The adoption of self-driving vehicles in Africa: insight from Ghana

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ABSTRACT

With the recent advancements in autonomous vehicles as a means of providing sustainable transport, governments, policymakers and automobile companies, including those in the emerging economies, need to understand what drives the adoption of the technology among people. This paper, for that matter, examines the factors that influence the intention of Ghanaians to use autonomous vehicles (AVs). The Technology Acceptance Model was adopted, extended and data analysed by using multiple linear regression in the Statistical Package for Social Sciences version 21 and then the PROCESS macro add-on. Subjective norm, attitude, and awareness were found to have a significant and positive direct influence on intention to use AVs. Intention to use AVs varies significantly by age and monthly income. Trust, perceived risk, perceived benefit, and perceived ease of use have a significant indirect effect on the intention to use AVs. Perceived usefulness has both a direct significant influence on intention to use AVs and a significant indirect effect on intention to use AVs when partially mediated by attitude. Recommendations have been given to government and all transport stakeholders.

ARTICLE HISTORY

Received 28 March 2021
Accepted 17 June 2022

KEYWORDS

Autonomous vehicles; intention; technology acceptance model; sustainable mobility; Ghana

1.0 Introduction

Transport activity forms an integral part of economic development and human welfare (Kahn Ribeiro et al., 2007). Globally, urban cities nowadays are constantly faced with rapidly rising populations which have led to changing patterns of movements in terms of shopping, leisure, and work (Sustainable Mobility Project 2.0, 2016). With continuous growth of economies and a rise in both urban population and vehicle ownership, there is increase in demand for mobility, especially in developing countries, which results in congested road networks (Asadi et al., 2016). Consequently, urban dwellers experience safety and environmental challenges – particularly increasing levels of noise and air pollution, traffic fatalities and injuries, fuel usage, and travel time. For example, the World Bank, in 2016, posited that transport represents 23% of global energy-related CO₂ emissions and the share of transport in greenhouse gas emissions would reach 33% by
2050. The global status report on road safety – 2018 published by the World Health Organization (WHO) estimates that road traffic crashes account for a loss of up to 3% of the gross domestic product (GDP) of most countries. These negative impacts of transportation are more prominent in the growing economies of the developing world (Igliński & Babiak, 2017). The World Bank, in 2014, reported the CO₂ emissions from transport as a percentage of fuel consumption in Ghana, Congo Republic, China, US to be 55.4%, 76.5%, 8.6% and 33.4%, respectively. According to Dotse et al. (2019), there is a serious road safety concern in Ghana – road crash fatalities have increased by 12–15% annually since 2008.

The consequences of increased vehicle population listed above have led many different nations and institutions such as the automobile industry and technology industry to try and find innovative ways of making the transport sector safer, less polluted, less congested, more fuel-efficient, and cheaper. The result is the creation and use of Autonomous Vehicles (AVs). The adoption of autonomous vehicles is anticipated to improve the lives of commuters in multiple dimensions (DfT, 2015a). It is expected that wide use of AVs will greatly improve traffic safety through the reduction in vehicular crashes and their associated deaths and injuries (Fagnant & Kockelman, 2015). Millard-Ball (2018) asserts that AVs will improve safety of pedestrians and cyclists and hence promote active transport. Moreover, the advent of AVs is predicted to substantially reduce emissions levels due to the use of electric batteries in running the vehicles and reduction of traffic congestion on roadways due to smooth traffic flow (Bajpai, 2016; Pettigrew et al., 2019). It is worth mentioning that AVs are also associated with some safety concerns. Although driver errors are eliminated, machine and/or technological errors are inevitable (Taeihagh & Lim, 2019; Banks et al., 2018).

Due to the wide range of benefits expected from AVs, most advanced and developed nations have led the autonomous vehicle charge by partnering with automobile and technology companies to set plans and policies in motion that allows for more autonomous vehicle testing and deployment on public roads. For instance, the UK set out plans and policies in 2015 in their Department for Transport report ‘The pathway to driverless cars’ to facilitate and encourage the growth of autonomous vehicles. A number of tests of AVs with the backing of governments and companies including Mercedes, Volvo, Tata, Ford and General Motors are ongoing in Europe and the US (Bajpai, 2016). As reported in Ziegler (2012), test runs of a fleet of Google cars have been undertaken on Mountain View California roads at a neighborhood-friendly speed of 25 mph.

Given the level of importance governments and automobile industries attach to the rolling out of AVs, evaluation of public attitudes towards AVs over time and geographical location is necessary to contributing to the development of strategies to addressing the concerns of the public to promote their interest in the AV technology (Bansal et al., 2016; Pettigrew et al., 2019). There is, therefore, a growing body of literature in Europe, the US and China. The studies and debate mostly cover areas including impacts of AVs, risks and trusts, legal and ethical issues, and safety, and how the aforementioned factors influence their adoption. It is argued that the individual’s behaviour and attitude toward AVs are critical to their adoption. The findings from Kyriakidis et al. (2015), which studied drivers’ attitudes towards AVs, suggest that safety, legal issues, software hacking affect driver’s trust and usage intention of AVs. Similarly, studies such as Taeihagh & Lim (2019) and Liu et al. (2020) examined different categories of the technological risks
associated with AVs including safety, liability, privacy, cybersecurity, and industry risks. Recently, the American Automobile Association (2019) reported that 71% of drivers in the US were afraid of riding with fully AVs. Choi and Ji (2015) examined the factors that drive the trust individuals have toward autonomous vehicles as well as user’s adoption aspects of autonomous vehicles based on the technology acceptance model and trust theory. The impact of socio-demographics on AVs usage has also been studied. For example, Schoettle and Sivak (2014b) reported that older people were more likely than younger ones to reject riding in an autonomous vehicle. Also, the authors found gender perceptions to vary significantly, with males being more likely to adopt AVs compared to females. This is consistent with the findings of Hulse et al. (2018) who found males to be more likely to perceive AVs as less risky and have a positive attitude towards AVs.

