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Opinions of active transportation users on policies to ensure their perceived safety in the era of autonomous vehicles

Sangwan Lee, Ph.D.

LX Spatial Information Research Institute, Korea Land and Geospatial Informatix Corporation, South Korea

A R T I C L E I N F O

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A B S T R A C T

Active transportation users, including pedestrians and bicyclists, have expressed significant safety concerns over the co-existence of autonomous vehicles (AVs) on the road in the future. However, insufficient emphasis has been paid to exploring the demands of safety-related public policies with empirical evidence, and even much of the previous literature has not fully incorporated the viewpoints of the active transportation users. Thus, this study explored the opinions of active transportation users on five safety-related policies in the era of AVs: (1) a speed limit restriction (policy 1), (2) human-occupied AVs at all times (policy 2), (3) active engagement of human drivers in school zones (policy 3), (4) trip-related data sharing (policy 4), and (5) AV technology-related data sharing (policy 5). This study developed five multinomial logit models using the 2019 BikePGH survey data collected in Pittsburgh, Pennsylvania, and revealed the following main findings. First, active transportation users who reported feeling extremely safe when sharing the road with AVs were significantly more likely to believe that none of the five policies were necessary. However, those who believed AVs would harm traffic injuries and fatalities favored policies 2 and 3. Also, those negatively affected by the fatal crash in Arizona expressed the need for policies 1 and 2. Additionally, those who have shared the road with AVs believed that policies 1, 2, and 3 were crucial. This research will benefit AV stakeholders, particularly transportation officials and planners, as it will offer guidelines to ensure the perceived safety of vulnerable road users and make roads safer for them in the AV era.

1. Introduction

As full automation will be offered to the public in the proximate future (Thompson, 2016), one of the major concerns people have expressed is that autonomous vehicles (AVs) can potentially endanger the lives of people when working improperly (Nascimento et al., 2020). For instance, an autonomously-driven Uber-modified SUV with the presence of a human occupant struck and killed a pedestrian in Tempe, Arizona, in March 2018 (Korzeniewski, 2018). This fatal crash drew widespread media attention, and many active transportation users (e.g., pedestrians and bicyclists) have raised considerable concerns about the safety of AVs when sharing roads with them (Penmetsa et al., 2019).

Although adequate public policies would have an essential role in enhancing the sense of safety on the road in the era of AVs, little attention has been paid to exploring the formulation and demand of safety-related public policies (Kalra & Paddock, 2016; Koopman & Wagner, 2017), mainly from the perspective of the active transportation users. Therefore, this study explored opinions of active transportation users on public policies to ensure their perceived safety in the era of AVs by developing five multinomial logit models (MNL) with the 2019 Bike Pittsburgh (BikePGH) survey data collected in Pittsburgh, Pennsylvania. This research has significant practical implications because it offers empirical evidence on the opinions of various public policies that could improve road safety when AVs are becoming more commonplace. Moreover, this study provides a timely snapshot of public policy perspectives, which helps prepare for the future of AVs. Also, this research is of great importance since it focuses on the perspectives of active transportation users, those who are the most vulnerable road users.

This paper is organized as follows. The second section reviews previous literature and presents research gaps that this paper aims to fill. The third paper provides details on the methodological approach used in this paper. The findings are presented in the fourth section. The last section discusses the key findings and concludes this paper.

E-mail address: esangwan@lx.or.kr.

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2. Literature review

2.1. Contexts of safety issues on autonomous vehicles

There are conflicting opinions on the implications of autonomous vehicles (AVs) on society (Schmidt et al., 2015; Bagloee et al., 2016; Gruel & Stanford, 2016; Taeihagh & Lim, 2019; Gkartzonikas & Gkritza, 2019). One of the sensitive subjects with opposing viewpoints is safety (Othman, 2021; Thomas et al., 2020). From the standpoint of proponents, AVs would have the potential to significantly reduce the number of crashs and save lives (Howard & Dai, 2014; Thompson, 2016) because the mode of transportation should adhere to legal requirements, such as speed limits and stop signs (Metz, 2018). Also, given that human errors have accounted for a high portion of the causes of vehicle crashes (Smith, 2013), AVs would lower crash rates by reducing or eliminating human errors (Webb et al., 2019). However, safety concerns would coexist while acknowledging a difference between safety concerns for the general public and those with disabilities (Bennett et al., 2020). AVs may not eliminate automobile crashs due to the possibility of machine errors (Taeihagh & Lim, 2019). For example, the Tesla autopilot 2016 was involved in a deadly crash, demonstrating the possible incapability of technology to prevent all crashs in some conditions (Banks et al., 2018). Moreover, the behavior of AVs is endangered significantly by a range of exogenous elements, including environmental factors, weather conditions, and unforeseen circumstances that have not been fully considered in AV technologies (Othman, 2021).

