Smart Transportation: Examining the Factors Influencing the Adoption of Autonomous Vehicles (AVs) in Ghana

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Abstract

Achieving sustainable cities and environmental stability seems attainable in light of inventions such as autonomous vehicles (AVs). However, this can only be realized when the public is willing to adopt such emerging technologies. This study investigates the potential factors influencing the adoption of AVs from the perspectives of engineering tutors from various technical institutes (universities and high schools) in Ghana. Using 213 valid responses collected, we tested a proposed structural model using a structural equation model in SPSS-Amos software. The results showed that respondents perceive AV technology positively and are willing to adopt (own or use). However, significant diverse views exist among the respondents' different sociodemographic groups. Example, those married raised concerns about the safety of AVs, and the highly educated had positive perceptions of the environmental friendliness of AVs. Men showed the strongest interest in owning or using AVs compared with women. Moreover, respondents who exhibited intentions to use AVs had concerns about the adequacy of road infrastructure to support AV operations. This study provides insight into the potential adoption of AVs in Ghana and the factors that could affect their adoption and acceptability. The study also highlights the challenges and opportunities as this technology advances.

Keywords: *Autonomous vehicles, Smart Transportation, Perceived safety, Adoption, Ghana.*

1.0 INTRODUCTION

Autonomous vehicle (AV) is a new technology that has the potential to transform the transportation industry and improve mobility for people around the world (Bagloee et al., 2016; Haboucha et al., 2017). Importantly, AVs are expected to eliminate road transport-related challenges caused by human errors, ultimately saving lives and properties (NHTSA, 2017.). The potential benefits of

AVs include increased safety, reduced traffic congestion, reduced emissions, fuel efficiency, and increased productivity (Bagloee et al., 2016; Eppenberger and Richter, 2021; Milakis et al., 2017; Nishikori et al., 2020; Salonen & Haavisto, 2019)

AVs also have the potential to offer accessible transportation (Zou et al., 2022) and enhanced job opportunities (Cohn et al., 2019). These benefits among others make this nascent technology a worthwhile pursuit for researchers, policymakers, and industry leaders.

Although Litman (2023) indicated that it takes decades for new technologies to penetrate existing markets, the current advances in technology will accelerate the introduction of AVs more quickly than expected. Thus, researchers and industry players are making significant progress in developing and testing this technology to make it safer, reliable, efficient, and available to individuals worldwide. Based on the Society of Automotive Engineers (SAE) current grouping of vehicles (see Figure 1) characterized by their level of automation and self-driving capabilities, experts predict that level 5 vehicles, which are fully autonomous, will be available to the market by 2030 (Litman, 2023).

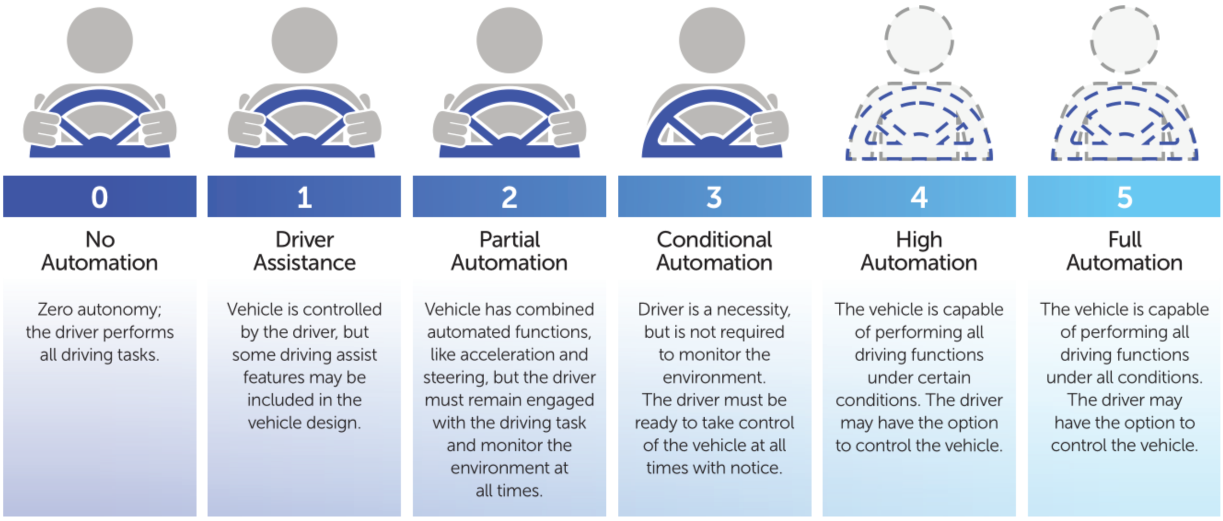

Fig. 1. ***SAE automation level of vehicles (NHTSA, 2017.)***

However, while many are enthused about the rapid development of AV technology and its potential benefits, there are challenges to its widespread adoption, especially in developing country settings. For instance, such an invention will require public confidence to adopt and use the technology and well-developed infrastructure to function effectively.

The prevailing factors that may influence individuals' intentions to adopt this new technology are still blurry, especially in developing country settings. For example, (Milakis et al., 2017)the potential effects of automated driving that are relevant to policy and society are explored, findings discussed in literature about those effects are reviewed and areas for future research are identified. The structure of our review is based on the ripple effect concept, which represents the implications of automated vehicles at three different stages: first-order (traffic, travel cost, and travel choices noted that it remains unclear what the benefits of AVs will be regarding safety, public health, economy and social equity. Indeed, potential consumers have reservations about the safety of AVs (Schoettle and Sivak, 2024) largely because the technology is new and the majority of the world's population are yet to experience AVs.

Penmetsa (Penmetsa et al., 2019) found that individuals who interacted with AVs had positive perceptions about their safety. In promoting the early adoption of this technology, they recommend to policymakers to give the public the opportunity to interact with AVs, arguing that this engagement and interactive experience will create a positive impact on people's perceptions and significantly contribute to the broader adoption of AV technology. The goal of this study, therefore, was to investigate the determinants of AV adoption in Ghana.