In spite of the efforts by governments in developed countries to promoting autonomous vehicles through formulation of plans and policies, no plans and/or policies have been formulated involving AVs technology in developing countries and especially countries in Africa. Moreover, it appears much attention has not been given to AVs in the form of research in the developing world. The earlier countries formulate plans and policies regarding autonomous vehicles, the better prepared they will be for the inevitable trickle-down of the technology from the developed nations. It is evident from the literature that Ghana, which continues to face tremendous increase in road traffic crashes and their associated fatalities and injuries (Boateng, 2021; Dotse et al., 2019); chronic traffic congestion, especially in its big cities (Osei et al., 2021); as well as high level transport related emissions (Musah et al., 2020) has so far not carried out any study or taken any form of action on the topic of autonomous vehicles adoption. The motivation of the study is to bridge this gap and highlight the attitude and behaviour of individuals in Ghana towards AVs.

Therefore, the main aim of this paper is to determine the factors that influence the intention to use autonomous vehicles among Ghanaians. This information will hopefully enable the government to be more proactive and better prepared in making decisions and policies about the emerging automobile technology (i.e. AVs). To be able to achieve the goal of the main objective, subsequent sub-objectives in the form of research questions are proposed:

- Do demographics (i.e. education, gender, income and age) influence intention to use AVs?
- Do the perceived benefits and risks of AVs influence intention to use AVs?
- Does trust in the technology influence intention to use AVs?
- Does attitude toward AVs influence intention to use AVs?
- Does awareness influence intention to use AVs?
- Does subjective norm influence intention to use AVs?

### 2.0 Methods

#### 2.1 Research model

The Technology Acceptance Model (TAM) formulated by Davis (1986) was adopted as the research model for use in this study to aid in determining factors influencing the intention to use AVs. TAM was modified and formulated by Davis based on the Theory
of Reasoned Action (TRA; Davis et al., 1989). The purpose of formulating TAM was to help researchers predict and explain the determinants of user acceptance concerning computer and information systems (Davis et al., 1989). More specifically, Davis et al. (1989) formulated TAM intending to be able to assess the impact of external factors on internal beliefs, attitudes, and intentions. The two internal beliefs presented in TAM to predict and explain user acceptance determinants were Perceived Ease of Use (PEOU) and Perceived Usefulness (PU; Davis et al., 1989). According to Ajibade (2018), TAM assumes that when users perceive technology to be easy to use and useful, they will be more committed to using the technology. TAM was constructed by Davis in 1986 as shown in Figure 1.

The reasons for adapting TAM in this study are as follows:

- TAM is simple, easy to use, and also less expensive to apply in research (Olushola & Abiola, 2017). Furthermore, TAM makes use of the simplest assumptions when analysing and explaining data (Olushola & Abiola, 2017).
- TAM is tailored more towards information and computer system usage through the application of ease of use and usefulness concepts and therefore it is better suited in explaining user behaviour concerning specific information and technology systems (Olushola & Abiola, 2017).
- Through various empirical studies, TAM has been tested thoroughly and both the tools used in the model and the model itself have been proven to be of high quality and statistically reliable (Legrisa et al., 2003). This has led TAM to be widely accepted in the information system community. Also, since TAM is an adaptation of the Theory of Reasoned Action (TRA; Davis et al., 1989) and the Theory of Planned Behaviour (TPB), Olushola and Abiola (2017) state that it should produce more accurate results about predicting or explaining behaviour.
- TAM provides a framework to predict the influence of external variables on behaviour (Davis, 1989). It also explains user behaviour towards technology acceptance under varying conditions, contexts, and control factors (Olushola & Abiola, 2017).

Figure 1. Original TAM model (Davis et al., 1989).
2.2 Theoretical framework and research hypothesis

TAM says that individuals’ intentions towards use are explained as a result of attitude, PEOU, and PU (Davis et al., 1989). This study, therefore, applies the original TAM framework to AVs usage intentions and to help in explaining the key factors influencing user intentions. The original TAM framework has been modified with the inclusion of other constructs and hypotheses in the model. In addition to the already existing constructs of attitude, PEOU, and PU, the model is composed of the following constructs: trust, subjective norm, awareness, perceived benefit, and perceived risk. Figure 2 shows the proposed conceptual model hypotheses based on the original TAM framework.

Intention and attitude

TAM suggests that intention is determined jointly by an individual’s attitude towards use and PU (Davis et al., 1989). Davis et al. (1989) go on further to suggest that individuals form their intentions based on whether they have a positive or negative attitude toward its use. For this study, a positive attitude towards AVs may increase an individual’s intention to use AVs. Studies such as Osswald et al. (2012), Nysveen et al. (2005), and Payre et al. (2014) have also noted that a positive attitude towards a particular technology may lead to a proportional increase in intention to use. Thus, the following hypothesis was postulated:

H1: attitude toward AVs has a positive influence on intention to use AVs
**Perceived ease of use and perceived usefulness**

PEOU and PU are two key components of the original TAM. PEOU represents the extent to which users find a technology or system to be free of effort or easy to use as the name suggests (Davis et al., 1989). PU refers to the user’s subjective take on whether a new technology or system will enhance their performance (Davis et al., 1989). In the context of intention to use AVs, it is important to consider PU and PEOU since AVs are a new technology that would require steep learning. Intention to use is directly influenced by PU whilst PEOU indirectly influences intention to use through PU and attitude (Davis et al., 1989). Yousafzai et al. (2007) also found in their study that PEOU directly influences PU and attitude. Therefore, the following hypotheses were formed:

**H2:** PU has a positive influence on intention to use AVs

**H3:** Attitude positively mediates the relationship between PU and intention to use AVs

**H4:** Attitude positively mediates the relationship between PEOU and intention to use AVs

**H5:** PU positively mediates the relationship between PEOU and intention to use AVs

**Perceived risk and perceived benefit**

Every technology comes with its associated risks and benefits in the eyes of the consumer and this is no different for AVs. This is confirmed by studies such as Menon et al. (2016), Nees (2016), and Schoettle and Sivak (2014b) in which individuals recognize the apparent benefits of AVs but are hesitant and concerned about the risks posed by using AVs. Studies have also shown that perceived risk may have a negative influence on an individual’s attitude and intention to use a particular technology (Marriott & Williams, 2018; Mitchell, 1999). For perceived benefit, studies such as the one by Siegrist (2000) suggest that higher perceived benefits will positively influence the adoption of new technologies. Perceived benefit may also positively influence PU since being aware of the perceived benefits of the technology might inform the individual’s decision on whether using it would better their performance. Based on these, it was hypothesised that:

**H6:** PU positively mediates the relationship between perceived benefit and intention to use AVs

**H7:** Attitude positively mediates the relationship between perceived benefit and intention to use AVs

**H8:** Perceived benefit positively influences intention to use AVs
H9: Attitude negatively mediates the relationship between perceived risk and intention to use AVs

