants. Among the respondents, 10 percent were unsure if they had interactions with AVs as pedestrians. For Public participants, 47 percent reported interaction with AVs while riding a bicycle, whereas 43 percent of BPG participants have such experiences. For the Public participants, 7 percent believe that BikePGH should actively oppose AVs. Only 3 percent of BPG participants are opposed to AVs regarding the BikePGH position.

The circumstances are coded into six categories: AV Safer, Cautious about AV, Negative about AV, No Difference, No Experience, and Others. Around 50 percent of both participant groups do not have prior experience of AV circumstances. For Public participants, 24 percent think that Pittsburgh's streets are safe with human-driven cars. This percentage is 15 percent for the BPG participants. On the other hand, 11 percent of BPG members consider Pittsburgh's streets to be unsafe or very unsafe with AVs. This percentage is 17 percent for the Public respondents. Public participants see fewer safety potentials from AVs than the BPG participants (62 compared to 72 percent).

The majority of both participant groups are in favor of testing and speed regulations for the AVs. Public participants are more in favor of school zone regulation of the AVs than the BPG participants. Approximately half of the respondents fully approved of Pittsburgh serving as a proving ground for AVs. Slightly more BPG participants are paying more attention to AVs and are getting familiar with the AV technologies compared to the public participants.

Table 1 Chi Squared Tests and Descriptive Statistics for Key Variables by BPG and Public Participants

Questions	**BPG (N=321)**	**Public (N=793)**	**p-val**	**Questions**	**BPG (N=321)**	**Public (N=793)**	**p-val**
InteractPedestrian			0.047*	RegulationTesting			0.199
1: Yes	41%	35%		1: Yes	72.90%	69.90%	
2: No	48%	56%		2: No	9.03%	12.90%	
3: Not Sure	11%	9%		3: Not Sure	18.10%	17.30%	
InteractBicycle			0.279	**RegulationSpeed**			0.038*
1: Yes	42.70%	46.70%		1: Yes	46.40%	53.00%	
2: No	48.00%	42.70%		2: No	30.50%	30.10%	
3: Not Sure	9.35%	10.60%		3: Not Sure	23.10%	16.90%	
BikePghPosition			0.008*	**RegulationSchoolZone**			0.01*
Actively Oppose	2.80%	7.19%		1: Yes	18.70%	27.10%	
Actively Support	49.80%	42.60%		2: No	49.50%	46.30%	
Neither Support nor Oppose	38.90%	38.80%		3: Not Sure	31.80%	26.60%	
No Opinion	8.41%	11.30%		RegulationShareData			0.451
CircumstancesCoded			0.074*	1: Yes	74.10%	70.60%	
AV Safer	2.49%	2.90%		2: No	11.80%	12.60%	
Cautious about AV	6.23%	6.18%		3: Not Sure	14.00%	16.80%	
Negative about AV	1.25%	4.04%		**FeelingsProvingGround**			0.019*

No Difference	40.50%	34.00%		1: Not at All	3.74%	9.33%	
No Experience	47.70%	49.60%		2: Little	8.41%	8.95%	
Others	1.87%	3.28%		3: Some	12.10%	13.50%	
SafetyHuman			0.01*	4: Moderate	22.70%	19.30%	
1: Very Unsafe	4.98%	5.42%		5: A Lot	53.00%	48.90%	
2: Unsafe	32.70%	26.70%		AdvocacyIssues			0.126
3: Not Sure (Neutral)	45.50%	38.60%		1: Not at All	2.49%	5.42%	
4: Safe	14.60%	24.20%		2: Little	13.70%	15.00%	
5: Very Safe	1.56%	4.29%		3: Some	41.10%	40.10%	
No experience	0.62%	0.76%		4: Moderate	38.00%	33.20%	
SafetyAV			0.094*	5: A Lot	4.67%	6.31%	
1: Very Unsafe	2.80%	6.18%		PayingAttentionAV			0.724
2: Unsafe	8.10%	10.10%		1: Not at all	0.93%	1.51%	
3: Not Sure (Neutral)	26.20%	22.20%		2: Little	7.48%	9.84%	
4: Safe	35.80%	31.80%		3: Some	30.20%	30.00%	
5: Very Safe	16.80%	19.30%		4: Moderate	34.30%	32.80%	
No experience	10.30%	10.50%		5: A Lot	27.10%	25.90%	
AVSafetyPotential			0.001*	FamiliarityTechnoology			0.489
1: Yes	72.30%	61.80%		1: Not at All	5.30%	6.81%	
2: No	3.43%	7.82%		2: Little	22.10%	20.70%	
3: Not Sure	24.30%	30.40%		3: Some	44.90%	41.90%	
				4: Moderate	17.40%	21.30%	
				5: A Lot	10.30%	9.33%	