Survey results reflect the debates. On the one hand, Motional (2021) observed that 54 percent of respondents thought that AVs would reduce their concern about intoxicated, distracted, tired, and aggressive drivers on the road. Also, Hulse et al. (2018) found that many people believed that AVs would be a relatively safe means of transportation compared to preexisting modes. On the other hand, a survey by Statista (2021) reported that the primary concern among 61 percent of potential customers was the possibility of safety risk due to machine error or malfunction. Casley et al. (2013) found that 74 percent of respondents in the U.S. neither trusted AVs nor felt that AVs would perform better than a human driver.

2.2. Active transportation users' perception of the safety issue

In the transport history, there have been periodic suppressions of older modes of transportation in favor of more cutting-edge modes to make room for new modes (Gaio & Cugurullo, 2022). The use of active transportation modes has been severely restricted as a result of this cyclical oppression. Their perception of his or her own comfort and safety when riding a bicycle or walking is heavily impacted by the infrastructure that is made available to them; for example, a grade-separated cycle track is preferable to a painted cycling emblem on a busy roadway. Active transportation modes would become less appealing to people when their comfort and safety are compromised. For instance, in March 2018, an autonomously driven Uber SUV with a human occupant was involved in a fatal collision with a pedestrian in Tempe, Arizona (Korzeniewski, 2018). Accordingly, active transportation users (e.g., pedestrians and bicyclists) have raised considerable concerns about their perceived safety while sharing roads with AVs (Rahman et al., 2021) since crashs involving them are more severe than crashs involving riders of other modes of transportation (Das, 2021). However, a limited body of studies has explored the perceived AV safety from the perspective of active transportation users. For instance, Pyrialakou et al. (2020) conducted a stated choice experiment and found that bicyclists felt that bicycling was the least safe mode of transportation near AVs. Similarly, a survey conducted by Schoettle and Sivak (2014) reported that 92 percent of respondents were highly concerned about the safety of AVs, especially when interacting between AVs and pedestrians. Also, Rahman et al. (2021) found that while some pedestrians and bicyclists praised the AVs for following traffic regulations and acting as a safer alternative to human drivers, many expressed anxiety about possible AV technology issues. Despite the efforts, further research to establish that AVs may be trusted by bikers is neglected and has to be emphasized more explicitly.

2.3. Public policies to address the safety issue

Few previous works attempt to develop guidelines to ensure road safety in the era of AVs. For instance, the United States Department of Transportation (2018) focused on prioritizing safety when integrating AVs into current transportation systems. With the federal standards, states should be able to enact and enforce adequate traffic laws, such as speed limits, AV licenses, and safety inspections (National Highway Traffic Safety Administration, the United States, 2017). Also, the Institute of Transportation Studies at the University of California, Davis, recommended that the state strengthen reporting requirements for AV-related safety incidents to greater accountability and more public information (D'Agostino et al., 2021). In addition, a report by Kinse et al. (2020) suggested that AVs should be programmed to operate at modest speeds (25mph or less) to ensure the safety of pedestrians and bicyclists.

3. Research gap

Despite the body of previous literature, there are critical research gaps that this study aims to fill. First and foremost, although ongoing efforts have largely been made to establish guidelines and criteria to alleviate the safety issue, little attention has been paid to exploring the formulation and demands of safety-related public policies with empirical evidence. Furthermore, much of the existing literature has not adequately incorporated active transportation users' perspectives, although they will also be essential stakeholders outside the AVs (i.e., active transportation users) in the future. Therefore, this study explored the demands of five potential transport policies to enhance perceived safety, particularly from the viewpoints of active transportation users.

4. Materials and methods

This study used the survey data gathered by Bike Pittsburgh (BikePGH) in 2019 and developed five multinomial logit models. The following subsections discuss the empirical settings in detail.