H10: Perceived risk negatively influences intention to use AVs

Trust

Trust is one of the most important elements that affect human-automation perceptions and interactions (Lee & Moray, 1994; Lee & See, 2004). Trust has also been found to play a key role in an individual’s intentions to use a particular technology (Carter & Bélanger, 2005; Choi & Ji, 2015; Gefen et al., 2003; Ghazizadeh et al., 2012; Lee & Moray, 1992; Mayer et al., 1995; Panagiotopoulos & Dimitrakopoulos, 2018). Trust may also have an impact on PU belief in terms of analysing the usefulness of the technology and whether to accept that belief at face value. Studies such as Choi and Ji (2015) and Ghazizadeh et al. (2012) have stated that trust may have an indirect influence on adoption intentions through PU as a mediating effect. In light of this, the following hypotheses were also formulated:

H11: Trust positively influences intention to use AVs

H12: PU positively mediates the relationship between trust and intention to use AVs

Subjective norm

This construct concerns with the social pressure individuals perceive from other important people in their lives to perform a particular behaviour (Ajzen, 1991). When an individual’s family members or friends either adopt a particular technology such as AVs or encourage the individual to adopt AV, there would be a greater appetite for the individual to adopt the AV (Bansal et al., 2016). Several authors have found that subjective norm does indeed influence an individual’s intention to adopt a particular technology (Huang & Lu, 2016; Nysveen et al., 2005; Pan & Truong, 2018; Wang, Fan et al., 2016). Due to the above, this hypothesis was formed:

H13: subjective norm positively influences intention to use AVs

Awareness

Prior knowledge of a particular technology aids significantly in an individual’s decision making (Kaplan, 1991). This is particularly true because with a higher awareness of a particular technology’s characteristics, in terms of its strengths and weaknesses, an individual finds it easy to make a decision that reduces the risk factor associated with it. Studies such as Park et al. (1994), Wei-Yun et al. (2010), and Qian and Yin (2017) have shown that awareness plays an important role in an individual’s attitude and intention
towards a particular technology. Awareness is therefore highly likely to influence an individual’s intention to use a particular technology which in this context is AVs. As a result, it was hypothesized that:

**H14: Awareness positively influences intention to use AVs**

### 2.3 Sampling and data collection

The survey for the study was conducted from July to August 2020 among the Ghanaian general public. No persons were excluded from the study except those who were under 18 years of age. Therefore, the survey included both drivers and non-drivers as AV use is not subject to just drivers. The sampling method used in conducting the survey was the convenience sampling method. The convenience sampling method was adopted since it is simple, easy to use, aids in hypothesis generation, fast and cheap (Dudovskiy, 2016). This study adopted both online and in-person interviews to administer the questionnaires. Three hundred (300) respondents completed and submitted their responses online. One hundred and fifty (150) questionnaires were distributed in-person in Kumasi. One hundred and forty (140) of the questionnaires distributed in-person were returned. This represented a response rate of 93.3%. Twenty-three (23) questionnaires out of the one hundred and forty were discarded because they were incomplete. Therefore the online and in-person approaches together resulted in 417 complete questionnaires for further analysis. Respondents were provided with the nature of AVs (including the different levels of automation) before answering the questionnaire, to encourage respondents to form their own opinions on AVs. The survey took approximately 20 minutes to complete.

### 2.4 Measures

The questionnaire focused on measuring constructs and their respective items. The constructs measured were as follows: PU, PEOU, attitude, intention to use, subjective norm, awareness, trust, perceived risk, and perceived benefit, which were self-developed. The constructs, items, and sources can be found in Table 1. The items under each construct were measured on a five (5) point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Apart from the aforementioned constructs, the questionnaire also had a section that solicited for demographic information of the respondents. The respondents’ demographics collected include gender, age, level of education, monthly income, driving experience and vehicle ownership. In this study, the data analysis and modelling effort were conducted by multiple linear regression using Statistical Package for Social Sciences (SPSS) version 21 and the PROCESS macro add-on in SPSS by Hayes (2012). PROCESS was adopted in this study for analysis because it has been applied in wide range of disciplines including social and behavioural sciences, health and business for estimating direct and indirect effects in single and multiple mediator models (Hayes, 2012; Yoo, 2019). Normally, multiple linear regression in SPSS is preferred when analysing data on an interval scale instead of the ordinal scale which this study uses.
by adopting a five (5)-point Likert scale. However, the decision to use multiple linear regression in SPSS to analyse ordinal scales in this study is justified by Hair et al. (2015) who state that it has become common practice for business researchers to treat the Likert scale as an interval scale. Hair et al. (2015) further justify its use by stating that there is empirical evidence that respondents treat Likert scales in surveys as an interval scale because they view the intervals between points on the Likert scale as equal in magnitude. The model was assessed using the following statistics: reliability, correlation, standardized coefficient (β), indirect effect (B), significance (p-value), F-value, and coefficient of determination (R²). Also, PROCESS macro was specifically used to measure the mediation effects of attitude and PU in the model. In analysing the model, the sample size was bootstrapped to 5000 and a 95% bias-corrected confidence interval was used to guard against biases.