Note: p-values with *** *indicate statistically significant at 90% confidence level. The variable names are* ***bold*** *with p-values with *.*

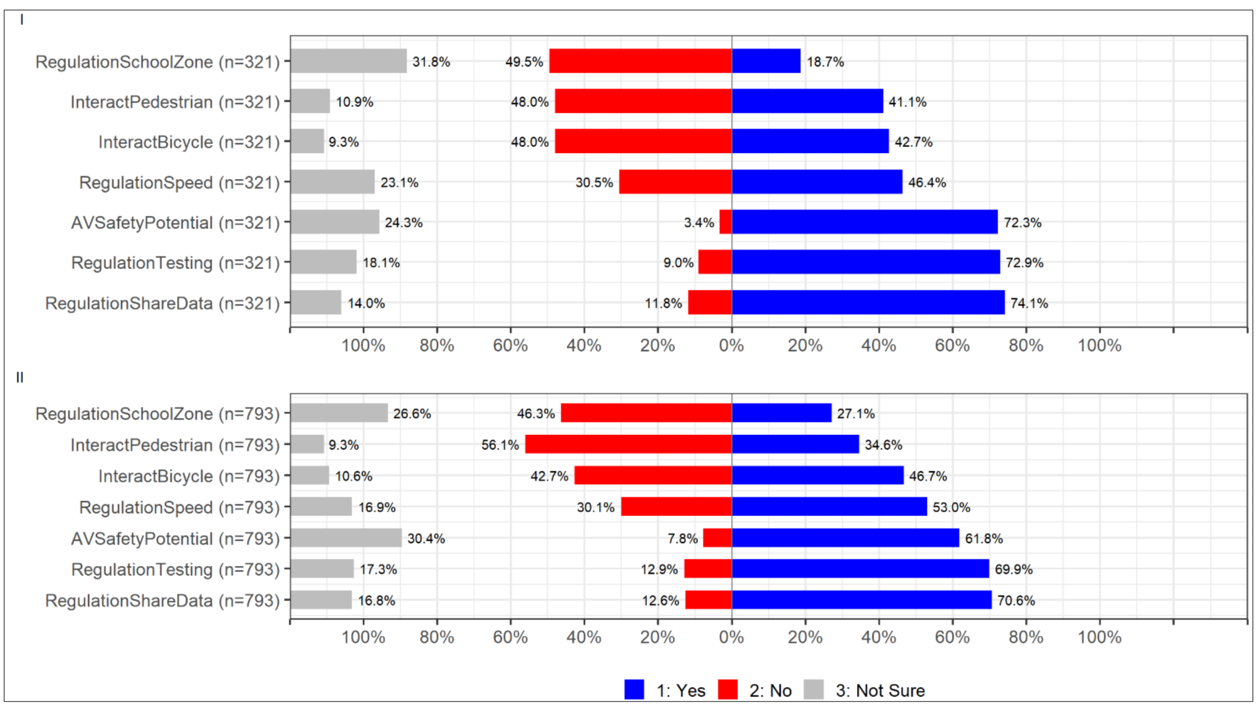

Figure 1 Distribution of regulation and interaction questions (I. BPG, II. Public).

Figure ***1*** shows the bar chart distribution of those questions with yes / no / not sure potential responses. These questions included regulatory, safety potential, and interaction related questions.

Figure ***1*** shows the results for both groups with the top portion showing the results for the BPG participants and the bottom portion showing the results for the Public participants. Public attitudes are higher for school zone and speed-related regulations for AVs compared to BPG participants. For other regulations, the differences of opinions are not significantly wide. More BPG participants believe AVs have the potential to improve safety than the Public participants.

METHODOLOGY

Multiple Correspondence Analysis (MCA)

MCA is an unsupervised learning algorithm that does not distinguish between explanatory variables and the response variable but requires the construction of a matrix based on pairwise cross-tabulation of each variable. For example, the dimension of the final dataset of this study is 1114×10 (total survey respondents=1114, and questions analyzed in this survey=10). For a table of qualitative or categorical variables with dimension 1114×10, MCA can be explained by taking an individual record (in row), *i [i= 1 to 1114]*, where 10 categorical variables (represented by 24 columns) have different sizes of categories. Based on these ten variables, MCA can generate the spatial distribution of the points by different dimensions.

Consider *P* as the number of variables (i.e., columns), and *I* as the number of responses (i.e., rows). This will generate a matrix of *'I multiplied by* P.*'* If L_p is the number of attributes for variable *p*, the total number of categories for all variables is, $L = \sum_{p=1}^{p} L_p$. It will generate another matrix *'I multiplied by* L.*'* In this matrix, each of the variables will contain several columns to show all of their possible categorical values.