4.1. Case study area: Pittsburgh, Pennsylvania

This study chose Pittsburgh, Pennsylvania, as a case study area for the following reasons. First, since the study area has been selected by the United States federal government as one of the initial testing grounds for AVs. The city is actively working to shape the development of AV technology and policies by allowing certain entities to test and operate AVs on the streets and sidewalks. For instance, the ride-hailing service firm Uber began testing semi-autonomous vehicles in September 2016, with the driver remaining in the vehicle at all times (Ricks, 2017). Therefore, the analysis of the case study area does not necessarily examine a hypothetical situation. Second, the city has emerged as a distinct hub of the AV industry (Blackburn et al., 2021) due to a favorable regulatory environment, local government incentives, and significant investments from firms and academic research institutions. As a result, several companies, such as Argo AI, Aurora, and Motional, and universities, such as Carnegie Mellon, have begun testing in the city (Dentons, 2019). The positioning of the case study area enables this study to explore the demands of public policies as if the public has used or experienced AVs. Third, so far, there have been no crashes resulting in the injury of any kind, nor have there been any cases in which a traffic law has been violated, although the AV testers operate approximately 100 level 4 AVs to conduct their tests, and the total vehicle miles traveled (VMT) of the AVs was approximately 10,200 in June of 2020 (Department of Mobility and Infrastructure, 2020). Also, the city set several principles to ensure AV safety, such as instituting transparent lines of communication and promoting collaboration between the city and diverse stakeholders. This condition may make it possible for this study to avoid having the respondents have biased impressions, such as having a higher level of oppositions toward AVs.

4.2. Survey data

This study used the survey data in 2019 collected by BikePGH, an organization promoting safety and accessibility for bikers and pedestrians in Pittsburgh, Pennsylvania (Penmetsa et al., 2019). Uber, a firm that provides car sharing services, began testing semi-AVs on Pittsburgh roads in September of 2016. Shortly after that, the organization, BikePGH, launched a survey to determine how active transportation users feel about AVs. The surveys were disseminated in the form of emails that were sent to BikePGH donor members, as well as through the BikePGH website, other social networking sites, and news agencies (Rahman et al., 2021). This survey collected valid 795 responses. The location patterns of the respondents provide evidence that Pittsburgh is adequately represented (Das, 2021). Regarding the socio-economic profiles of the respondents, the age distribution among the survey respondents was under 18 (0.1%), 18–24 (4.3%), 25–34 (26.0%), 35–44 (22.3%), 45–54 (16.3%), 55–64 (18.4%), and over 65 (12.4%). Also, most (approximately 95%) owned a car and smartphone. However, the survey data did not collect information on essential socio-demographic characteristics, including income, gender, and race/ethnicity, which is a significant limitation of the data source that this study acknowledged.

This research significantly benefited from using the survey data for the following reasons. First, the survey focused on active transportation users, including pedestrians and bicyclists. Second, the survey documented the opinions of active transportation users on potential transportation policies to ensure their safety on the road. Third, the survey gathered in-depth information about their knowledge, experiences, worries, and expectations regarding road sharing with AVs. Fourth, the survey collected data on the experiences of active transportation users who have interacted with autonomous vehicles (AVs) as part of a pilot program in the city, whereas earlier literature has primarily focused on a hypothetical future.

4.3. Variables

4.3.1. Dependent variables

Table 1 lists and describes the dependent variables, which were five safety-related transport policies. The five potential policies include (1) a restricted speed limit (policy 1), (2) human-occupied AVs at all times (policy 2), (3) active engagement of human drivers in school zones (policy 3), (4) trip-related data sharing (policy 4), and (5) AV technology-related data sharing (policy 5). Each of the dependent variables was used in each multinomial logit model.

Table 1
Description of dependent variables in final model specification.

Name	Description	Category
Policy 1	Should autonomous vehicle (AVs) speeds be capped at 25 miles per hour (mph) when operating in autonomous mode? (The dependent variable is used in model 1)	Yes/ No/ Not Sure
Policy 2	Should AVs always have two full-time employees (pilot and co-pilot)? (The dependent variable is used in model 2)	Yes/ No/ Not Sure
Policy 3	Do you think that AVs should operate in manual mode while in an active school zone? (The dependent variable is used in model 3)	Yes/ No/ Not Sure
Policy 4	Should AV companies be required to share some non-personal data (e.g., the number of trips; pick-up/drop-off locations; the number of miles driven) with the proper authorities (e.g., Department of Mobility; PennDOT; Public Safety)? (The dependent variable is used in model 4)	Yes/ No/ Not Sure
Policy 5	Should AV companies be required to disclose information and data about the limitations, capabilities, and real-world performance of their cars with the proper authorities? (The dependent variable is used in model 5)	Yes/ No/ Not Sure

This study selected the five policies since they have often been mentioned in reports or academic articles to alleviate safety concerns around AVs. For instance, UC Davis (D'Agostino et al., 2021) suggests sharing data on AV-related safety incidents, trips, and technology. Kinse et al. (2020) suggest that AVs should be programmed to operate at modest speeds (25mph or less).