| Construct: Attitude | Questionnaire Items | Adapted from (Source) |
|---------------------|---------------------|-----------------------|
| Perceived ease of use (PEOU) | I would find it easy to learn to operate AVs | Davis (1989) and Davis et al. (1989) |
|                      | I would not require mental effort to use AVs | |
|                      | I would find AVs easy to understand | |
|                      | AVs would be easy to use | |
| Perceived usefulness (PU) | The use of AVs would make me more productive (e.g. eating, working and making calls whilst riding in an AV) | Davis (1989) and Davis et al. (1989) |
|                      | Using AVs would make my driving more comfortable | |
|                      | Using AVs would make my driving easier | |
|                      | AVs would be a useful means of transport | |
| Construct: Intention | Should AVs be available in the future, I plan to use them | Davis (1989) and Davis et al. (1989) |
|                      | Should AVs be available in the future, I plan to buy one | |
|                      | I would recommend the use of AVs to family and friends should they be available in the future | |
| Perceived risk | I would be worried about system and technological failures in AVs | Self-developed |
|                      | I would be worried about cyber-attacks on AVs (e.g. system hacks) | |
|                      | I would be worried about the high initial price of AVs | |
|                      | I would be worried about whether AVs are morally correct and ethical | |
|                      | I would be worried about my private information being disclosed when using AVs | |
|                      | I would be worried about the legal liability of users or owners of AVs | |
|                      | AVs would reduce employment in the automotive industry | |
| Perceived benefit | AVs would reduce vehicle emissions | Self-developed |
|                      | AVs would increase traffic safety | |
|                      | AVs would increase the mobility of those unfortunate not to be able to drive (e.g. the disabled and the elderly) | |
|                      | AVs would reduce transportation costs | |
|                      | AVs would increase fuel efficiency | |
|                      | AVs would require less land use | |
|                      | AVs would reduce traffic congestion | |
| Subjective norm | People important to me would expect me to use AVs in the future | Ajzen (1991) |
|                      | I would also use AVs if people around me use them | |
|                      | People important to me would want me to use AVs in the future | |
| Trust | AVs are reliable | Choi and Ji (2015) |
|                      | AVs are dependable | |
|                      | AVs can be trusted | |
| Awareness | I am familiar with AVs | Self-developed |
|                      | I am familiar with how AVs operate | |
|                      | I know the difference between AVs and traditional vehicles | |
in the bootstrap estimate. Also, a significant indirect effect was obtained when lower bounds and upper bounds bootstrap confidence intervals did not cross zero. Other studies such as Banks et al. (2018) and Ziegler (2012) indicate that demographics may influence intention to use AVs. Therefore, four (4) control variables namely age, gender, income, and education level were added to the model to test whether or not they influence intention to use AVs. Also, all questionnaire answer options and construct items were represented with discrete variables in SPSS.

3.0 Results

3.1 Demographics

The results show that almost equal proportions of males (49.9%) and females (50.1%) responded to the survey. The data shows a relatively younger population with 62.6% of the respondents between the ages of 18 to 29 years. Those over 60 years represented only 2.9% of respondents. This age trend, however, is in line with that of the Ghanaian population which is reported by the Ghana Statistical Service to have a younger population (Ghana Statistical Service, 2013). Majority of the respondents (92.6%) are either high school graduates or higher level. Moreover, thirty percent of respondents fall within the monthly income range of GH₵500 – 1000. All the details on the demographics of the study have been presented in Table 2.

3.2 Reliability analysis

All constructs yielded a Cronbach’s alpha between 0.7–0.9. The full results are shown in Table 3.

3.3 Correlation analysis

Table 4 presents results for correlations whilst Table 5 presents results for means, standard deviations, and linearity. Skewness (SK) and Kurtosis (KU) of all variables were between –2 and +2. Perceived risk and trust ($r = -0.108, p < .05$) had a negative and significant correlation. All other relationships between the variables had significant and positive correlations as seen in Table 4.

3.4 Model fit

Table 6 and Table 7 show the results for how well the model fits the data. The predictor variables explained 70.7% of the variance in intention to use AVs, adjusted $R^2 = .707$. The variables statistically significantly predicted intention to use AVs, F (11, 405) = 92.319, $p < .001$ indicating that the model is a good fit for the data.
Table 2. Demographics of the respondents.

| Demographic Group | Frequency | Percent (%) |
|-------------------|-----------|-------------|
| **Gender**        |           |             |
| Male              | 208       | 49.9        |
| Female            | 209       | 50.1        |
| Total             | 417       | 100.0       |
| **Age**           |           |             |
| 18–24             | 166       | 39.8        |
| 25–29             | 93        | 22.3        |
| 30–39             | 56        | 13.4        |
| 40–49             | 56        | 13.4        |
| 50–59             | 34        | 8.2         |
| 60+               | 12        | 2.9         |
| Total             | 417       | 100.0       |
| **Education Level** |       |             |
| Basic Education (Primary/JHS) | 31 | 7.4 |
| Senior High School | 62 | 14.9 |
| Bachelor degree   | 261       | 62.6        |
| Post Graduate     | 63        | 15.1        |
| Total             | 417       | 100.0       |
| **Monthly Income** |       |             |
| Below GH₵ 500     | 116       | 27.8        |
| GH₵ 500–1000      | 126       | 30.2        |
| GH₵ 1000–2000     | 74        | 17.7        |
| GH₵ 2000–3000     | 41        | 9.8         |
| GH₵ 3000–4000     | 16        | 3.8         |
| GH₵ 4000–5000     | 14        | 3.4         |
| Greater than GH₵ 5000 | 30 | 7.2 |
| Total             | 417       | 100.0       |
| **Vehicle Ownership** |     |             |
| Yes               | 128       | 30.7        |
| No                | 289       | 69.3        |
| Total             | 417       | 100.0       |
| **Driving Experience** |   |             |
| None              | 154       | 36.9        |
| Less than a year  | 77        | 18.5        |
| 1 to 5 years      | 83        | 19.9        |
| 5 to 10 years     | 59        | 14.1        |
| Greater than 10 years | 44 | 10.6 |
| Total             | 417       | 100.0       |

Table 3. Reliability of constructs.

| Construct         | Cronbach’s alpha | No. of items |
|-------------------|------------------|--------------|
| Awareness         | 0.753            | 3            |
| Attitude          | 0.847            | 4            |
| Intention         | 0.839            | 3            |
| PU                | 0.788            | 4            |
| PEOU              | 0.771            | 4            |
| Trust             | 0.883            | 3            |
| Subjective norm   | 0.880            | 3            |
| Perceived benefit | 0.718            | 7            |
| Perceived risk    | 0.793            | 7            |

3.5 Direct and indirect effects

The standardized direct and indirect effects of variables were determined. Additionally, the effect and role of the mediators of the original TAM model variables, and the adapted TAM model including the extended and the control variables were determined. The
mediating roles were determined based on Nitzl et al. (2016). The independent variable should be statistically significant to the mediator. The mediator is assumed to have a full mediating effect if the mediator significantly affects the dependent variable while the independent variable does not significantly affect the dependent variable. On the other hand, the mediator has a partial mediating effect if the mediator and the independent variable both significantly affect the dependent variable. Lastly, the mediator is assumed to have no mediating effect if both the mediator and the independent variable do not significantly affect the dependent variable.