The cloud of categories is considered as a weighted combination of *J* points. Category *j* is represented by a point denoted by C^j with the weight of n_j. For each of the variables, the sum of the weights of category points is *n*. In this way, for the whole set *J*, the sum is nP. The relative weight w_j for point C^j is $w_j = n_j/(nP) = f_j/P$. The sum of the relative weights of category points is 1/P, which makes the sum of the whole set as 1 *(23).*

$w_j = \frac{n_j}{nP} = \frac{f_j}{P}$ with $\sum_{j \in J_q} w_j = \frac{1}{P}$ and $\sum_{j \in J} w_j = 1$

Here, $n_{jj'}$ represents the number of individual records which have both categories k and k'. The squared distance between two categories C^j and $C^{j'}$ can be represented by **Equation 1** *(23):*

$$(C^j C^{j'})^2 = \frac{n_j + n_{j'} - 2n_{jj'}}{n_j n_{j'}/n} \tag{1}$$

The numerator of Equation (1) is the number of individual records associating with either j or j' but not both. For two different variables, p, and p', the denominator is the familiar "theoretical frequency" for the cell (j, j') of the $J_p \times J_{p'}$ two-way table.

Different frameworks of MCA have been developed while keeping goals similar *(27, 28).* In recent years, several studies applied MCA in transportation research (*29-38*).

RESULTS AND DISCUSSIONS

The variables with high p-values (greater than 0.10, see Table 1) indicate that both groups of participants are not significantly different in attitude towards AVs for the associated attributes. The p-values from Table 1 indicate that the responses associated with the nine questions show a significant difference in responses for two types of participants (InteractPedestrian, BikePghPosition, CircumstancesCoded, SafetyHuman, SafetyAV, AVSafetyPotential, RegulationSpeed, RegulationSchoolZone, and FeelingsProvingGround). The group of the participants is considered as the tenth variable. To conduct the MCA analysis, ten variables are considered for analysis. Figure 2 illustrates the percentages of inertia (i.e. variance) explained by each MCA dimension. The first two dimensions explained nearly 20% of total inertia.

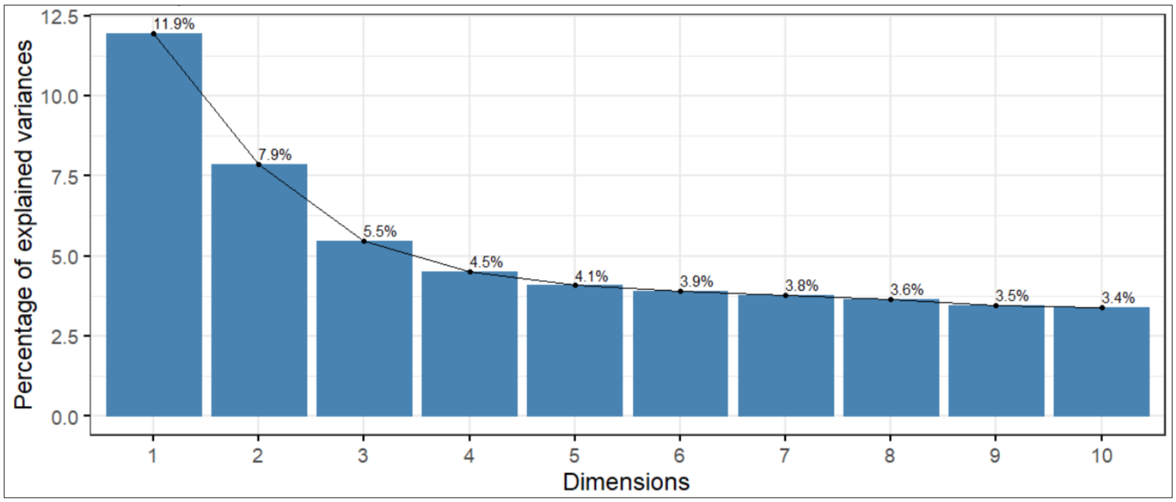

Figure 2 Inertia explained by 10 dimensions.

MCA plots or biplots are sometimes difficult to interpret due to the large number of attributes on a two-dimensional plot. The parameter squared cosine (cos2) indicates the degree of association between variable attributes and an axis. If a variable attribute is well represented by two dimensions, the sum of the cos2 will be approximately one. Sometimes, three-dimensional display is needed if two dimensions do not sufficiently cover inertia or variance. Figure 3 displays the cos2 values of the row categories (on all dimensions) in an ascending order bar plot. The closer the locations of the attributes in the MCA plot, the closer the associations. The research team developed six different clusters based on the coordinate values of the attributes.

It is also important to show which attributes are dominant in each axis. The top 5 attributes of dimension 1 (i.e., Axis 1) are

- *FeelProving_1: Not at All,*
- *RegulationSchoolZone_1: Yes,*
- *BpgPos_Actively Oppose,*
- *AVSafetyPotential_2: No*, and
- *SafetyAV_1: Very Unsafe*.