Ghana's transportation sector faces several challenges, including inadequate road infrastructure, poor road safety, and traffic congestion. In addition, many Ghanaians have limited access to public transportation, particularly in rural areas. These challenges are exacerbated by rapid population growth and urbanization, as well as limited government funding for transportation infrastructure. Considering these challenges, there is potential for AVs to improve transportation in Ghana. AVs could provide a more efficient and convenient transportation option for Ghanaians, particularly in urban areas where traffic congestion is a major issue. They could also help address issues related to road safety, as AVs are designed to reduce the risk of accidents caused by human error (Litman, 2023)driverless or robotic largely due to fatigue and stress.

2.0 LITERATURE

Literature has shown that in developed countries, where this new AV technology is rapidly evolving, a significant amount of knowledge exists on AVs impacts (Kim, 2018; Milakis et al., 2017) and adoption (Jing et al., 2019; Wang &Akar, 2019; Nishihori et al., 2020; Othman, 2021). Several studies have explored the various factors influencing the adoption of AVs with the focus on sociodemographic (Charness et al., 2018; Garidis et al.,2020.; Golbabaei et al., 2020; Haboucha et al., 2017; Souza & Castañon, 2021; Topolšek et al., 2020), Perceived safety (Fagnant and Kockelman, 2015; Garidis et al., 2020.; Kyriakidis et al., 2015; Souza and Castañon, 2021; Topolšek et al., 2020), perceived effort and performance expectancy, (Kyriakidis et al., 2015; Payre et al., 2014; Schoettle & Sivak, 2014; Venkatesh et al., 2003), perceived environment impact,(Fagnant & Kockelman, 2015, 2018; Payre et al., 2014; Schoettle & Sivak, 2014), knowledge of AV technology (Penmetsa et al., 2019), and road infrastructure (Čudina Ivančev et al., 2022; Hu et al., 2021; Liu and Song, 2019; Othman, 2022; Schoenmakers et al., 2021; Tengilimoglu et al., 2023a).

However, in the context of West Africa, little is known about these influencing factors as researchers from only a few countries have given attention to AV adoption (Fig. 2). This may be due to the absence of AVs in most countries in Africa, including Ghana (Ackaah et al., 2022). Recently, few researchers have seen the need to investigate the adoption of AVs in Ghana (Ackaah et al., 2021, 2022; Akuh et al., 2023a) because of the potential benefits of this new technology over the traditional system.

To contribute to the literature regarding the potential factors that will influence the adoption of AVs in Ghana, we explored factors such as those relating to socio-demographics and AV technology. These factors are discussed in the next sections(see Fig. 2).

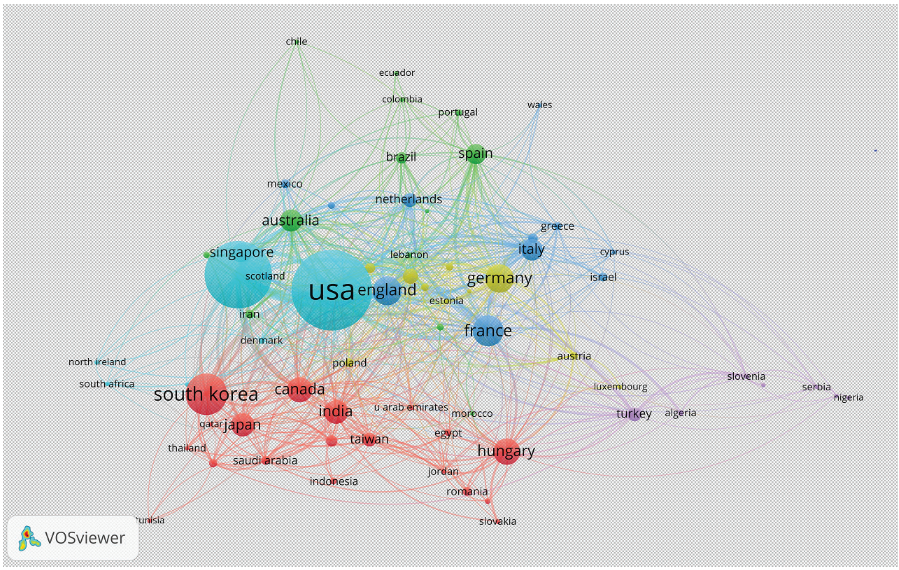

Fig. 2. AV adoption studies by country (Source: Authors' analysis, 2021)

2.1 Socio-demographic factors

Several studies have shown a correlation between sociodemographic characteristics and AV adoption (Charness et al., 2018; Golbabaei et al., 2020). Different demographic groups have different levels of acceptance and attitudes towards AVs (Garidis et al., 2020). Age is a key demographic factor that affects AV adoption (Ackaah et al., 2022). Younger generations tend to be more accepting of AVs than older generations (Garidis et al., 2020.; Haboucha et al., 2017; Souza & Castañon, 2021). Gender is another demographic factor that affects AV adoption. A review conducted by (Souza and Castañon, 2021) found that men were more likely to accept or adopt AVs than women. However, this gap may narrow over time as AV technology becomes more widely known and accepted and when a fully autonomous vehicle is available (Topolšek et al., 2020). Education is also a key factor that affects AV acceptability. People with higher levels of education tend to be more accepting of AVs than those with lower levels of education (Garidis et al., 2020.; Haboucha et al., 2017; Souza & Castañon, 2021). Income could also affect AV acceptability (Ackaah et al., 2022). People with higher incomes tend to be more accepting of AVs than those with lower incomes.

Furthermore, cultural factors could affect AV acceptability, as different cultures may have different attitudes towards technology and may place different values on safety, privacy, and job displacement. For example, a survey conducted by (Haboucha et al., 2017) found that individuals in Israel were more accepting of AVs than individuals from North America. Similar research findings revealed that individuals from Japan, UK and Germany have different acceptance levels (Taniguchi et al., 2022). Overall, sociodemographic factors can have a significant impact on the adoption of AV.