Table 4. Correlations of constructs.

| Construct       | (1)   | (2)   | (3)   | (4)   | (5)   | (6)   | (7)   | (8)   | (9)   |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1. Awareness    |       |       |       |       |       |       |       |       |       |
| 2. Attitude     | .333**|       |       |       |       |       |       |       |       |
| 3. PU           | .340**| .724**|       |       |       |       |       |       |       |
| 4. PEOU         | .383**| .513**| .583**|       |       |       |       |       |       |
| 5. Trust        | .209**| .361**| .390**| .399**|       |       |       |       |       |
| 6. Subjective   | .244**| .593**| .609**| .540**| .426**|       |       |       |       |
| norm            |       |       |       |       |       |       |       |       |       |
| 7. Perceived    | .346**| .506**| .552**| .499**| .426**| .529**|       |       |       |
| Benefit norm    |       |       |       |       |       |       |       |       |       |
| 8. Perceived    | .189**| .260**| .266**| .161**| -.108*| .099* | .268**|       |       |
| risk            |       |       |       |       |       |       |       |       |       |
| 9. Intention    | .370**| .770**| .719**| .544**| .346**| .675**| .491**| .217**|       |

Table 5. Descriptive statistics of constructs.

| Construct       | M    | SD   | SK   | KU   |
|-----------------|------|------|------|------|
| Awareness       | 2.786| 1.00 | .493 | -.006|
| Attitude        | 2.362| .777 | .568 | .854 |
| Intention       | 2.333| .934 | .439 | -.144|
| PU              | 2.172| .741 | .651 | 1.09 |
| PEOU            | 2.360| .773 | .295 | .680 |
| Trust           | 2.711| .836 | .042 | .451 |
| Subjective      | 2.707| .950 | -.018| -.313|
| norm            |      |      |      |      |
| Perceived       | 2.567| .616 | -.153| .992 |
| benefit norm    |      |      |      |      |
| Perceived risk  | 2.201| .735 | .430 | .034 |

Note. M – Mean; SD – Standard Deviation; SK – Skewness and KU – Kurtosis

Table 6. Model coefficient of determination.

| R       | R²   | Adjusted R² | Std. Error of the estimate |
|---------|------|-------------|---------------------------|
| .846    | .715 | .707        | .50543                    |

Table 7. Model fit summary.

| Model    | Df   | F-statistic | Significance |
|----------|------|-------------|--------------|
| Regression | 11   | 92.39       | ***p < 0.001 |
| Residual  | 405  |             |              |
Original TAM model

Results show that the standardized direct effect of attitude on intention to use AVs was significantly and positively related ($\beta = .415$, $t > 1.96, p < .001$). The standardized direct effect of PU was also significantly and positively related to intention to use AVs ($\beta = .212$, $t > 1.96, p < .001$). Table 8 presents a summary of the direct effects of variables on intention to use AVs.

Analyses as shown in Table 9 also indicate that the standardized indirect effect of PU on intention to use was significant ($B = .4979, LLCI = .3930, ULCI = .6086$) and partially mediated by attitude (PU$\rightarrow$attitude$\rightarrow$intention). The total effect of perceived usefulness on intentions was positive (0.710) and significant. PEOU has three specific indirect effects on intention. The standardized indirect effect of PEOU on intention to use AVs when partially mediated by attitude (PEOU$\rightarrow$attitude$\rightarrow$intention) is also significant ($B = .4281$, 

Table 8. Summary of direct effects on intention to use.

| Variable         | Standardized coefficient ($\beta$) | t-statistic | Significance |
|------------------|-----------------------------------|-------------|--------------|
| Gender           | .008                              | $t < 1.96$  | ns           |
| Age              | .116                              | $t > 1.96$  | ***          |
| Education level  | -.009                             | $t < 1.96$  | ns           |
| Monthly income   | -.095                             | $t > 1.96$  | **           |
| Awareness        | .077                              | $t > 1.96$  | *            |
| Attitude         | .415                              | $t > 1.96$  | ***          |
| PU               | .212                              | $t > 1.96$  | ***          |
| Trust            | -.022                             | $t < 1.96$  | ns           |
| Subjective norm  | .295                              | $t > 1.96$  | ***          |
| Perceived benefit (PB) | -.023                           | $t < 1.96$  | ns           |
| Perceived risk   | -.006                             | $t < 1.96$  | ns           |

Original TAM model

The table shows that the standardized direct effect of attitude on intention to use AVs was significantly and positively related ($\beta = .415$, $t > 1.96, p < .001$). The standardized direct effect of PU was also significantly and positively related to intention to use AVs ($\beta = .212$, $t > 1.96, p < .001$). Table 8 presents a summary of the direct effects of variables on intention to use AVs.

Analyses as shown in Table 9 also indicate that the standardized indirect effect of PU on intention to use was significant ($B = .4979, LLCI = .3930, ULCI = .6086$) and partially mediated by attitude (PU$\rightarrow$attitude$\rightarrow$intention). The total effect of perceived usefulness on intentions was positive (0.710) and significant. PEOU has three specific indirect effects on intention. The standardized indirect effect of PEOU on intention to use AVs when partially mediated by attitude (PEOU$\rightarrow$attitude$\rightarrow$intention) is also significant ($B = .4281$, 

Table 9. Summary of mediating effects of attitude and PEOU and the standardized indirect effect of variables.

| Variable         | Effect | Dependent variable | Effect | LLCI  | ULCI  | Mediating role |
|------------------|--------|--------------------|--------|-------|-------|----------------|
| PEOU             | Direct effect | PEOU$\rightarrow$intention | Nil    |       |       | Partial        |
|                  | Indirect effect | PEOU$\rightarrow$attitude$\rightarrow$intention | .428** | .3355 | .5205 | Partial        |
|                  | Direct effect | PEOU$\rightarrow$PU$\rightarrow$intention | .435** | .3246 | .5495 | Partial       |
|                  | Indirect effect | PEOU$\rightarrow$PU$\rightarrow$attitude$\rightarrow$intention | .169*  | .0852 | 1.924 | Partial       |
| PU               | Direct effect | PU$\rightarrow$intention | .212***| .1751 | .2432 | Partial       |
|                  | Indirect effect | PU$\rightarrow$attitude$\rightarrow$intention | .4979**| .3930 | .6086 | Partial       |
| Perceived benefit (PB) | Direct effect | PB$\rightarrow$intention | -.023  | -.0314 | -.0169 | Partial       |
|                  | Indirect effect | PB$\rightarrow$attitude$\rightarrow$intention | .537***| .4227 | .6542 | Partial       |
|                  | Direct effect | PB$\rightarrow$PU$\rightarrow$intention | .535** | .4319 | .6357 | Partial       |
|                  | Indirect effect | PB$\rightarrow$PU$\rightarrow$attitude$\rightarrow$intention | .157** | .0782 | .2132 | Partial       |
| Perceived risk   | Direct effect | Perceived risk$\rightarrow$intention | -.006  | -.0122 | -.0041 | Full          |
|                  | Indirect effect | Perceived risk$\rightarrow$attitude$\rightarrow$intention | -.236* | -.3713 | -.1065 | Full          |
| Trust            | Direct effect | Trust$\rightarrow$intention | -.242**| -.3842 | -.1981 | Partial       |
|                  | Indirect effect | Trust$\rightarrow$PU$\rightarrow$intention | .309***| .2204 | .4023 | Partial       |
|                  | Direct effect | Trust$\rightarrow$PU$\rightarrow$attitude$\rightarrow$intention | .116** | .0882 | .1725 | Partial       |