The top 5 attributes of dimension 2 (i.e., Axis 2) are

- SafetyAV_1: Very Unsafe,
- FeelProving_1: Not at All,
- BpgPos_Actively Oppose,
- AVSafetyPotential_2: No, and
- RegulationSchoolZone_3: Not Sure.

The attributes with top 5 high cos2 values for two dimensions are *FeelProving_1: Not at All, BpgPos_Actively Oppose, FeelProving_5: A Lot, SafetyAV_1: Very Unsafe*, and *AVSafetyPotential_1: Yes*. Majority of these attributes are in Cluster 6.

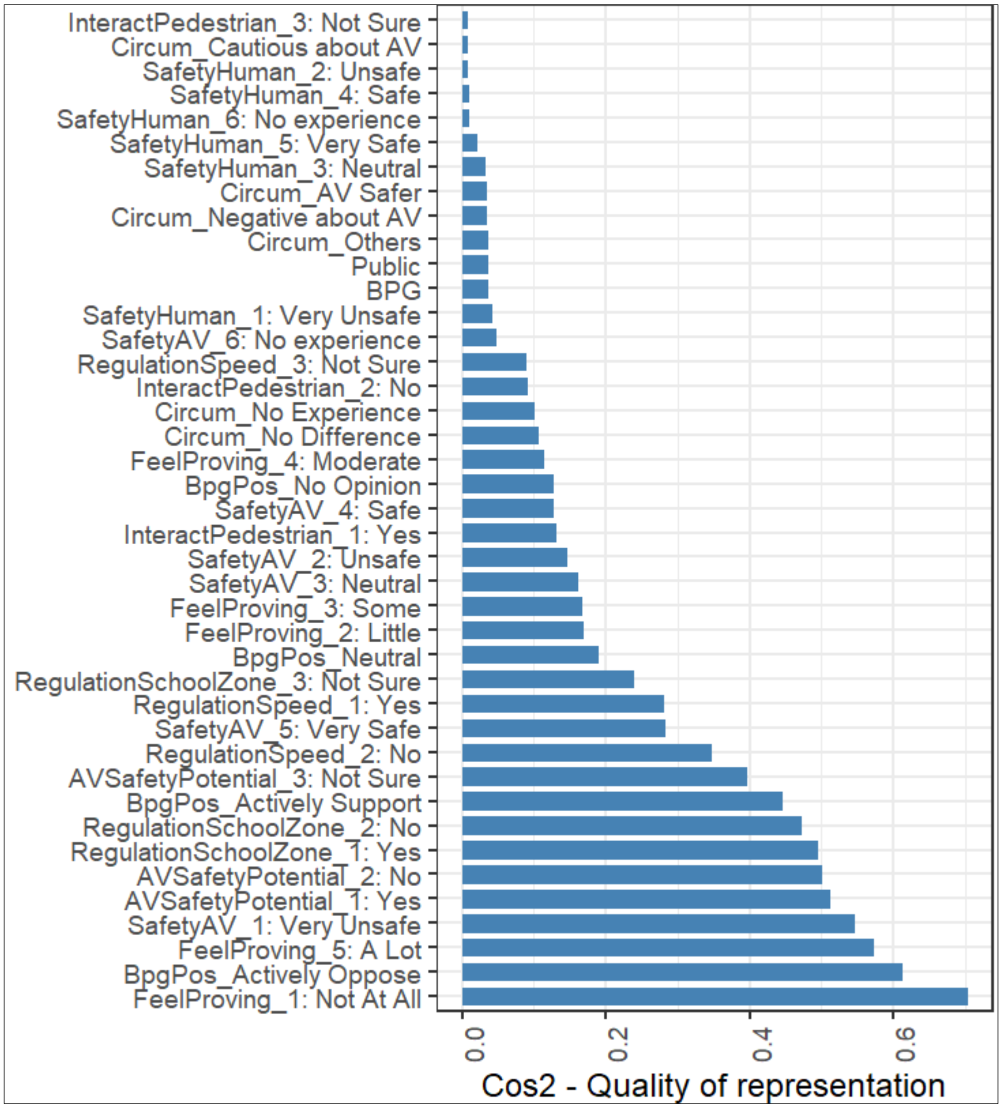

Figure 3 Quality of representation by the attributes.