These questions collect information about active transportation users' perceptions of a certain policy by selecting one of the three response categories (i.e., yes, not sure, or no). Table 2 shows the distribution of the dependent variables by the response category. A substantially higher proportion of respondents (nearly 80 percent) indicated that potential policies 4 and 5 were generally needed for the respondents. Another interesting finding was that around 35% indicated a need for policies 1 and 2, whereas 50% showed good sentiments toward potential policy 3.

4.3.2. Independent variables

The final models used nine independent variables (see Table 3). Three survey instruments on safety-related perception were used as covariates of interest in Table 3: (1) general attitudes toward the safety of AVs, (2) opinions about the effectiveness of AVs in reducing traffic crashes, and (3) the influence of fatal crashs in Arizona on their perception. Also, the set of the independent variables included a general attitude toward the safety of human-driven cars. In addition, this study included two additional variables on experiences of sharing the road with AVs as bicyclists and pedestrians to determine how their experience would influence opinions about transportation policies. Other covariates, such as familiarity with AV technology and age, were included in this study as independent variables.

The independent variables in the final model specifications were selected given the findings of the previous literature. For instance, Shi et al. (2021) found that after a successful AV ride, their perceptions of AV safety were dramatically shifted to the positive side. Moreover, Jefferson and McDonald (2019) observed that the decline in a positive view, on the other hand, was significantly greater than the decline in negative emotion since the AV crash in Arizona. Moreover, this study searched for the best model specification with a forward stepwise approach that was taken from earlier research (Murray-Tuite et al., 2021). Specifically, the final model only preserved statistically significant variables in the utility functions.

Due to the data limitation, the final model specifications could not include detailed socio-demographic characteristics, such as household income and gender. It is a limitation since several studies have discovered the socio-demographic factors associated with perceptions of AV safety (Kyriakidis et al., 2015; Salonen, 2018; Hulse et al., 2018), and this study acknowledged it. Description statistics for each of the independent variables used in this study are presented in Table 4.

4.4. Analytic method: Multinomial Logit Model

This study developed five conditional Multinomial Logit Models (MNL) each for five potential policies in Table 1. The following are some of the reasons why the analytical method was appropriate in this study. First, MNL allows exploring why a respondent in the survey chose one alternative from the finite set of mutually exclusive and collectively exhaustive alternatives (i.e., Yes/No/Not Sure for each of five potential policies in this study) (Koppelman & Bhat, 2006). Specifically, the fundamental decision rule of the model follows utility-based choice theory (also called utility maximization theory); in other words, an individual will choose an alternative j if the utility of the alternative j is

Table 2
Descriptive statistics of dependent variables.

Policy	Total		No		Not Sure		Yes	
	Count	%	Count	%	Count	%	Count	%
Policy 1	792	100.0	269	34.0	220	27.8	303	38.2
Policy 2	792	100.0	318	40.2	198	25.0	276	34.8
Policy 3	793	100.0	208	26.2	189	23.8	396	50.0
Policy 4	793	100.0	102	12.9	100	12.6	591	74.5
Policy 5	791	100.0	65	8.2	53	6.7	673	85.1

Table 3
Description of independent variables in final model specifications.

Variables	Description	Categories
AV Safe	1 if the respondent feels very safe when sharing the road with AVs, 0 otherwise	Yes/ No
AV Unsafe	1 if the respondent thinks that AVs will have a negative impact on traffic injuries and fatalities, 0 otherwise	Yes/ No
Arizona negative	1 if the fatal crash in Arizona negatively changes the opinion about sharing the road with AVs, 0 otherwise	Yes/ No
Car Unsafe	1 if the respondent feels very unsafe when sharing the road with human-driven cars, 0 otherwise	Yes/ No
AV approval	1 if the respondent approves the use of public streets as a proving ground for AVs, 0 otherwise	Yes/ No
familiar AV Tech	1 if the respondent is familiar with the technology behind AVs, 0 otherwise	Yes/ No
Experience bike	1 if the respondent has shared the road with AVs while riding a bicycle on the streets, 0 otherwise	Yes/ No
Experience ped	1 if the respondent has shared the road with AVs while walking or using a mobility device (e.g., wheelchair) on the streets, 0 otherwise	Yes/ No
Elderly	1 if the respondent ages 65 or older, 0 otherwise	Yes/ No

Table 4
Descriptive statistics of independent variables.