2.2 Knowledge and AV Adoption

The perception of individuals about AV technology may affect its adoption (usage and ownership). Generally, studies have investigated influencing factors associated with AV adoption. One key factor that is revealed to influence the adoption of AVs is the knowledge of the public about AV technology. Thus, as the public understanding of AV technology improves, it is anticipated that their acceptance of AVs will also increase (Chikaraishi et al., 2020; Hussain et al., 2021a). In other words, the intentions of the public to own or use AVs will be based on their knowledge about technology. Awareness of

AVs, understanding of AV technology, and experience with AVs (Penmetsa et al., 2019), and trust in AVs are key factors that affect their adoption. People who are aware of AVs and their potential benefits are more likely to accept them. However, in some cases, knowledge of AV technology does not influence adoption. (see Taniguchi et al., 2022)the UK and Germany and speculates on the implica tions for policy and practice. Three on-line surveys of 3,000 mem bers of the public in total, which were conducted in January 2017 (Japan. We assumed that engineering tutors in all the technical institutes in Ghana should have some adequate level of AV technology. Hence, we seek to investigate how the knowledge will influence AV adoption.

2.3 Effort and performance expectancy

Factors such as effort and performance expectancy are said to affect AV adoption. For effort expectancy, Venkatesh (Venkatesh et al., 2003) indicated that people prefer impact technologies that require little effort or adjustment. Therefore, the more effortless and intuitive an autonomous vehicle is to use, the more acceptable it will likely be to consumers. Other authors also highlighted the importance of effort expectancy and performance expectancy for autonomous vehicle acceptance, though they use different terminology at times: (Kyriakidis et al., 2015) discussed "usability" and "functionality" as two key factors: "Usability" refers to how easy and effortless autonomous vehicles are to use, corresponding to effort expectancy. "Functionality" refers to how well autonomous vehicles perform their key functions, corresponding to performance expectancy. They argue that both usability and functionality will be critical for consumer acceptance.

Payre et al. (2014) discussed "complexity of use" and "usefulness" as key factors, again corresponding to effort expectancy and performance expectancy. They found that perceived usefulness has a stronger impact on acceptance, but the complexity of use also influenced willingness to adopt. Schoettle & Sivak (2014) found that both "operability" and "performance" are important determinants of public acceptance of self-driving vehicles. Operability relates to ease of use, while performance relates to capability. While the relative impact of each factor may differ depending on study and stage of technology development, effort and performance expectancy appear to be consistently important across the literature.

2.4 Safety

Safety plays a crucial role in influencing the adoption of autonomous vehicles. The perception of safety among potential users and regulatory bodies significantly impacts their acceptance and willingness to adopt this transformative technology. Several studies have highlighted a positive relationship between AV safety and adoption (Haboucha et al., 2017; Hussain et al., 2021a; Li et al., 2022; Montoro et al., 2019; Prasetio & Nurliyana, 2023; Topolšek et al., 2020). The perception of safety is a key factor influencing public acceptance of AVs. Topolšek et al. (Topolšek et al., 2020) found that the safety of autonomous cars correlates significantly with their purchasing intention. Similarly, (Garidis et al., 2020.) found a positive relationship between safety and public acceptance of AVs. Research by (Hussain et al., 2021a) revealed that individuals who perceived AVs as safer were more likely to consider adopting them. Thus, their perceptions about AV general safety influence those who are likely to shift to AVs. Other researchers found that individuals were more concerned about AV safety when it came to their willingness to adopt AVs (Kyriakidis et al., 2015; Souza & Castañon, 2021). For instance, the fatal accident involving a Tesla Model S operating in Autopilot mode drew considerable attention and raised concerns about AV safety. Such incidents can create a negative perception of AV safety and hinder the adoption (Fagnant & Kockelman, 2015). Generally, the literature shows that concerns about safety were among the primary barriers to AV adoption.

2.5 Environmental impacts

Environmental impact is an important factor influencing public acceptance of AVs. However, the direction of this influence is complex and depends on expectations of how autonomous vehicles may impact the environment compared to conventional vehicles. On the one hand, AVs have the potential to reduce negative environmental impacts through features like eco-driving, platooning, and ride-sharing (Fagnant & Kockelman, 2015). This could make AVs appear more environmentally friendly and thus increase their acceptability. Studies suggest that about 30% of the population consider environmental friendliness an important attribute of AVs (Payre et al., 2014). On the other hand, concerns have been raised about how autonomous vehicles could increase traffic, vehicle miles traveled (VMT), and ultimately, greenhouse gas emissions if they become cheaper to use and provide more convenience (Fagnant & Kockelman, 2018). This could decrease their perceived environmental friendliness and acceptance. Uncertainties about the overall environmental impacts of autonomous vehicles also contribute to mixed views among the public (Schoettle & Sivak, 2014).

2.6 Road infrastructure

The successful deployment of AVs, much like any other mode of road transportation, relies heavily on the presence of adequate infrastructure. Researchers have identified infrastructure as one of the key factors influencing the seamless integration of AVs into existing road transport systems (Tengilimoglu et al., 2023a)many challenges for road infrastructure need to be overcome before those benefits can be achieved. This study addressed multiple dimensions of the implications of CAV deployment for road infrastructure through a comprehensive survey with 168 experts from different sectors and regions around the world. The issues are grouped into five categories: (1. Consequently, numerous studies have been conducted to explore and address the specific infrastructure requirements necessary for the successful deployment of AVs (Čudina Ivančev et al., 2022; Madadi et al., 2021; Tengilimoglu et al., 2023b)an increasing amount of research has been dealing with the development of autonomous vehicles (AVs. The widespread adoption of AVs will require significant changes to infrastructure because concerns about how humans will interact with AVs have been raised. However, making changes to the existing infrastructure, such as dedicating specific lanes for AVs, could be a possible solution (Schoenmakers et al., 2021)there is still a lack of evidence-based research on the consequence of dedicated lanes for AVs on human drivers' behavior. To bridge this research gap, a driving simulator experiment was conducted to investigate the behavior of human drivers exposed to different road design configurations of dedicated lanes on motorways. The experiment sample consisted of 34 (13 female. Liu and Song (2019)autonomous vehicles (AVs investigated dedicated lanes for AVs and proposed that dedicating separate lanes for AVs could reduce road crashes and promote AV adoption.

A well-maintained road network is essential to ensure the safe navigation of AVs. Clear and visible road markings, signages, and lane delineation will play a vital role in enabling AVs to perceive and interpret their surroundings accurately. To support the deployment and adoption of AVs, there is a need for infrastructure upgrades (Čudina Ivančev et al., 2022)an increasing amount of research has been dealing with the development of autonomous vehicles (AVs and well-established regulations and standards for AVs)(Hu et al., 2021).