Table 2 MCA Outputs for the Attributes

Attributes	**Coordinates**		**Contribution**		**cos2**			**Quad**	**Clus**
	Ax 1	**Ax 2**	**Ax 1**	**Ax 2**	**Ax 1**	**Ax 2**	**Tot**		
SafetyAV_5: Very Safe	-0.843	0.721	3.565	**3.962**	0.162	0.119	0.281	2	1
RegulationSchoolZone_2: No	-0.635	0.352	**5.136**	2.401	0.360	0.111	**0.471**	2	1
FeelProving_5: A Lot	-0.661	0.365	**5.904**	2.739	0.438	0.134	**0.572**	2	1
Circum_AV Safer	-0.877	0.610	0.578	0.424	0.022	0.011	0.033	2	1
BpgPos_Actively Support	-0.640	0.375	**4.942**	2.582	0.331	0.114	**0.445**	2	1
SafetyHuman_2: Unsafe	-0.127	-0.015	0.125	0.003	0.006	0.000	0.007	3	2
SafetyAV_4: Safe	-0.506	0.032	2.279	0.014	0.126	0.001	0.126	2	2

RegulationSpeed_2: No	-0.758	0.472	**4.688**	2.756	0.249	0.096	0.345	2	2
InteractPedestrian_1: Yes	-0.370	0.300	1.346	1.343	0.078	0.052	0.130	2	2
Circum_No Difference	-0.426	0.061	1.764	0.054	0.102	0.002	0.104	2	2
Circum_Cautious about AV	-0.300	0.083	0.151	0.017	0.006	0.000	0.006	2	2
AVSafetyPotential_1: Yes	-0.501	0.163	**4.393**	0.702	0.462	0.049	**0.511**	2	2
SafetyHuman_4: Safe	0.085	0.155	0.042	0.210	0.002	0.007	0.009	1	3
RegulationSpeed_1: Yes	0.513	-0.062	3.634	0.080	0.275	0.004	0.279	4	3
InteractPedestrian_3: Not Sure	0.205	-0.129	0.111	0.066	0.005	0.002	0.006	4	3
InteractPedestrian_2: No	0.213	-0.180	0.661	0.713	0.053	0.038	0.091	4	3
Group_Public	0.096	0.070	0.177	0.144	0.023	0.012	0.035	1	3
Circum_No Experience	0.286	-0.143	1.084	0.411	0.079	0.020	0.098	4	3
SafetyAV_6: No experience	0.425	-0.465	0.507	0.922	0.021	0.025	0.046	4	4
SafetyAV_3: Neutral	0.265	-0.673	0.444	**4.338**	0.021	0.138	0.160	4	4
RegulationSpeed_3: Not Sure	-0.177	-0.595	0.158	2.709	0.007	0.081	0.088	3	4
RegulationSchoolZone_3: Not Sure	0.005	-0.781	0.000	**7.020**	0.000	0.238	0.238	4	4
FeelProving_4: Moderate	-0.030	-0.665	0.005	3.681	0.000	0.113	0.113	3	4
BpgPos_Neutral	0.209	-0.502	0.457	**4.009**	0.028	0.160	0.188	4	4
FeelProving_3: Some	0.493	-0.927	0.859	**4.614**	0.037	0.130	0.166	4	5
BpgPos_No Opinion	0.590	-0.850	0.986	3.109	0.041	0.085	0.126	4	5
AVSafetyPotential_3: Not Sure	0.654	-0.745	3.308	**6.512**	0.172	0.223	**0.394**	4	5
SafetyAV_1: Very Unsafe	2.277	2.178	**7.293**	**10.118**	0.285	0.260	**0.545**	1	6
FeelProving_1: Not at All	2.279	1.788	**10.832**	**10.115**	0.435	0.268	**0.702**	1	6
BpgPos_Actively Oppose	2.414	1.965	**9.325**	**9.378**	0.367	0.243	**0.610**	1	6
AVSafetyPotential_2: No	2.097	1.648	**7.783**	**7.289**	0.308	0.190	**0.499**	1	6
SafetyHuman_6: No experience	0.524	-0.955	0.053	0.268	0.002	0.007	0.009	4	--
SafetyHuman_5: Very Safe	-0.149	0.729	0.021	0.763	0.001	0.019	0.020	2	--
SafetyHuman_3: Neutral	-0.003	-0.215	0.000	0.772	0.000	0.032	0.032	3	--
SafetyHuman_1: Very Unsafe	0.390	0.752	0.217	1.228	0.008	0.032	0.040	1	--
SafetyAV_2: Unsafe	1.037	-0.552	2.761	1.187	0.113	0.032	0.145	4	--
RegulationSchoolZone_1: Yes	1.208	0.215	**9.734**	0.467	0.479	0.015	**0.494**	1	--
Group_BPG	-0.237	-0.173	0.437	0.354	0.023	0.012	0.035	3	--
FeelProving_2: Little	1.096	-0.734	2.854	1.942	0.116	0.052	0.168	4	--
Circum_Others	0.853	0.664	0.565	0.519	0.022	0.013	0.035	1	--
Circum_Negative about AV	0.972	0.222	0.824	0.066	0.032	0.002	0.033	1	--