Table 8. Summary of direct effects on intention to use.

| Variable         | Standardized coefficient ($\beta$) | t-statistic | Significance |
|------------------|-----------------------------------|-------------|--------------|
| Gender           | .008                              | $t < 1.96$  | ns           |
| Age              | .116                              | $t > 1.96$  | ***          |
| Education level  | -.009                             | $t < 1.96$  | ns           |
| Monthly income   | -.095                             | $t > 1.96$  | **           |
| Awareness        | .077                              | $t > 1.96$  | *            |
| Attitude         | .415                              | $t > 1.96$  | ***          |
| PU               | .212                              | $t > 1.96$  | ***          |
| Trust            | -.022                             | $t < 1.96$  | ns           |
| Subjective norm  | .295                              | $t > 1.96$  | ***          |
| Perceived benefit (PB) | -.023                           | $t < 1.96$  | ns           |
| Perceived risk   | -.006                             | $t < 1.96$  | ns           |

Table 9. Summary of mediating effects of attitude and PEOU and the standardized indirect effect of variables.
LLCI = .3355, ULCI = .5205). Further, the standardized indirect effect of PEOU on intention to use AVs when partially mediated by PU (PEOU→PU→intention) is significant (B = .4353, LLCI = .3246, ULCI = .5495). Lastly, the indirect effect of the multi-step mediation by PU and attitude on intention (i.e. PEOU→PU→attitude→intention) is 0.169 and significant at 95% confidence interval (LLCI = 0.0852, ULCI = 0.1924). PEOU has a significant total effect of 1.032 on intention to use AVs. Table 9 shows a summary of mediating effects of attitude and PEOU and the standardized indirect effect of variables on intention to use AVs.

Extensions of the adapted TAM model

The direct effect of awareness on intention to use AVs was found to be positive and significant (β = .077, t > 1.96, p < .05). The standardized direct effect of subjective norm on intention to use AVs was positive and significant (β = .295, t > 1.96, p < .001). The results show that the standardized direct effect of trust on intention to use AVs was negative and non-significant (β = −.022, t < 1.96, p > .05). Along with trust, perceived risk (β = −.006, t < 1.96, p > .05) and perceived benefit (β = −.023, t < 1.96, p > .05) were also found to be negative and not have a significant standardized direct effect on intention to use AVs.

However, all three, that is, trust, perceived risk and perceived benefit have specific indirect effects on intention to use AVs. Firstly, the results show that perceived usefulness plays a partial mediating role in the relationship between trust and intention to use AVs. The standardized indirect effect of trust on intention to use AVs (Trust→PU→intention) was significant (B = .3090, LLCI = .2204, ULCI = .4023). Also, the standardized indirect effect of trust by the multi-step mediation by PU and attitude on intention (i.e. Trust→PU→attitude →intention) is 0.116 and significant. Although trust has a non-significant direct effect, it has a significant total effect 0.403 on usage of AVs through the two specific indirect effects. Secondly, perceived risk has a significant standardized indirect effect on intention to use AVs (B = −.2364, LLCI = −.3713, ULCI = −.1065) and is significantly fully mediated by attitude (Perceived risk→attitude→intention). Moreover, perceived benefit has a negative non-significant direct effect and three positive significant specific indirect effects on intention. The standardized indirect effect of perceived benefit on intention to use AVs is partially mediated by PU (B = .5347, LLCI = .4319, ULCI = .6357) and attitude (B = .5372, LLCI = .4227, ULCI = .6542). The effect of the multiple-step mediation, that is, PB→PU→attitude →intention is 0.157, 95% confidence interval (LLCI = .0782, ULCI = .2132]. The negative direct effect of PB, is dominated by the total of its three positive specific indirect effects to result in a total significant positive effect of 1.206 on usage of AVs.

Control variables

Including the demographic variables of gender, age, monthly income, and level of education in the analysis as control variables revealed that gender and education level had no significant effect on intention to use AVs whilst age (β = .116, t > 1.96, p < .001) and monthly income (β = −.095, t > 1.96, p < .05) had a significant effect on intention to use AVs.
4.0 Discussion

Initially, a Cronbach’s alpha test was performed on the constructs in the model and the results showed great internal consistency and high reliability. Also, all variables were normally distributed because Skewness (SK) and Kurtosis (KU) fell in the −2 to +2 range (Tabachnick & Fidell, 2007). Apart from perceived risk and trust, all other variables had significant and positive correlations with intention to use AV. There were no non-significant correlations obtained in the analysis. The model was a good fit as the variables significantly predicted intention to use AVs. Some variables in the model were postulated to only have a direct effect on intention to use AVs – awareness, subjective norm, attitude and the control variables (age, gender, education level, and monthly income) whilst other variables such as PU, trust, perceived risk, and perceived benefit were modelled with the assumption of having both a direct effect and an indirect effect on the intention to use AVs through mediators. PEOU is the only variable that was modelled to have only an indirect effect on intention to use AVs. Attitude and PU were the mediators in this model. Multiple linear regression in SPSS was used specifically to determine the standardized direct effect whilst PROCESS macro (. Hayes, 2012) was used specifically for measuring standardized indirect effects and mediating effects.

Attitude is the highest predictor of intention to use AVs in this study. This indicates that if an individual’s preconceived attitude towards AVs leans more positively, then they are more likely to adopt AVs. Thus, H1 is supported. Other studies have also confirmed this assumption stating that a positive attitude leads to a greater intention to use (Ajzen, 1991; Davis et al., 1989; Payre et al., 2014). Attitude is therefore seen as an important determinant of the adoption and successful implementation of AVs technology.