Variable	N	Missing Value	Mean	S.D.
AV Safe	787	8	0.30	0.46
AV Unsafe	788	7	0.15	0.35
Arizona negative	792	3	0.37	0.48
Car Unsafe	792	3	0.09	0.28
AV approval	792	3	0.37	0.48
familiar AV Tech	792	3	0.48	0.50
Experience bike	792	3	0.53	0.50
Experience ped	793	2	0.61	0.49
Elderly	788	7	0.12	0.33

greater than other alternatives (Koppelman & Wen, 1998). Second, MNL has been a widely used discrete choice model in the transportation field for decades (McFadden, 1974; Wang & Ross, 2018).

However, it is essential to acknowledge the limitation of MNL that inconsistent and biased parameter estimations and marginal effects can be produced due to the violation of the assumption that the error components are identically and independently distributed across alternatives as well as individuals (i.e., the IIA property) (Koppelman & Bhat, 2006; McFadden, 1974).

The probability $Pr_n(j)$ that individual n selects alternative j can be expressed as in the equation below (Ben-Akiva & Lerman, 1985; Koppelman & Bhat, 2006; Train, 2009):

$$Pr_n(j) = \frac{\exp\left(\beta_j X_{jn} + \varepsilon_{jn}\right)}{\sum_{m=0}^{J}\exp\left(\beta_m X_{mn} + \varepsilon_{mn}\right)}$$

where $\beta_j X_{jn}$ shows a systematic linear component of the utility of alternative j that are considered constant across the population. The β represents the coefficients (also called parameter estimations), and X is the nine independent variables in the multivariate MNL model.

In addition, the marginal effects of each independent variable to determine the impact of one indicator variable on the outcome probability of a given choice alternative. The equation is as follows (Greene, 2017; Murray-Tuite et al., 2021):

$$ME_{X_{n(i)}}^{Pr_n(i)} = \Pr\left[Pr_n(j) = 1 | X_{n(i)} = 1\right] - \Pr\left[Pr_n(j) = 1 | X_{n(i)} = 0\right]$$

As shown in the equation, the marginal effects of one indicator variable on the predicted probability of choosing alternative j are computed as the difference in estimated probabilities when the indicator variable $X_{n(i)}$ changes from zero to one while all other variables are equal to their means.

5. Results

This study developed five multinomial logit models (MNL) to examine the association between nine individual characteristics of active transportation users and their opinions (i.e., No, Not Sure, or Yes) on each of five AV safety-related policies (see Tables 5–9). Each model specified the first category (No) as the reference category; therefore, the first column of the tables compared 'Not Sure' category against 'No' category, while the second column, which was of particular importance, compared 'Yes' category against 'No' category. Furthermore, the tables presented estimated marginal effects in three, four, and five columns.

Table 5
The final model specification and marginal effects of multinomial logit model 1.

	Final Model Specification		Marginal Effect		
	Not Sure against No	Yes against No	No	Not Sure	Yes
	Coef. (Std. Err)	Coef. (Std. Err)	Esti.	Esti.	Esti.
Intercept	0.654** (0.271)	0.659** (0.272)	–	–	–
AV Safe	−0.839*** (0.233)	−1.009*** (0.259)	0.152	−0.057	−0.095
AV Unsafe	−0.013 (0.434)	0.570 (0.396)	−0.042	−0.061	0.103
Arizona negative	0.456* (0.253)	0.975*** (0.246)	−0.116	−0.012	0.128
Car Unsafe	0.184 (0.426)	1.323*** (0.382)	−0.118	−0.100	0.218
AV approval	−0.944*** (0.238)	−1.834*** (0.244)	0.226	0.006	−0.232
familiar AV Tech	−0.613*** (0.207)	−0.417* (0.213)	0.087	−0.074	−0.012
Experience bike	0.257 (0.209)	0.462** (0.219)	−0.058	0.002	0.056
Experience ped	0.147 (0.213)	0.134 (0.220)	−0.023	0.014	0.009
Elderly	0.264 (0.307)	0.526 (0.320)	−0.064	−0.003	0.067
Model Statistics					
Observations	763				
McFadden Pseudo R^2	0.167				
Log Likelihood	−692.201				

*Significant at $p < 0.10$;*Significant at $p < 0.05$;*Significant at $p < 0.01$.