However, as with Ghana, the deployment of AVs in many developing countries will face many challenges (Othman, 2022) regarding road infrastructure. The lack of adequate road infrastructure has been identified in many studies as a major contributing factor to the majority of road crashes and other road transport-related challenges. This deficiency has had far-reaching impacts on mobility and accessibility across various contexts. Therefore, considering the significance of road infrastructure for AVs, our study also focuses on investigating the influence of road infrastructure on AV adoption in Ghana.

2.7 Objectives of AV adoption in Ghana

The extent of autonomous vehicle (AV) adoption in Ghana remains largely uncertain since limited studies have been conducted on this subject, primarily due to the absence of AVs within the country. This study aims to provide insight into AV adoption in Ghana by so doing adding to the existing literature on this important mobility option which is to revolutionize the road transport industry shortly. We intend to address the following research questions:

- Is there a variation in how different sociodemographic groups perceive AV technology (i.e., effort expectancy-ease of use, performance expectancy, safety, environmental impact, and road infrastructure)?
- Do the level of perception of these groups of individuals regarding AV technology (i.e., effort expectancy, performance expectancy, safety, environmental friendliness) and road infrastructure influence their adoption (intention to own and intention to use)?”

3.0 METHODOLOGY

3.1 Study design

The study employed a survey method where a questionnaire was used as a data collection instrument. The questionnaire was administered to engineering tutors. The survey was administered online and face-to-face to tutors from various technical universities and technical/vocational institutions in Ghana between the months of June and September 2022. Two approaches were used to collect the data for the study. First, we explained the purpose of the study to engineering academic workers (lecturers and technicians) who converged for a three-month technical and vocational training program organized by the Commission for Technical and Vocational Education and Training CTVET) of Ghana and AVIC International. The training program was on training teachers and technicians on modern equipment provided to the various institutions. Teachers and technicians (two each selected for two sets of badges) from all technical universities and technical institutes (high schools) across the country attended the training program. After explaining the purpose of the survey, the link to the online questionnaire was sent to their WhatsApp applications, and they were asked to share it with their colleagues who could not attend the training program. Secondly, a self-administered paper-based questionnaire was administered. In total, 221 responses were received, of which 213 were valid for the study. Thus, 131 valid responses were received from the online surveys and 82 from the face-to-face self-administered survey.

The survey was divided into three main sections to align with the study’s objectives. In the first section, we collected information regarding the sociodemographic characteristics of the respondents (Table 1) and asked questions about their knowledge of AV technology. The second and third sections of the survey are discussed later under questionnaire items. The total sample of the questionnaire

(Table 1) comprised 88.3% males and 11.7% females, with the majority between the ages of 26 and 35 years. 67% were married (35 with kids and 32 without kids). Regarding education, 49.8% are pursuing or have first degrees, 29% have masters degree and 11% have Ph.D. About 46% earned a monthly income of less than 3,000 Ghana cedis, 50.7% owned a car, and about a third (34%) had 5 years of driving experience. Regarding the common mode of transportation, 53.5% used private cars, 13.6% used taxis, 5.2% used app-enabled service vehicles (Uber, Tango, Bolt etc.), and 27.7% used public transport. For knowledge about AV technology, 42.7% have a simple background from social media, 19.7% have a good background, 13.6% have a strong background, and 23.9% have no knowledge about the technology (the first time I heard of AV).

Table 1 Socio-demographic characteristics of respondents

Variables	**Levels**		**Sample**
		Frequency	Percentage
Gender	Male	188	88.30%
	Female	25	11.70%
Age	18-25	20	9.40%
	26-35	92	43.20%
	36-45	60	28.20%
	Above 45	41	19.20%
Marital Status	Single	68	31.90%
	Married with no Kid	69	32.40%
	Married with Kids	76	35.70%
Education Background	Diploma	21	9.90%
	Bachelor's degree	106	49.80%
	Masters	62	29.10%
	Ph.D.	24	11.30%
Monthly Income	>3000	98	46%
	3000-6000	44	20.70%
	6000-10000	48	22.50%
	10000-15000	19	8.90%
	<15000	4	1.90%
Car Ownership	Yes	108	50.70%
	No	105	49.30%
Driving Experience	No license	54	25.40%
	Within 5 years	74	34.70%
	5-10 years	30	14.10%
	Above 10 years	55	25.80%
Transport Mode	Private car	114	53.50%
	Taxi	29	13.60%
	Public Transport	59	27.70%
	App-enable service vehicles	11	5.20%
AV Knowledge	First time I heard of AV	51	23.90%

	A simple background from social media	91	42.70%
	A good background	42	19.70%
	A strong background	29	13.60%

3.2 Questionnaire items

The questionnaire is divided into three sections. The first section was discussed earlier (sociodemographic characteristics of respondents). In the second section, we focused our attention on the adoption of AVs, where we asked respondents to agree or disagree on whether they intended to own or use AVs. The final (Third) section focused on the respondents' perception of AV technology. The questions were on perceived effort expectancy, perceived performance expectancy, perceived safety, perceived environmental friendliness, and perceived road infrastructure. We used a 5-Likert Scale to measure the level of agreement and disagreement of the perceived factors. These variables, questions/measuring items, where they were adapted from, and their coding are presented in Table 2.

Table 2 Questionnaire items, sources and coding

Variables	questions/measuring items	Adapted from	Coding
Intention to own (ITO)	I would like to own an autonomous vehicle as a private vehicle	(Garidis et al., 2020.; Li et al., 2022)	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed
Intention to own (ITU)	I will prioritize the use of autonomous vehicle over conventional one	(Jing et al., 2019)it is	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed
Effort Expectancy(EE)	I imagine the operation of an autonomous vehicle to be easier than that of a conventional vehicle	(Lee et al., 2019; Li et al., 2022)	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed
Performance Expectancy (PE)	I think autonomous vehicles will be faster and more efficient than conventional vehicles.	(Garidis et al., 2020.)	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed

Safety (SF)	Autonomous vehicles would drive more safely.	(Garidis et al.,2020.;	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed
Environmental Friendliness (EF)	Autonomous vehicles would be environmentally friendly than conventional vehicles.	(Garidis et al., 2020)	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed
Rod Infrastructure (RINF)	The road infrastructure is adequate to support autonomous vehicle in Ghana	Self-constructed	5= Strongly agreed, 4= Agreed, 3= Neutral, 2=Disagreed, 1= Strongly disagreed

3.3 Data analysis

A descriptive data analysis was used, followed by a Pearson correlation analysis. Furthermore, we conducted a reliability test using Cronbach's alpha to evaluate the internal consistency of the results of the different test items (Garidis et al., 2020.). Finally, following the objective of this study and the complex nature of the research questions to be investigated, we developed structural equation models (SEM) using SPSS-Amos software version 25. A conceptualized model was developed to identify the causal linkage between the variables.