Note: Ax= Axis; ***Bold*** *number indicates top 10 values.*

Figure 4 shows the MCA plot generated for the variable attributes. Five different clusters are shown in Figure 3. As the MCA plot is limited (-1,1), Cluster 6 is not shown in the MCA plot (see Table 2). General inspection of the MCA plot shows that participants of similar mindset are clustered in groups. For example, participants with negative views are clustered in the first quadrant, participants with positive attitudes are clustered in the second quadrant, and those with neutral responses are clustered in the third or fourth quadrant. One unique feature of MCA is its ability to identify the cooccurrences of the responses. Discussions on these clusters are given below:

Cluster 1 (BpgPos_Actively Support, Circum_AV Safer, FeelProving_5: A Lot, RegulationSchoolZone_2: No, and SafetyAV_5: Very Safe)

This cluster is associated with participants who have positive views on AVs. The participants think that BikePGH should actively support AVs. They consider Pittsburgh's streets safe with human-driven cars. Their experiences of AV circumstances are positive. They are in favor of

Pittsburgh as the proving ground of AVs. The participants of this group think that there should not be any regulation for AVs in the school zone. The cos2 and contribution values of three attributes of this cluster are in the top 10 cos2 and contributions values. The higher values indicate that this cluster is well represented among the survey participants. The percentage values of Table 3 indicate that these attributes are well explained in Axis 1.

Table 3 Overall Contributions of the Clusters

Cluster	Contribution		cos2	
	Axis 1	Axis 2	Axis 1	Axis 2
1	24%	13%	29%	17%
2	18%	5%	23%	7%
3	7%	2%	10%	3%
4	2%	25%	2%	26%
5	6%	15%	6%	15%
6	43%	40%	31%	33%

Cluster 2 (AVSafetyPotential_1: Yes, Circum_Cautious about AV, Circum_No Difference, InteractPedestrian_1: Yes, RegulationSpeed_2: No, SafetyAV_4: Safe, and SafetyHuman_2: Unsafe)
This cluster is associated with participants who have prior interaction with AVs as pedestrians. The participants consider that AVs are safer than human drivers. They feel no difference or somewhat cautious while interacting with AVs in the real world. They consider that there are safety potentials for AVs. They do not think that there should be any speed regulation on AVs. Two of the attributes of this cluster are in the top 10 cos2 and contribution values. This cluster is moderately represented among the survey participants. The percentage values of Table 3 indicate that these attributes are thoroughly explained in Axis 1.

Cluster 3 (Circum_No Experience, Group_Public, InteractPedestrian_2: No, InteractPedestrian_3: Not Sure, RegulationSpeed_1: Yes, and SafetyHuman_4: Safe)
This cluster is associated with Public participants, especially those with no prior interaction with AVs as pedestrians or bicyclists. The participants consider that Pittsburgh's streets are safe with human-driven cars. The participants are also in favor of regulation of speed for AVs. None of the attributes of this cluster are in the top 10 cos2 and contribution values.

Cluster 4 (BpgPos_Neutral, FeelProving_4: Moderate, RegulationSchoolZone_3: Not Sure, RegulationSpeed_3: Not Sure, SafetyAV_3: Neutral, SafetyAV_6: No experience)
This cluster is associated with participants who have neutral views (i.e., responses with not sure) on AVs. The participants of this cluster have no experience or show neutral views as to whether the Pittsburgh's streets are safe with AVs. The participants have a neutral view about whether the BikePGH should oppose or support AVs. These participants are not sure about the regulation of AVs for school zone and speed control. Three attributes of this cluster are in the top 10 contributors of dimension 2. This cluster is moderately represented among the survey participants. The percentage values of Table 3 indicate that these attributes are well explained in Axis 2.

Cluster 5 (AVSafetyPotential_3: Not Sure, BpgPos_No Opinion, FeelProving_3: Some)

This cluster is also associated with participants who have somewhat neutral views on AVs. They do not have any opinion towards BikePGH's position on AVs. They are unsure about the safety

Figure 4 MCA plot of the attributes.

potential of AVs. They are somewhat in support for the proving ground of AVs. The cos2 and contribution values of two attributes of this cluster are in the top 10 cos2 and contributions values. The higher values indicate that this cluster is somewhat represented among the survey participants.

Cluster 6 (AVSafetyPotential_2: No, BpgPos_Actively Oppose, FeelProving_1: Not at All, and SafetyAV_1: Very Unsafe)

The participants of these clusters have strong opposing views on AVs. They feel that Pittsburgh's streets will be totally unsafe with AVs. They oppose using Pittsburgh as the proving ground for AVs. They consider that BikePGH should actively oppose AVs. They do not see any safety potential from AVs. The cos2 and contribution values of all attributes of this cluster are in the top 10 cos2 and contributions values. The higher values indicate that this cluster is very well represented among the survey participants. The percentage values of Table 3 indicate that these attributes are thoroughly explained in both axes. Even though the frequency of these attributes was fairly low, these attributes dominate the map by showing the strong cooccurrences of these attributes in the responses.