Perceived ease of use exerts an indirect effect on intention to use AVs through a positive effect on attitude. This result supports H4 and is consistent with the findings of some previous studies that sought to evaluate the relationship between intention to use a technology and perceived ease of usage. Although both PEOU and PU, have positive influence on attitude, the effect of PEOU is lesser compared to that of PU on attitude. This finding is consistent with the report by Herrenkind et al. (2019) The implication of this is that perceived ease of use alone may not be enough for individuals to develop positive attitudes towards AVs. Although a technology product may be easy to use, users may develop negative attitude towards it and consequently abandon it in the long run if it no longer experiences the expected usefulness (Hong et al., 2002). Further, PEOU has a positive influence on PU and therefore supports H5. This finding is backed by Zhang et al. (2019) who revealed that PEOU had a significant effect on PU. This means that individuals are not likely to perceive AVs to be useful if they anticipate that usage of AVs would require much effort. Prospective users of AVs may expect functional simplicity in autonomous vehicle technology. The more complex the functional design of AVs, the more likely individuals, especially those who are not technology savvy would doubt the usefulness of the new technology. Perceived ease of use is therefore the second most important factor after perceived benefit with regards to total effect on AVs usage.

As one of the highest predictors, PU was found to directly affect the intention to use AVs. This reveals that if individuals believe that using new technology such as AVs will indeed improve and enhance their productivity, they will be more intent on using AVs, therefore supporting H2. The findings of Zhang et al. (2019) and Xu et al. (2018) are consistent with
this assumption, showing PU as a strong predictor of intention to use. However, others such as Herrenkind et al. (2019) and Davis et al. (1989) regard PU as a weak predictor of intention. However, the authors state that the influence of PU on intention to use is low at the initial stages but will grow over time. Also, PU was found in this study to have an indirect influence on intention to use AVs through a positive relationship with attitude. This supports hypothesis H3. This implies that individuals will tend to develop positive attitudes towards AVs when they believe that AVs would be useful for their commute.

Although the direct effect of awareness on intention to use AVs was significant, it was one of the weakest predictors of intention to use AVs. Supporting hypothesis H14 and the findings of Jing et al. (2019), the result of this study indicates that individuals who are aware of the existence and knowledgeable on the operation of AVs and how they differ from traditional vehicles are generally having more intent on using AVs. Those who are informed about the various modes of services and benefits of AVs are more likely to accept it (Hair et al., 2015) because of the likelihood of developing high level of positive attitude towards the technology. Moody et al. (2020), for example, found in their study that individuals who are more aware of AVs perceived AVs to be safer; an attribute that increases intention to use. It is worth mentioning that, negative information can, however, decrease the intention to use, while positive information may increase AV acceptance (Golbabaie et al., 2020).

On the other hand, subjective norm was found to be the second strongest predictor of intention to use AVs. This suggests that the influence of friends and/or family plays a massive role in individuals’ intention to use AVs. Acheampong and Cugurullo (2019) observed a positive correlation between social influence and AVs’ perceived benefits as well as perceived ease of use. As mentioned by Brown et al. (2014), many customers consult with their friends or families when purchasing a vehicle. The more positive the influence from friends and/or family, the more likely the individual will use AVs and this supports hypothesis H13. Other studies such as Madigan et al. (2017) and Panagiotopoulos and Dimitrakopoulos (2018) also agree that subjective norm has a positive effect on intention to use.

Surprisingly, trust was not found in this study to exert a direct effect on an individual’s intent to use AVs and therefore H11 is not supported. This contradicts various studies (e.g. Choi & Ji, 2015; Panagiotopoulos & Dimitrakopoulos, 2018; Xu et al., 2018) that stated that trust is a strong predictor of intention to use AVs; it has a significant direct effect on intention to use AVs. On the other hand, trust was found to have an indirect effect on intention to use AVs through mediation by PU. The result supports hypothesis H12 and corroborates with Choi and Ji (2015) who asserted that trust has a significant direct influence on PU. This further indicates how important trust is when it comes to the adoption of AV technology.

The perceived risks and benefits associated with AVs did not play a role in directly impacting an individual’s intention to use AVs. Perceived benefit in contrast to the findings of Siegrist (2000) does not positively directly influence intention to use AVs. The hypothesis H8 was therefore not supported. Perceived benefit however positively influences PU and attitude thereby supporting hypotheses H6 and H7. However, the mediation tests indicate that perceived benefit is the most important factor when it comes to the total effects on AVs. In spite of its non-significant negative direct effect, its three positive specific indirect effects on AVs usage through attitudes and perceived usefulness
contribute to it having the highest significant total effect on the use of AVs. Similarly, perceived risk, consistent with the findings of Bronfman and Vazquez (2011), and Midden and Huijts (2009) did not have a significant negative direct influence on intention to use AVs. Consequently, hypothesis H10 was not supported. This result, however, is not consistent with the findings of Ward et al. (2017) and Xu et al. (2018) who posited that perceived risk had a significant influence on intention to use. As hypothesised in this study (H9), perceived risk was found to negatively influence intention to use AVs through a mediation effect of attitude. When individuals are concerned and worried about the risks associated with AVs, they tend to develop negative attitude towards AVs. This is consistent with the findings of Jing et al. (2019). Table 10 shows a summary of the resulting supported and unsupported hypotheses of the study.