Table 6
The final model specification and marginal effects of multinomial logit model 2.

	Final Model Specification		Marginal Effect		
	Not Sure against No	Yes against No	No	Not Sure	Yes
	Coef. (Std. Err)	Coef. (Std. Err)	Esti.	Esti.	Esti.
Intercept	−0.505** (0.247)	−0.781*** (0.244)	–	–	–
AV Safe	−0.193 (0.233)	−0.341 (0.235)	0.058	−0.007	−0.051
AV Unsafe	0.671* (0.364)	1.372*** (0.326)	−0.224	0.009	0.214
Arizona negative	0.145 (0.233)	0.806*** (0.213)	−0.106	−0.040	0.147
Car Unsafe	−0.003 (0.381)	0.740** (0.320)	−0.084	−0.061	0.146
AV approval	−0.455** (0.225)	−0.494** (0.220)	0.102	−0.042	−0.059
familiar AV Tech	−0.391** (0.197)	−0.080 (0.190)	0.048	−0.065	0.016
Experience bike	0.377* (0.199)	0.541*** (0.194)	−0.099	0.024	0.075
Experience ped	0.359* (0.203)	0.408** (0.197)	−0.082	0.032	0.050
Elderly	0.169 (0.269)	−0.719** (0.318)	0.065	0.090	−0.155
Model Statistics					
Observations	763				
McFadden R^2	0.078				
Log Likelihood	−759.217				

* Significant at $p < 0.10$;* Significant at $p < 0.05$;* Significant at $p < 0.01$.

Table 7
The final model specification and marginal effects of multinomial logit model 3.

	Final Model Specification		Marginal Effect		
	Not Sure against No	Yes against No	No	Not Sure	Yes
	Coef. (Std. Err)	Coef. (Std. Err)	Esti.	Esti.	Esti.
Intercept	0.488* (0.288)	1.056*** (0.261)	–	–	–
AV Safe	−0.386 (0.247)	−0.726*** (0.229)	0.099	0.012	−0.112
AV Unsafe	−0.393 (0.489)	0.673* (0.400)	−0.043	−0.145	0.188
Arizona negative	0.244 (0.274)	0.721*** (0.240)	−0.089	−0.037	0.127
Car Unsafe	0.063 (0.365)	−0.166 (0.345)	0.012	0.029	−0.042
AV approval	−0.813*** (0.255)	−0.979*** (0.230)	0.152	−0.034	−0.118
familiar AV Tech	−0.420* (0.223)	−0.381* (0.202)	0.066	−0.031	−0.034
Experience bike	0.041 (0.221)	−0.161 (0.201)	0.013	0.025	−0.039
Experience ped	0.201 (0.226)	0.377* (0.207)	−0.051	−0.006	0.058
Elderly	1.143*** (0.365)	1.058*** (0.349)	−0.182	0.083	0.098
Model Statistics					
Observations	763				
McFadden R^2	0.098				
Log Likelihood	−718.013				

*Significant at $p < 0.10$;*Significant at $p < 0.05$; *Significant at $p < 0.01$.

Overall, the magnitudes and directions of coefficients and marginal effects were generally consistent with the hypotheses. The parameter estimation and marginal effects of each model are presented and discussed in detail in the following subsections.

Table 8
The final model specification and marginal effects of multinomial logit model 4.

	Final Model Specification		Marginal Effect		
	Not Sure against No	Yes against No	No	Not Sure	Yes
	Coef. (Std. Err)	Coef. (Std. Err)	Esti.	Esti.	Esti.
Intercept	1.074** (0.428)	2.600*** (0.356)	–	–	–
AV Safe	0.031 (0.340)	−0.661** (0.262)	0.056	0.062	−0.118
AV Unsafe	0.436 (0.671)	0.379 (0.578)	−0.040	0.013	0.027
Arizona negative	−0.178 (0.395)	0.210 (0.309)	−0.014	−0.038	0.052
Car Unsafe	−0.921* (0.559)	−0.348 (0.367)	0.047	−0.068	0.021
AV approval	−0.936** (0.389)	−1.298*** (0.313)	0.129	0.014	−0.143
familiar AV Tech	−0.538* (0.311)	−0.252 (0.248)	0.031	−0.035	0.004
Experience bike	−0.101 (0.303)	0.063 (0.238)	−0.003	−0.016	0.020
Experience ped	−0.006 (0.306)	0.370 (0.243)	−0.031	−0.033	0.065
Elderly	−0.116 (0.457)	0.179 (0.355)	−0.013	−0.028	0.041
Model Statistics					
Observations	764				
McFadden R^2	0.073				
Log Likelihood	−530.914				

* Significant at $p < 0.10$; * Significant at $p < 0.05$; * Significant at $p < 0.01$.