Figure 5 shows a global pattern of the individual respondents. The BPG participants are shown in blue color, and public participants are shown in brown.

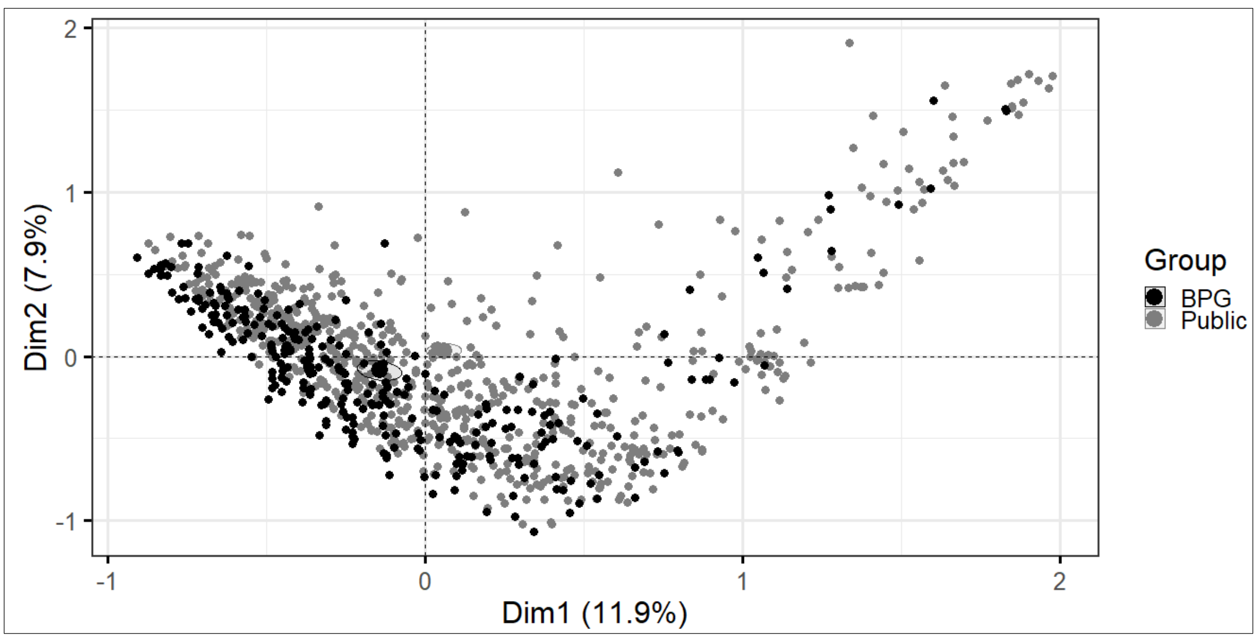

Figure 5 Biplot of individual respondents.

Figure 6a illustrates the individual respondents grouped by two variables: RegulationSchoolZone and RegulationSpeed. The distribution of the attributes shows that these two regulations have similar patterns. Participants asking for school zone regulation for AVs are also asking for speed regulation for AVs. Figure 6b illustrates the individual respondents grouped by two variables: AVSafetyPotential, and FeelingsProvingGround. The distribution of the attributes shows that these two variables have similar patterns. Participants who think of no safety potentials for AVs are also against the proving ground of AVs in Pittsburgh.