3.4 Structural Equation model

Structural equation modeling (SEM) is a statistical technique used to analyze the relationships between observed (measured) and latent (unobserved) variables (Stein et al., 2012). SEM involves two main approaches such as measurement models and structural models. The structural model, which is the focus of this paper and also used by similar paper (Naderi & Nassiri, 2023), represents the relationships between latent variables, indicating the direct and indirect effects among the latent variables. A path diagram typically represents the structural model, where the paths between variables represent the hypothesized relationships. The general form of a structural equation model (Stein et al., 2012) can be represented as:

$$\xi = \Lambda\xi + B\eta + \varepsilon$$

where ξ is a vector of observed indicators, Λ is a matrix of factor loadings, η is a vector of latent variables (factors), B is a matrix of structural regression coefficients, and ε is a vector of error terms.

Due to the uncertainties surrounding the complex nature of AV technology, several studies have resorted to the SEM (Jing et al., 2019; Topolšek et al., 2020; Li et al., 2022; Prasetio & Nurliyana, 2023; Naderi and Nassiri, 2023; Acheampong & Cugurullo, 2019; Hussain et al., 2021b) to analyze factors influencing their adoption and acceptability. Based on the nature and complexity of our study, we developed an SEM model (see Fig. 3) to explore the research objective and our research questions. .

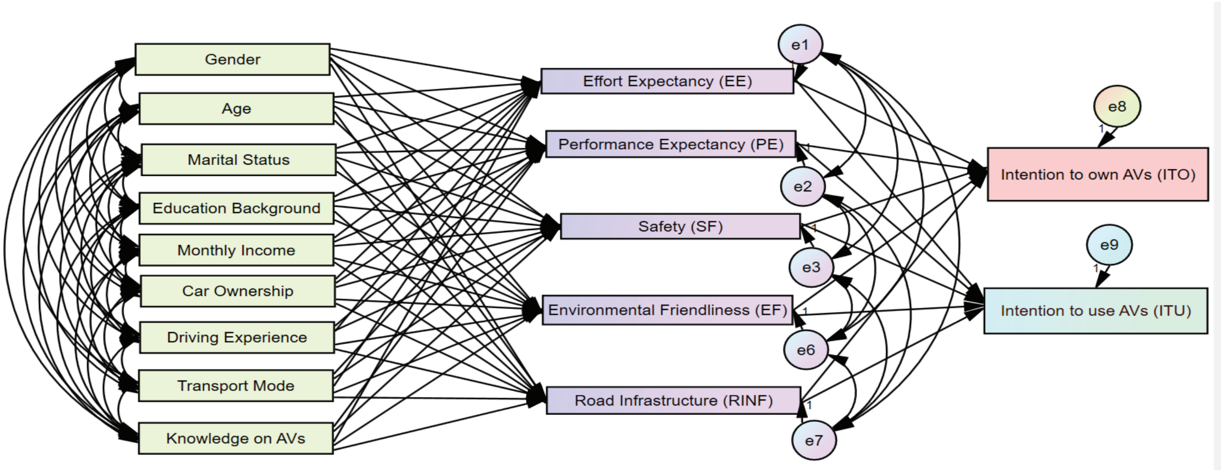

Fig. 3. Conceptualized model (intention to own AV and intention to use)

4.0 RESULTS

4.1 Descriptive statistics

Table 3 shows the results of the descriptive statistics of AV variables (of interest) we examined. About 31% of the respondents have the intention to own AVs, while 33.3% have not yet decided about their intention to own (mean=3.18). However, for the intention to use AVs, 44.6% (mean=2.92) agreed they intend to use AVs, and 23.5% have not decided. For factors influencing adoption (intention to own or use) AVs, 76.1% (mean= 2.14) of the respondents perceived AVs to be easy to use (effort expectancy). Again, 49.8% (mean=2.59) perceived AVs to be faster and more efficient than conventional vehicles (performance expectancy). Furthermore, 41.3% of respondents agreed that AVs, when successfully deployed, will drive more safely than driver-driven vehicles. Hence, they were less concerned about safety (mean=2.76; Std. deviation=1.118). Moreover, about 41.4% (mean=2.61) of the respondents agreed that AVs would be environmentally friendly (less polluting), but 34.3% did not know how AVs could be friendly to the environment. Finally, 71.8% of the respondents think that the road infrastructure is not adequate to support AVs in Ghana. Thus, respondents generally have concerns (mean=3.9; Std. deviation = 1.193) about road infrastructure and its ability to support AV operations (see Table.3).

Table 3 Variables of interest

AV Variables	Percentage of responses						
	5	4	3	2	1	Mean	Std. Deviation
Intention to own (ITO)	9.4%	19.7%	33.3%	18.8%	18.8%	3.18	1.219
Intention to use (ITU)	8%	36.6%	23.5%	19.2%	12.7%	2.92	1.177
Effort Expectancy (EE)	26.3%	49.8%	12.7%	6.1%	5.2%	2.14	1.041
Performance Expectancy (PE)	14.1%	35.7%	31.9%	13.6%	4.7%	2.59	1.04
Safety (SF)	13.6%	27.7%	36.2%	14.1%	8.5%	2.76	1.118
Environmental Friendliness (EF)	17.4%	31%	34.3%	8%	9.4%	2.61	1.146
Rod Infrastructure (RINF)	4.2%	13.6%	10.3%	31.9%	39.9%	3.9	1.193

N=213

4.2 Correlation analysis

To explore the extent to which the variables investigated linearly relate to each other and the strength and direction of their relationship, we conducted a Person correlation test, and the results (Table 4) show that overall, there were positive and significant correlations between almost all the variables except road infrastructure and performance expectancy (ß = -0.061). The highest strength of correlation was between environmental friendliness and performance expectancy (ß = 0.562), followed by intention to use AV and intention to own AV (ß = 0.454). The test also revealed that the correlation between road infrastructure and intention to use AV is stronger (ß = 0.438) than between road infrastructure and intention to own (ß = 0.337). This implies that road infrastructure could be one of the factors that may affect the adoption of AVs in Ghana.