Table 9
The final model specification and marginal effects of multinomial logit model 5.

	Final Model Specification		Marginal Effect		
	Not Sure against No	Yes against No	No	Not Sure	Yes
	Coef. (Std. Err)	Coef. (Std. Err)	Esti.	Esti.	Esti.
Intercept	0.938 (0.647)	3.895*** (0.494)	–	–	–
AV Safe	−1.162*** (0.443)	−0.790** (0.321)	0.057	−0.027	−0.029
AV Unsafe	0.064 (1.114)	0.322 (0.807)	−0.020	−0.013	0.033
Arizona negative	−1.257** (0.637)	0.253 (0.402)	−0.007	−0.089	0.096
Car Unsafe	0.395 (0.588)	−0.399 (0.453)	0.022	0.044	−0.067
AV approval	−0.129 (0.553)	−1.299*** (0.416)	0.082	0.061	−0.143
familiar AV Tech	−1.213*** (0.431)	−0.759** (0.327)	0.056	−0.032	−0.023
Experience bike	0.349 (0.404)	0.087 (0.288)	−0.007	0.016	−0.008
Experience ped	0.514 (0.427)	0.116 (0.298)	−0.010	0.024	−0.013
Elderly	−1.090* (0.650)	−0.318 (0.395)	0.027	−0.048	0.020
Model Statistics					
Observations	762				
McFadden R^2	0.123				
Log Likelihood	−352.994				

*Significant at $p < 0.10$; *Significant at $p < 0.05$; * * * Significant at $p < 0.01$.

5.1. Policy 1

Table 5 shows that, as expected, the log odds of choosing Yes against No would decrease by 1.009 if the active transportation user feels very safe when sharing the road with autonomous vehicles (AVs). Similarly, the log odds of choosing Yes against No would decline by 1.834 if the respondent approved using public streets as a proving ground for AVs. The parameter estimates and marginal effect results showed that people familiar with AV technology had significantly negative opinions about the policy. However, for those who negatively changed their opinion about sharing the road with AVs due to the fatal crash in Arizona, the speed limit regulation received a positive view (marginal effects on Yes of 0.128). Interestingly, an indicator variable of whether the respondent thinks that AVs will have a negative impact on traffic injuries and fatalities was found to be an insignificant factor. Additionally, those with experience sharing the road with AVs thought the restricted speed limit policy was necessary.

5.2. Policy 2

Table 6 indicates that, expectedly, the log odds of choosing Yes for the policy would significantly increase by 1.372 if the respondent thinks that AVs will have a negative impact on traffic injuries and fatalities. Moreover, the marginal effect of choosing Yes was 0.214, which was significantly larger than other estimations. Also, the marginal effect of 0.147 indicates that those who are negatively influenced by the fatal crash in Arizona showed the need for the policy. Additionally, given the significant and positive parameter estimation, pedestrians and bicyclists who have shared the road with AVs so far answered that the policy is necessary. However, the log odds of selecting Yes against No would decline by −0.494 if the respondent approves the use of public streets as a proving ground for AVs.

5.3. Policy 3

As shown in Table 7, active transportation users with a positive perspective of AV safety on the road (coefficient of −0.726) held opposing views to those with a negative perception (coefficient of 0.673). The predicted probability of selecting Yes for individuals with positive perceptions was 0.188 greater than the others, while individuals with negative perceptions were 0.112 lower than others. An additional notable finding regards the elderly; specifically, the log odds of choosing Yes against No would significantly increase by 1.058 if the respondent ages 65 or more.

5.4. Policy 4

The findings of Table 8 reveal that in terms of the policy regarding trip-related data sharing, only three factors were found to be significant predictors of categorizing the opinions. For instance, the marginal effect of −0.118 reveals that the predicted probability of choosing Yes for active transportation users who feel safe when sharing the road with AVs was 0.118 lower than others. Also, the log odds of choosing Yes against No would decrease by 1.298 if the respondent approves of using public streets as a proving ground for AVs.