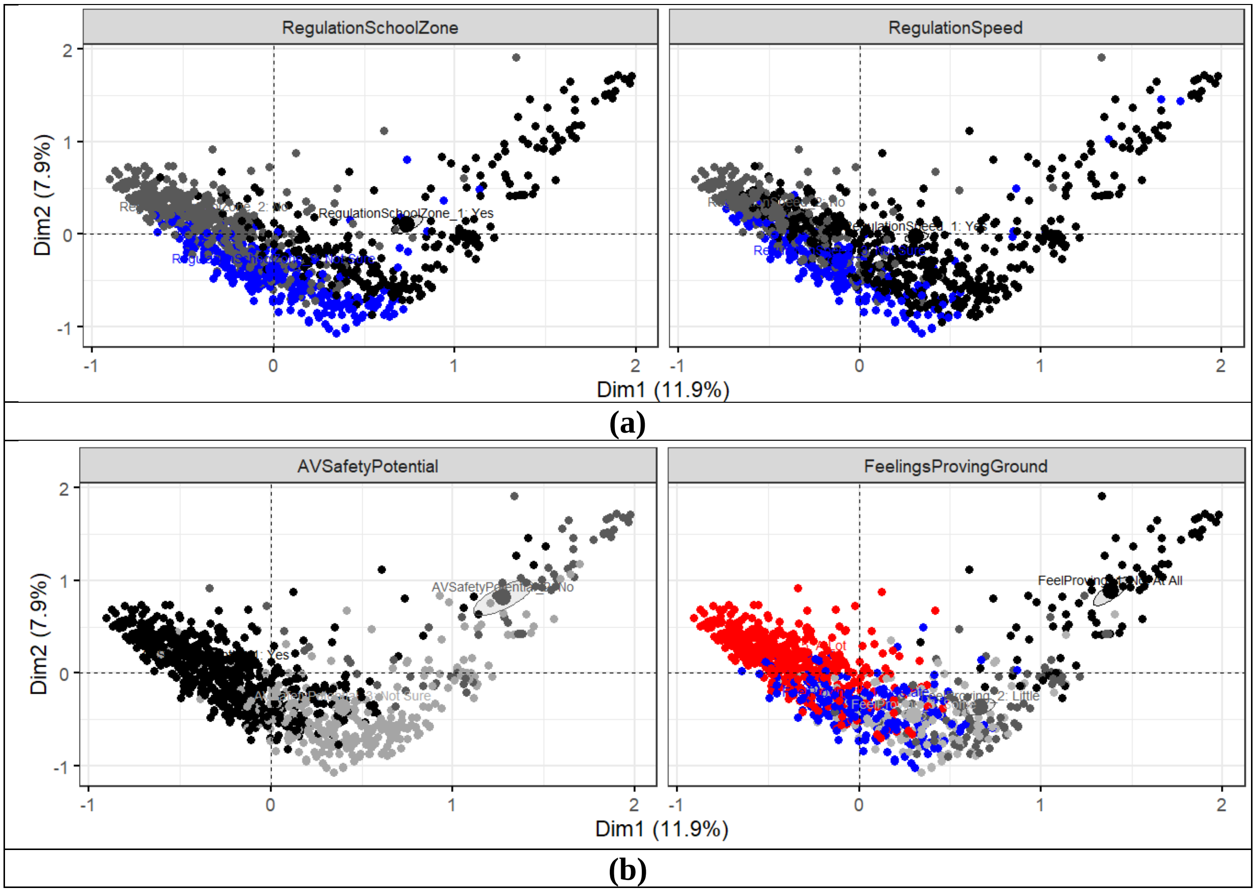

Figure 6 (a) Factor map of RegulationSchoolZone, and RegulationSpeed, (b) Factor map of AVSafetyPotential, and FeelingsProvingGround.

CONCLUSIONS

Gaining the feedback from the end-users and understanding acceptability thresholds will be critical to the extensive deployment of AVs. Additionally, comprehending public perception of emerging technologies like AVs is crucial for policymaking. AV companies predict that AVs will be sufficiently reliable and affordable and replace most human driving by 2030, providing independent mobility to roadway users *(36).* As AV technologies are rapidly growing, there is a need to regulate these technologies and their adoptions in the real-world roadway condition.

Non-motorized travel modes, such as walking and biking, have become popular due to health benefits and environment protection. Unfortunately, non-motorized crashes have been sharply rising, perhaps due to this increase in non-motorized activity in urban locations. As both AVs and non-motorized travels are gaining paces in recent years, it is important to understand the perception of the public towards the interaction between non-motorized roadway users and AVs.

To assist policy development for AV adoption, this study evaluated attitudes of participants towards AV with sensitivity to their experiences with AVs technology. The current study shows that pedestrians with previous interactions with AVs consider AVs safer than human drivers and recognize the safety potential for AVs. For those without previous interactions, the survey shows that they are associated with believing Pittsburgh streets are safe with human-driven cars and that the speed in which AVs are allowed to operate should have a cap. The results of the study provide evidence that experiences and knowledge with AVs are associated with positive attitudes and perceptions. This finding supports the value of having demonstration projects that provide the opportunity for pedestrians and bicyclists to interact with AVs.

The current study does have limitations. First, the survey is limited to a certain region. Second, comprehensive details of circumstances (interaction between AVs and vulnerable users) are not publicly available. Text mining on these narratives can help in understanding the missing link between the perception of AV acceptance among the non-motorists.

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AUTHOR CONTRIBUTION STATEMENT

The authors confirm the contribution to the paper as follows: study conception and design: Subasish Das; data collection: Subasish Das, and Anandi Dutta; analysis and interpretation of results: Subasish Das, Kay Fitzpatrick, Anandi Dutta; draft manuscript preparation: Subasish Das, Kay Fitzpatrick, and Anandi Dutta. All authors reviewed the results and approved the final version of the manuscript.

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