Table 4 Pearson correlation and reliability test

Variables	ITO	ITU	EE	PE	SF	EF
Intention to own (ITO)	-					
Intention to own (ITU)	.454**	-				
Effort Expectancy (EE)	.255**	.437**	-			
Performance Expectancy (PE)	.199**	.224**	.424**	-		
Safety (SF)	.346**	.237**	.207**	.207**	-	
Environmental Friendliness (EF)	.259**	.421**	.425**	.562**	.280**	-
Rod Infrastructure (RINF)	.337**	.438**	.278**	-0.061	.153*	.136*

Significant at p< 0.1, p<0.05*, p< 0.01**

4.3 Results of structural equation model(SEM)

4.3.1 Model Fitness Analysis

Model fit indices were used to assess the overall fit of the SEM model to observe data. There are several commonly used model fit indices (Akuh et al., 2023b; Hussain et al., 2021b), including the chi-square test, normed fit index (NFI), comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA). The chi-squared test is a measure of absolute fit that compares the observed covariance matrix to the model-implied covariance matrix. A non-significant chi-square value indicates a good fit; however, the chi-square test is sensitive to sample size and can be problematic for large samples (Hu & Bentler, 1999). CFI and TLI are measures of relative fit that compare the fit of the specified model to that of a null model. A CFI or TLI value greater than .90 indicates an acceptable fit, whereas a value greater than .95 indicates a good fit. RMSEA is a measure of absolute fit that estimates the amount of error in a model per degree of freedom. An RMSEA value less than .05 indicates a good fit, while a value less than .08 indicates an acceptable fit (Hu & Bentler, 1999).

The results in Table 5, according to the cutoff values of the various indices, showed that our SEM fits the data well.

Table 5 Result of Model fitness

Fit index	Estimates	Cut-off values (Hu and Bentler, 1999)
Chi-square	P value = 0.384	non-significant
Normed Fit Index (NFI)	0.978	>. 9
Tucker-Lewis index TLI	0.935	>. 9
Comparative Fit Index (CFI)	0.990	>. 9
Root Mean Square of Error Approximation (RMSEA)	0.056	<.08

4.3.2 Perception towards AVs

The conceptualized SEM presented in Fig. 3. The results as presented in Table 6 showed that "Gender" has a negative significant relation with Effort Expectancy (ß = -1.409; p=0.008), Performance Expectancy (ß = -2.254; p=0.000), and Road infrastructure (ß = -1.474; p=0.035). For "Age", only Effort Expectancy was significant (ß = 0.904; p=0.000). This indicates that individuals who were older had concerns about the effort required to operate AVs, and if it takes less effort, then their adoption will increase. Regarding "Marital Status" (1=single, 0=married/married with children), there was a negative significant correlation (ß = -0.851; p=0.003) with safety. This means that respondents who were married or married with kids had concerns about the safety of the AVs as compared with those who were single. Thus, as their concerns increased, their likelihood of adopting AVs decreased. For "Education," the estimated coefficients were negative for Effort Expectancy (ß = -1.474; p=0.035) and Road Infrastructure (ß = -0.777; p=0.040) but positive for Environmental Friendliness (ß = 0.623; p=0.073). In terms of "Driving Experience," a positively significant relationship exists between environmental friendliness (ß = 0.511; p=0.025) and road infrastructure (ß = 0.468; p=0.059). Again, regarding "Transport Mode" often used by individuals, three variables were positively significant. These variables are "Effort Expectancy (ß = 0.517; p=0.002), "Safety" (ß = 0.407; p=0.039), and "Environmental Friendliness" (ß = 0.414; p=0.036). This result implies that respondents who already use app-enabled transport services, such as Uber, Tango, and Bolt, had less concern about the effort required to operate AVs. Furthermore, they also had less concern regarding the safety and environmental friendliness of AVs. Regarding the "Knowledge of AVs," both "Effort Expectancy" (ß = -0.638; p=0.001) and "Environmental Friendliness" (ß = -0.574; p=0.016) had negative significant relationships.

Table 6 Results of sociodemographic characteristics of respondents (SEM estimation)

Predictors		Response Variables	Estimate	S.E.	C.R.	P-value
Gender	--->	Effort Expectancy (EE)	-1.409	0.533	-2.644	0.008**
	--->	Performance Expectancy (PE)	-2.254	0.609	-3.699	0.000**
	--->	Road infrastructure (RINT)	-1.474	0.698	-2.111	0.035*
Age	--->	Effort Expectancy (EE)	0.904	0.256	3.527	0.000**
Marital Status	--->	Safety (SF)	-0.851	0.288	-2.949	0.003**
Education	--->	Effort Expectancy (EE)	-0.847	0.289	-2.927	0.003**
	--->	Environmental Friendliness (EF)	0.623	0.348	1.791	0.073
	--->	Road infrastructure (RINT)	-0.777	0.379	-2.05	0.040*
Driving Experience	--->	Environmental Friendliness (EF)	0.511	0.228	2.244	0.025*
	--->	Road infrastructure (RINT)	0.468	0.248	1.885	0.059
Transport Mode	--->	Effort Expectancy (EE)	0.517	0.164	3.147	0.002**
	--->	Safety (SF)	0.407	0.198	2.061	0.039*
	--->	Environmental Friendliness (EF)	0.414	0.197	2.096	0.036*
Knowledge of AV	--->	Effort Expectancy (EE)	-0.638	0.198	-3.22	0.001**
	-->	Environmental Friendliness (EF)	-0.574	0.238	-2.41	0.016*

Significant levels in bold font at p< 0.1, p<0.05*, p< 0.01*

4.3.3 Intention to own AV

Table 7 presents the results of the standardized direct and indirect effects of the variables of interest and the sociodemographic characteristics of respondents on intention to own AVs. Among the variables, only three (Effort Expectancy, Performance Expectancy, and Road Infrastructure) had a direct significant effect on the intention to own an AV. The results indicate that effort expectancy and road infrastructure had statistically significant direct effects at p < 0.005 and p < 0.001, with estimated coefficients of ß = 0.18 and ß =0.287, respectively. While performance expectancy is marginally significant at p < 0.084 (ß= 0.143). The result generally indicates that the higher the perception about AVs that they require less effort to operate and will perform better than driver-driven vehicles, the higher the interest in owning them.