5.5. Policy 5

Table 9 reveals that respondents who have a positive perception of the Safety of AVs and strong familiarity with AV technology were more likely to say that AV companies should not be required to disclose information and data on the vehicles' limitations, capabilities, and real-world performance. Additionally, the predicted probability of choosing No for those who approve of public streets as a proving ground for AVs was 0.082 higher than the others.

6. Discussion and conclusion

Enormous resources and efforts have been devoted to the advancement of autonomous vehicle (AV) technology (Othman, 2021), and AVs have been slowly but steadily making their way onto our roads (Hagenzieker et al., 2020). However, there have been concerns raised about the possible safety risks that AVs could pose to active transportation users, including pedestrians and bicyclists since they would have to share the road environment with AVs. Nonetheless, perceived safety issues of active transportation users have not yet been a frequent research issue in transportation planning. Moreover, there has been little systematic investigation on what they might think about safety-related transport policies. Thus, this research developed five multinomial logit models using survey data collected by BikePGH in Pittsburgh, Pennsylvania, in 2019 to explore opinions on five potential transportation policies: (1) a restricted speed limit (policy 1), (2) human-occupied AVs at all times (policy 2), (3) active engagement of human drivers in school zones (policy 3), (4) trip-related data sharing (policy 4), and (5) AV technology-related data sharing (policy 5).

Several key findings and their associated discussions are as follows. First, as discussed in the previous section, there has been debate on the implications of AVs on society, notably regarding safety on the road (Othman, 2021; Thomas et al., 2020). In a similar vein, this study also demonstrates that active transportation users, including pedestrians and bicyclists, show conflicting opinions on the five policies. On the one hand, those with a positive perception of AV safety are significantly more likely to answer that all five potential policies are unnecessary. On the other hand, the findings of this study indicated that suitable transportation regulations are necessary to ensure the safety of a wide variety of demographic groups and to incorporate AVs into the existing transportation systems, particularly active transportation. The findings were consistent with those that were discovered in earlier research. For example, most people are terrified of cars that are operated by artificial intelligence (AI), but despite this, they are eager to implement this technology as soon as it becomes available (Cugurullo & Acheampong, 2023)..

More importantly, the findings of this study demonstrated, and this is perhaps the most important takeaway, that different peoples' attitudes toward AVs necessitate different public policies. For instance, individuals who believe that AVs will impact traffic injuries and fatalities negatively have favorable opinions on policies 2 and 3. Moreover, those who have been adversely impacted by the deadly crash in Arizona express the necessity for policies 1, 2, and 3. In addition, active transportation users who have shared the road with AVs believe that policies 1, 2, and 3 are critical public policies. Interestingly, the elderly would require policy 3 rather than all five policies. Transportation planning frameworks in the future will need to incorporate the understanding of the demands of certain public policies that this study offered.

This research is original on three fronts and provides some important contributions to the field. First, this study is of great importance to transportation agencies and planners since it provides empirical evidence on the demands of the potential public policies to ensure safety in the era of AVs. That is, this study offers a crucial understanding since adequate transport policies would be essential in improving a sense of safety while riding AVs or sharing the road with them. Furthermore, this research is crucial since it places emphasis on the most vulnerable road users. This study on the safety issue of active transportation users will be topical for the transportation discipline because crashes involving these users are more serious than crashes involving riders of other modes of transportation (Das, 2021). Moreover, this study can offer a timely snapshot of the opinions of public policies, given research, testing, and deployment of AV technologies have recently grown in popularity worldwide. Therefore, this study can offer significant practical implications when preparing for the era of AVs.

The author acknowledges several limitations of the research. First, since the survey was limited to Pittsburgh, the results may not represent the perceptions of pedestrians and bicyclists in other U.S. cities and countries (Moody et al., 2020). As a result, there is a problem with the generalizability of this study. Second, this study investigated only five potential transport policies, although there are additional policies to ensure safety in the era of AVs. Third, due to a lack of data, the final model specifications did not include critical covariates, such as household income and gender. This may explain why the five models showed lower model performances. Fourth, as AV technology continues to evolve, individual attitudes may shift. That is, the findings in this research can only represent their attitudes toward currently available AV technology. Fifth, future research will be needed to explore the effectiveness of the measures aimed at ensuring road safety for active transportation users. Sixth, the measures may draw considerable controversy between proponents and opponents, which needs to be examined in future studies in further detail. Lastly, this research lacks a theoretical framework, which prevents it from providing logical coherence and connecting the ideas and findings.

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Sangwan Lee: Conceptualization, Methodology, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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