The non-significant effects of gender and education level are confirmed by other studies (e.g. Herrenkind et al., 2019; Payre et al., 2014; Xu et al., 2018; Zhang et al., 2020). This means that contrary to the usual notion that females are less likely to adopt new technology, the female in Ghana is as willing as their male counterparts to adopting AVs. The non-significant impact of educational level could mean that the level of awareness of AV and exposure to the technology do not vary significantly by the educational level. On the other hand, intention to use AVs was found to vary significantly by age. The age group of an individual makes a difference in whether that individual is more intent or less intent on using AVs. Most studies on effect of age on AV acceptance reported that young people are more technology savvy, ready to explore new technology and therefore open to AV technologies (Liu et al., 2019; Robertson et al., 2017). The older people are comparatively not technologically inclined, less aware of AVs and therefore perceive AVs as more challenging (Hulse et al., 2018; Moody et al., 2020). Their attitudes toward AVs are more negative and therefore less willing to pay for them (Abraham et al., 2016) Similarly, AV acceptance varied significantly among different monthly income cohorts. This is in line with the findings of Herrenkind et al. (2019) which suggested that income in the context of a family budget has a significant effect on intentions. Further, previous studies have reported that higher-income individuals are more willing to

Table 10. Summary of hypotheses.

| Hypothesis | Status   |
|------------|----------|
| H1         | Supported|
| H2         | Supported|
| H3         | Supported|
| H4         | Supported|
| H5         | Supported|
| H6         | Supported|
| H7         | Supported|
| H8         | Not supported|
| H9         | Supported|
| H10        | Not supported|
| H11        | Not supported|
| H12        | Supported|
| H13        | Supported|
| H14        | Supported|
purchase AVs (Kyriakidis et al., 2015; Bansal et al., 2016). Conversely, other studies (e.g. Acheampong, 2017; Simsekoglu & Nayum, 2019) have reported that income and age have no significant effect on intentions.

5.0 Implications

The results of the modelling discussed in the previous section provide a deeper understanding of the direct and indirect impacts of various factors on AVs adaptation which have practical and theoretical implications. Theoretically, the basis and assumptions of the original TAM were upheld – attitude, perceived usefulness and perceived ease of use had the expected effects (direct or indirect) on intention to use AVs. Further, the conceptual framework of this study (modified TAM framework) gives a better insight into the determinants of AVs adoption among different cohorts of people. This serves as a good source of information to transport policymakers, planners and auto manufacturing companies on the strategies and measures to put in place in order to enhance the public acceptance and adoption of AVs.

The result suggests that attitude and perceived usefulness plays a major role as mediators in the adoption of AVs. If the goal is to increase the interest of the public, there is the need to have a critical look at programmes and policies directed at promoting positive attitudes and their influential factors including perceived ease of use, perceived benefits and perceived usefulness. The perceived usefulness can be promoted by cultivating positive attitudes that help to earn the trust of the individuals towards AVs services and operations in all situations. Trust is known to be a major factor that significantly influence the reliance on automation and connects people’s beliefs about automation and their intention to use it (Lee & See, 2004; Parasuraman et al., 2008). The user perception on the accuracy of AVs technology must therefore be improved by the provision of information that help users understand the operations of AVs and take away issues that will otherwise increase their perceived risks about AVs. The designers and manufacturers of AVs must, for example, ensure that functions that allow drivers to take over control whenever they desire to do so are provided (Kyu Choi & Gu Ji, 2015) to promote trust and consequently cultivate positive attitude among users.

Further, awareness programmes and campaigns are necessary to market the benefits and usefulness of AVs to the people. Policy makers must make a conscious effort to direct these awareness programmes towards the older individuals who are likely to be less aware of new technologies rather than the younger ones whose tech-savviness levels are relatively high. Moreover, since intention to use AVs vary significantly by income levels, interventions that will make AVs affordable and promote the interests of low income level individuals are important. For example, policies targeted toward the reduction of premium on AVs should be developed in order to increase the interest of low-income individuals in using AVs.
6.0 Conclusions and recommendations

6.1 Conclusions

This paper examined the factors that may be influential to intention to use AVs. To determine the influential factors, an extended TAM AV model was developed which incorporated the original TAM constructs (PU, PEOU, and attitude), subjective norm, trust, awareness, perceived risk, perceived benefit, and intention to use. The relationships between these factors were analysed with multiple linear regression.

The findings from the study were as follows; the basis and assumptions of the original TAM were upheld. Subjective norm, attitude, and awareness were found to have a direct significant influence on intention to use AVs. Attitude and subjective norm were the strongest and second strongest direct predictors of intention to use AVs, respectively. On the other hand, trust, perceived risk, perceived benefit, and PEOU had no direct significant influence on the intention to use AVs but rather they were found to have a significant indirect effects on intention to use AVs and were partially and/or fully mediated by attitude and/or PU. Also, PU was found to have both direct significant influence on intention to use AVs and significant indirect effect on intention to use AVs when partially mediated by attitude. PEOU and perceived benefit, in increasing order, were found to have the highest significant total effect on the intention to use AVs. In terms of the control variables, age and monthly income were the only ones found to have a significant influence on intention to use AVs.

6.2 Recommendations

Since PU, attitude, subjective norm, awareness, age and income were significant direct determinants of intention to use AVs with attitude and PU also acting as mediators for trust, perceived benefit and perceived risk, the government can target those areas to improve acceptance of AVs. In terms of PU, the government must educate the public on the usefulness of AVs and how beneficial AVs are in terms of increasing productivity. For attitude, the government can encourage a positive mindset towards AVs through enthusiasm and positive advocacy campaigns. Also, attitude can be enhanced by highlighting the positive impact AVs would have on the transportation system and the environment. Regarding subjective norm and awareness, Ghanaian culture is one that lays a great deal of importance on the opinions of family and friends. Therefore, the government can increase awareness by undertaking widespread education on the positive impacts of AVs and through advertisements in both online and offline media. The awareness should target especially the older age group who usually have low awareness of new technology. With the government increasing awareness, word of mouth begins to spread among friends and family of the public, inevitably leading to a greater appetite to use AVs. For income, the government can introduce policies that would allow for AVs to be set at reasonable prices and for individuals to have subsidies and tax benefits associated with AV use. It is recommended that designers and manufacturers of AVs must ensure that users can easily take over control whenever they desire to do so in order to promote trust and positive attitude towards the new technology.
6.3 Limitations and future research

A limitation of the study is that since part of the survey was online, any clarification on the survey that was needed by the respondent or misunderstanding about the survey that the respondent had could not be explained or corrected unlike in the face-to-face interviews. Another limitation is that the study leaned too much toward the 18 to 24 year-old age group. The 18 to 24-year-old age group alone represented more than one-third (39.80%) of the respondents and thus was overrepresented compared to the other age groups. Future research can contemplate sample weighting methods to fix the age issue. The last limitation is that respondents have not had an AV experience before, therefore, most of their responses were based on how they think they will feel if they experienced riding in an AV and what they have read on the internet or watched on television rather than what they have already experienced. Since there is no AV technology yet in Ghana, this study focused on the predicting factors and their influence on intention to use AVs. However, in the future when AVs are available in Ghana, further research can be done on the link between intention to use and actual use/behaviour of AVs.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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