Similarly, the availability of adequate road infrastructure will lead to higher interest in the ownership of AVs. Regarding the indirect effect, three factors (Gender, Transport Mode, and Knowledge of AV) were statistically significant. Gender and knowledge on AVs showed negative significant relations (ß = -0.119; p= 0.009 and ß = -0.109, p = 0.068 respectively) while transport mode had positive significant effects (ß =0.13; p= 0.007). This means that for gender (male, female =2), males were more likely to own AVs, and for knowledge of AVs, individuals with less knowledge had less interest in owning AVs. Furthermore, individuals who use app-enabled service vehicles had a higher interest in owning AVs.

Table 7 SEM results of individuals intention to own AVs

`Effect type	Factors	Estimate	P-value
Standardized Direct Effects	Effort Expectancy (EE)	0.18	0.005**
	Performance Expectancy (PE)	0.143	0.084
	Environmental Friendliness (EF)	0.287	0.001**
Standardized Indirect Effects	Gender	-0.119	0.009**
	Transport Mode	0.13	0.007**
	Knowledge of AV	-0.109	0.068

Significant levels in bold font at p< 0.1, p<0.05*, p< 0.01*

4.3.4 Intention to use AV

Intention to use AV is referred to as the degree to which a user intends to use AVs in general, regardless of whether they personally own one or not. This concept is influenced generally by factors such as perceived ease of use and perceived safety (Li et al., 2022) among other important factors. The results showed that Effort Expectancy, Performance Expectancy, and Environmental Friendliness relating to the perception of AVs had a direct effect on the intention to use AVs. The estimated coefficients were ß = 0.254 (p = 001), ß = 0.145 (p = 0.058), ß= 0.151 (p =0.040) respectively. This means that on a scale of 1 to 5, a rise in a level of positive perception about these factors will increase the intention of individuals to use AVs by 25.4%, 14.5% and 15.1%, respectively. Furthermore, "Road infrastructure" also had a direct positive significant correlation (ß = 0.314; p = 0.001). This indicates that as the perception of individuals about the adequacy of the road infrastructure increases the intention to use AVs increases by 31.4%. With regards to indirect effect, the result shows that only "Transport Mode" had a positive correlation (ß = 0.150; p = 0.006). This implies that a rise in the use of app-enabled service vehicles such as Uber, Tango Bolt etc., will lead to higher use of AVs. Again, "Gender" (ß = -0.138; p = 0.006) and "Knowledge of AV" (ß = -0.130; p = 0.038) were estimated with negative coefficients. This result indicated in Table 8 shows that females have less intention to use AVs and are even less interested when they don't have adequate knowledge of AV technology.

Table 8 SEM results of individuals intention to use AVs

Effect type	Factors	Estimates	P-value
Standardized Direct Effects	Effort Expectancy (EE)	0.254	0.001**
	Performance expectancy (PE)	0.145	0.058
	Environmental Friendliness (EF)	0.151	0.04*
	Road infrastructure (RINT)	0.314	0.001**
Standardized Indirect Effects			
	Gender	-0.138	0.006**
	Transport Mode	0.15	0.006**
	Knowledge of AV	-0.13	0.038*

Significant levels in bold font at p< 0.1, p<0.05*, p< 0.01*

5.0 DISCUSSION

This study explored the perception of Ghanaians with engineering backgrounds on AV technology and how this perception may influence the adoption of AVs. Two research questions were formulated, which we explored through a proposed SEM. Broadly, the variables that were used in building the SEM comprised sociodemographic characteristics of respondents, perceived effort expectancy, perceived performance expectancy, perceived safety, and perceived environmental friendliness, as well as road infrastructure. Consistent with previous findings, the results revealed that different sociodemographic groups perceived AV technology differently (Garidis et al., 2020.; Haboucha et al., 2017; Souza & Castañon, 2021).

In terms of the first research question i.e., "Is there a variation in how different sociodemographic groups perceive AV technology (i.e., expectations regarding effort, performance, safety, environmental impact)?", females were found to be more concerned about the effort required to operate the AVs, the performance of AVs and road infrastructure to support their operations. For age, the older respondents were concerned about the effort required, while individuals who were married/married with kids were more concerned about the safety aspect of the AV technology. The observed differences in age may be because younger generations are more comfortable with technology and open to new innovations. Education correlated negatively with effort expectancy and road infrastructure but positively with environmental friendliness. This result means that individuals with higher education perceived AVs to be more friendly towards the environment than those with lower education. However, individuals with lower education have higher concerns about the effort required to operate an AV and also believe that for AVs to operate efficiently, there is a need for an improved road infrastructure (Tengilimoglu et al., 2023a).

In terms of driving experience, those with greater experience were less concerned about the environmental friendliness of AV and were less concerned about road infrastructure. Regarding transport modes often used by individuals, respondents already using app-enabled transport services such as Uber, Tango, and Bolt had less concern about the effort required to operate AVs. They also had less concern regarding the safety of AVs. This could mean that because these individuals are already familiar with app-enabled transport services, they know that AVs will rely on the same or similar application system to function and, hence, won't be difficult to use. In terms of knowledge of AVs, individuals with less knowledge had a negative perception of the effort required to operate AVs and also had the same perception of environmental friendliness. However, knowledge did not correlate with safety. These results did not support the findings of (Hussain et al., 2021b). As AV technology continues to evolve, it will be important for manufacturers, policymakers, and other stakeholders to understand these variations and work to address concerns and promote the benefits of AVs to different demographic groups.

The last (second) research question we investigated was "Do the level of perception of individuals regarding AV technology (i.e., effort expectancy-ease of use, performance expectancy, safety, environmental friendliness), and road infrastructure influence their adoption (intention to own and intention to use)?". The findings from our SEM showed that effort expectancy, performance expectancy and road infrastructure had a direct effect on both intention to own and intention to use. Thus, if the AVs are designed to be easy to use, perform better than driver-driven vehicles, and the road infrastructure is improved to support their operation, they will receive public adoption. Road infrastructure will play a critical role for AVs to receive public acceptance and be used by many commuters. Environmental friendliness was a significant predictor for intention to use and for intention to own. This means those who intend to adopt the AVs are more concerned about the environment. Although several studies have found safety to be an important factor influencing the adoption of AVs by the public, our study did find safety as an influencing factor (it was not a significant predictor of intention to own or use). This may be explained by the fact that engineers believed that if AVs are unsafe, laws will not permit deployment.

The indirect effect was significant for only three factors i.e., gender, transport mode, and knowledge about AVs. Respondents' mode of commute correlated positively with the intention to own and use. The findings revealed that individuals who used app-enabled transport services exhibited higher intentions to own and use AVs. However, men showed a higher intention to own or use AVs than women. However, women showed more concern towards the safety of AVs and will hesitate to adopt them until they are convinced that this new technology is fully safe. Furthermore, the findings revealed that knowledge played an important role in adopting AVs. Thus, individuals with good knowledge of AVs were willing to own and use AVs. Unfortunately, knowledge of AVs is relatively low (see Fig. 4). Thus, AV technology is still new to most of the respondents, which could be why the majority do not have adequate knowledge. There is, therefore, the need to create awareness using appropriate platforms and legislation as part of efforts towards promoting AV technology.

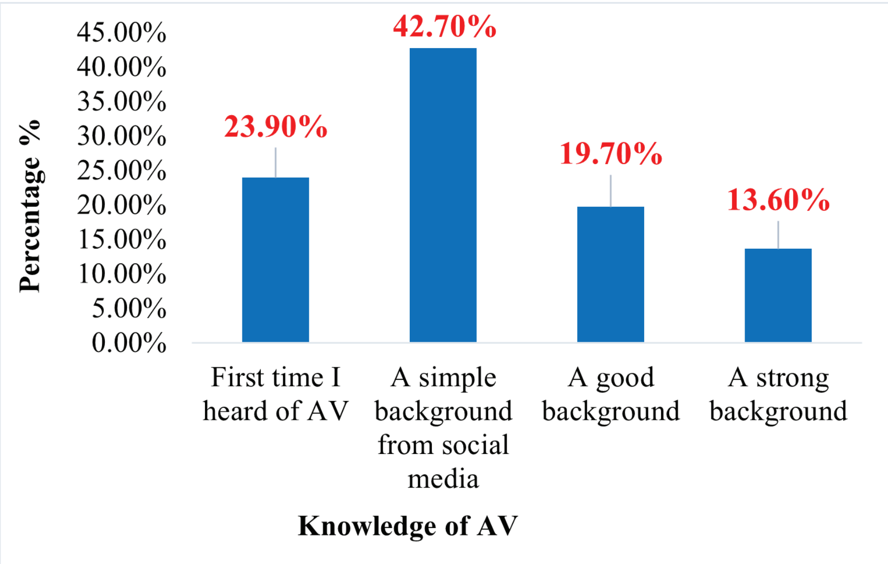

Fig. 4. The level of knowledge of AV technology

6.0 CONCLUSION AND POLICY IMPLICATIONS

Despite the above potential limitations associated with the study, the findings are insightful and offer directions for policy. Ghana's transportation system faces several challenges, such as traffic congestion, road safety (crashes), and limited access to public transport. These challenges impact job accessibility and quality of life in most urban centers. AVs have the potential to address these challenges. Challenges, including those revealed in this study, i.e., inadequate road infrastructure, low level of knowledge about AVs, and safety concerns, however, will have to be addressed first. AVs could provide a more efficient and convenient transportation option for Ghanaians, particularly in urban areas, if the comprehensive plan for AV adoption that addresses road infrastructure (smart traffic signals, road sensors, dedicated AV lanes and communication systems), regulatory, and public acceptance barriers can be developed. This could involve partnerships between the government, private sector, and academic institutions to develop the necessary infrastructure and regulatory frameworks, as well as public education campaigns to increase awareness and acceptance of AV technology. As AV technology continues to evolve, it will be important for manufacturers, policymakers, and other stakeholders to enable the public to have direct experience, educate the public and increase awareness and understanding of AVs to promote acceptance and adoption.

In conclusion the study aimed to provide insight into Ghanaians' perception of AV technology and, by so doing, add to the limited literature on AVs in the region. We surveyed individuals with engineering backgrounds to investigate their perceptions towards driverless or AV technology and whether the level of their perception will influence AV adoption. We developed SEM to explore our research questions. The study revealed that sociodemographic factors play an important role in AV adoption. Females and individuals who were married/married with kids were more concerned about the safety of the AV technology, a phenomenon that contribute to low interest in adopting the technology. Indeed, only 40% of the respondents indicated that AVs would be safer than driver-driven vehicles. The less educated had more concerns about the effort required to operate the AVs. In comparison, those already using app-enabled service vehicles had fewer concerns about the effort required to operate them. Road infrastructure to support the operation of AVs in the country was perceived to be a major barrier to the realization of the technology.

In terms of AV factors, perceived effort expectancy, performance expectancy, and road infrastructure directly affected the intention to own and use AVs, while perceived environmental friendliness directly affected only the intention to use AVs. Knowledge about AVs significantly influences individuals' intentions to own or use AVs. Male respondents showed higher interest in owning or using AVs than their female counterparts, and non-app-enabled transport service users seem less interested in AV technology. Importantly, a significant proportion do not have adequate knowledge of this new mobility option, which has implications for adoption.

7.0 LIMITATIONS

This study has some drawbacks. First, part of the questionnaire of this study was administered online without any measure to ensure that only people with engineering backgrounds responded to the questions; there is a possibility that some respondents might fall outside the targeted group. This should be taken into consideration when interpreting the results. Secondly, because AVs are yet to arrive in Ghana, most responses may be based on how these individuals perceived the AV technology. These responses might change when the respondents experience AVs. Poor knowledge about AVs could consequently be because the technology is not in existence in Ghana, and the interpretation of the results and the generalization of the findings should consider these nuances. Finally, this study reveals factors likely to affect adopting autonomous vehicles in Ghana from the perspective of individuals with engineering backgrounds (Mechanical, Automobile, and Electrical) from academic institutions without considering those working in the industry with other engineering backgrounds and other non-engineering groups. Future works should compare the perceptions of the latter and former groups.

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